Electronics World

JULY, 1966
60 CENTS

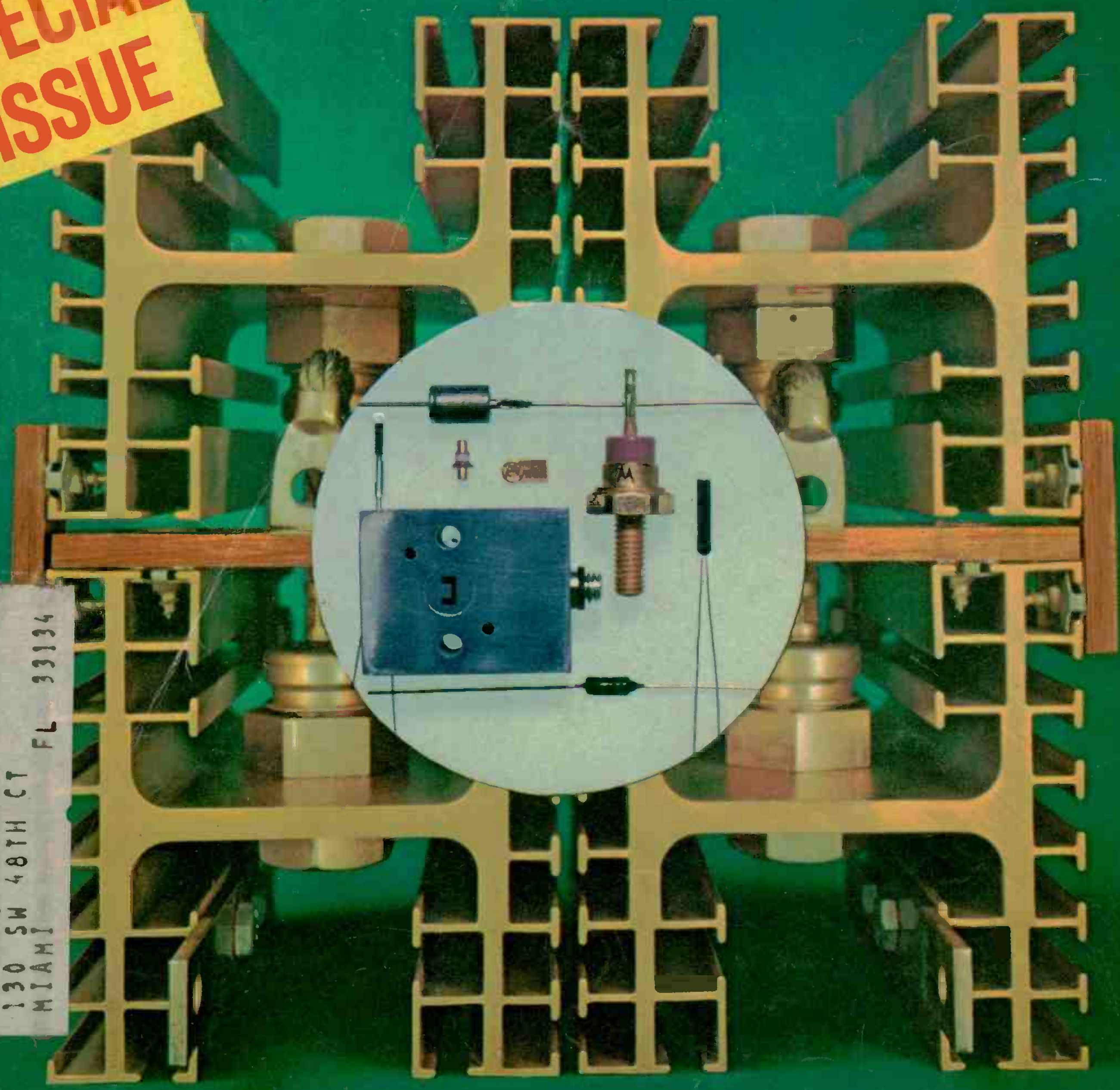
TIME AND PRECISION TIME MEASUREMENTS

A NEW AUTOMATIC MULTIPLEX DETECTOR CIRCUIT

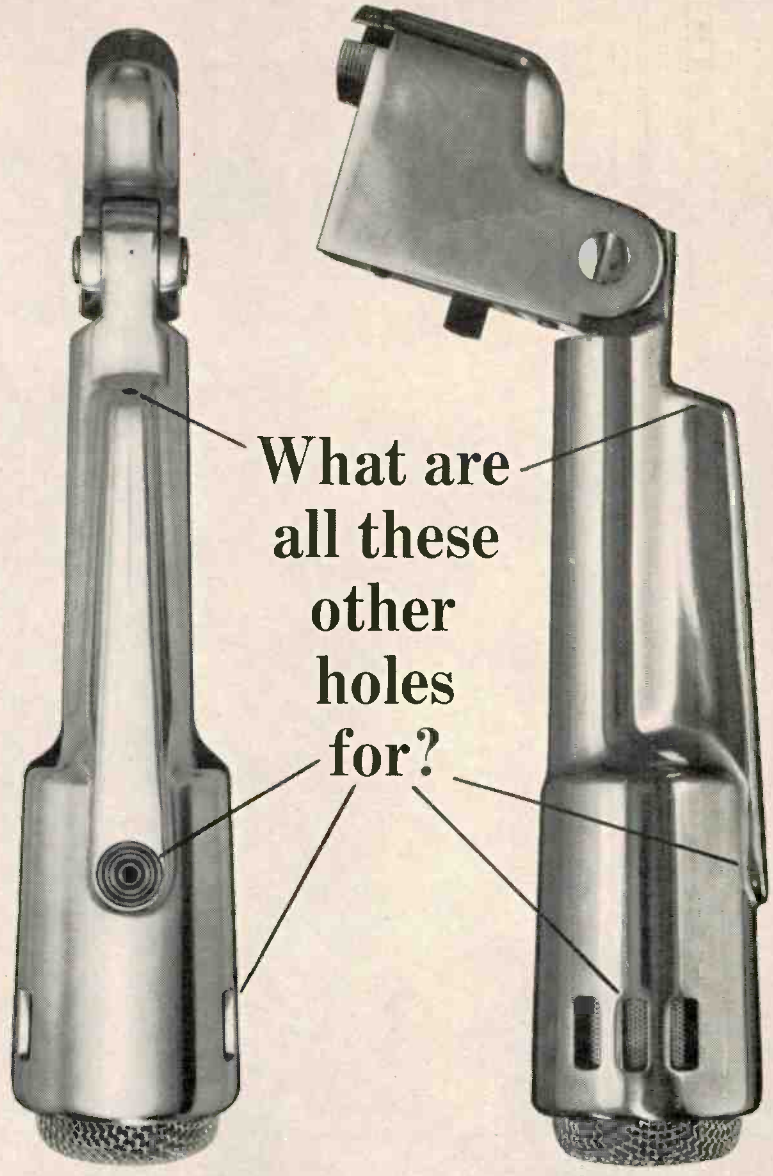
INSULATED GATE TRANSISTORS—IGFET's, MOSFET's, MOST's

SPECIAL ISSUE

SOLID-STATE DIODES



If the Electro-Voice Model 664 picks up sound here...



The holes in the top, sides and rear of the Electro-Voice Model 664 make it one of the finest dynamic cardioid microphones you can buy. These holes reduce sound pickup at the sides, and practically cancel sound arriving from the rear. Only an Electro-Voice Variable-D® microphone has them.

Behind the slots on each side is a tiny acoustic "window" that leads directly to the back of the 664 Acoustalloy® diaphragm. The route is short, small, and designed to let only highs get through. The path is so arranged that when highs from the back of the 664 arrive, they are cut in loudness by almost 20 db. Highs arriving from the front aren't affected. Why two "windows"? So that sound rejection is uniform and symmetrical regardless of microphone placement.

The hole on top is for the mid-range. It works the same, but with a longer path and added filters to affect only the mid-frequencies. And near the rear is another hole for the lows, with an even longer path and more filtering that delays only the bass sounds, again providing almost 20 db of cancellation of sounds arriving from the rear. This "three-way" system of ports insures that the cancellation of sound from the back is just as uniform as the pickup of sound from the front—without any loss of sensitivity. The result is uniform cardioid effectiveness at every frequency for outstanding noise and feedback control.

Most other cardioid-type microphones have a single cancellation port for all frequencies. At best, this is a compromise, and indeed, many of these "single-hole" cardioids are actually omnidirectional at one frequency or another!

In addition to high sensitivity to shock and wind noises, single-port cardioid microphones also suffer from proximity effect. As you get ultra-close, bass response rises. There's nothing you can do about this varying bass response — except use a Variable-D microphone with multi-port design* that eliminates this problem completely.

Because it works better, the E-V 664 Dynamic Cardioid is one of the most popular directional microphones on the market. It has both high and low impedance outputs available at the plug. Frequency range is peak-free from 40 to 15,000 Hz (cps). Output is —58 db. To learn more about Variable-D microphones, write for our free booklet, "The Directional Microphone Story." Then see and try the E-V 664 at your nearby Electro-Voice microphone headquarters. Just $85.00 in satin chrome or non-reflecting gray, or $90.00 in gold finish (list prices less normal trade discounts).

*Pat. No. 3,115,207

ELECTRO-VOICE, INC., Dept. 762N
629 Cecil Street, Buchanan, Michigan 49107

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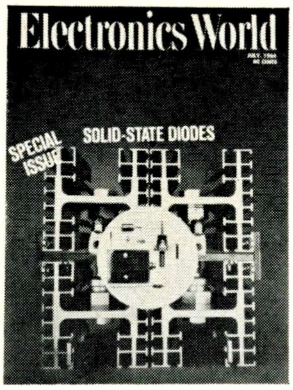

THIS MONTH'S COVER highlights some of the semiconductor diodes discussed in our special section on this subject. The large assembly that almost completely fills the cover is an International Rectifier single-phase bridge with four silicon rectifier diodes on heat sinks. It can deliver over 400 V at 200 A. The large rectangular unit within the circle is a Sylvania waveguide-block-mounted microwave mixer diode designed for 50-100 GHz. The tiny RCA unit just above it is a tunnel diode. Immediately to the left and right of the tunnel diode are two Motorola varactor diodes. The two slender vertical units are Texas Instruments light-sensor diodes, while the horizontal diodes at the upper left and lower right are TI low-power zeners. . . . . .Photo: Bruce Pendleton.

ZIFF-DAVIS PUBLISHING COMPANY

Electronics World

JULY 1966 VOL. 76, No. 1

CONTENTS

MONTHLY FEATURES

Electronics World: Published monthly by Ziff-Davis Publishing Company at 307 North Michigan Ave., Chicago, Illinois 60601. One year subscription $6.00. Second Class Postage paid at Chicago, Illinois and at additional mailing offices. Subscription service: Portland Place, Boulder, Colorado 80302.

COMING NEXT MONTH

ENCLOSURES FOR HIGH-COMPLIANCE LOUDSPEAKERS

By using the practical graphs supplied by Roger H. Russell of Sonotone, it is possible to design and build a small, completely sealed hi-fi speaker enclosure to meet your special requirements.

ELECTROMECHANICAL CHOPPERS

Widely used in industrial electronic instrumentation, these contact modulators convert slowly varying signals or changes in d.c. levels into a.c. square waves that can be handled more easily by amplifiers. Sidney L. Silver discusses the various types of choppers and suggests some of their important applications.

SELECTING THE PROPER INDICATING LIGHT

This article by Warren Walker of Dialight Corp. is a virtual encyclopedia of information on these important components and tells how to specify correctly lamps and lamp housings for all types of electronic equipment. This is an article to which you will refer time and time again—one that you will want to keep.

DIRECTORY OF BATTERY-OPERATED TAPE RECORDERS

A comprehensive guide to the recorders of approximately 20 companies, including electrical and mechanical specifications in tabular form for easy comparison of features. Prices, photographs, and available accessories are also included.

RADIATION MEASUREMENTS IN SPACE

Our ability to detect and measure the various types of radiation encountered in space is vital to interplanetary travel plans. How these measurements are made is covered by Joseph H. Wujek, Jr. in this timely and important article.

OSCILLOSCOPE PROBES

While probes are only an accessory to the scope, they have a strong influence on the accuracy of any measurement. Choosing a probe and understanding its characteristics are covered in this article by Walter H. Buchsbaum.

*All these and many more interesting and informative articles will be yours in the **August** issue of ELECTRONICS WORLD ... **on sale July 19th.***

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Editorial and Executive Offices
One Park Avenue
New York, New York 10016 212 679-7200

NEW YORK OFFICE 212 679-7200
James J. Sullivan
Joseph E. Halloran

MIDWESTERN OFFICE
307 North Michigan Avenue
Chicago, Illinois 60601 312 726-0892
Midwestern Advertising Manager, Royce Richard

WESTERN OFFICE
9025 Wilshire Boulevard
Beverly Hills, California 90211
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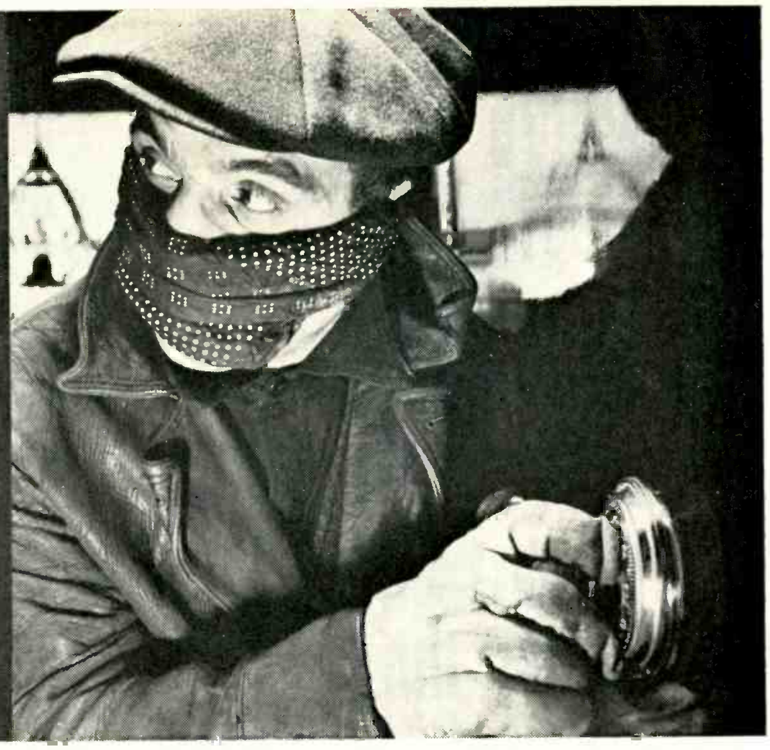

Every 40 seconds a burglary takes place in the United States.

TECHNICAL INFORMATION

The RADAR SENTRY ALARM is a complete U.H.F. Doppler Radar System which saturates the entire protected area with invisible r.f. microwaves. It provides complete wall to wall—floor to ceiling protection for an area of up to 5,000 square feet. Without human movement in the protected area, the microwave signal remains stable. Any human movement (operation is unaffected by rodents and small animals) in the area causes the doppler signal to change frequency approximately 2 to 4 cps. An ultra-stable low frequency detector senses this small frequency change, amplifies it and triggers the police type siren—which is heard up to a half mile away.

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- *relay unit for activating house lights*
- *battery operated horn or bell which sounds in the event of: powerline failure; equipment malfunction or tampering*

At that rate, it's a multi-million dollar a year business...for burglars.

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And you don't have to be a super-salesman to sell the best protection available—a Radar Sentry Alarm unit. All you have to do is demonstrate it...it sells itself.

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U. S. Air Force
Detroit Board of Education
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So take advantage of your profession! Put your technical knowledge and experience to work for you in a totally new area—an area that will make money for you!

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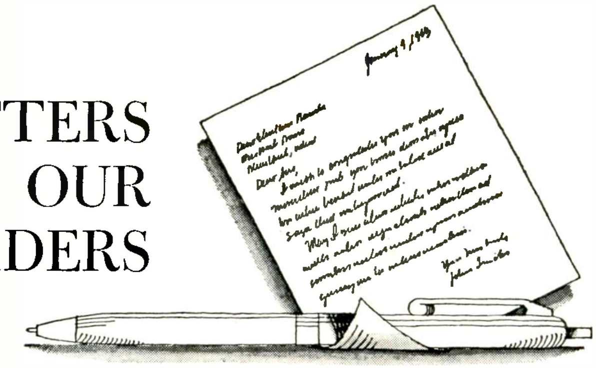
Address ______________________

City ____________ **State & Code** ____________

LETTERS FROM OUR READERS



NUMERICAL CONTROL SYSTEMS

To the Editors:

A recent issue (February) carried a letter from Mr. Robert McGlynn regarding the need for good training on numerical control systems. The *Cincinnati Milling Machine Co.* has an excellent factory course for training maintenance and operating personnel.

Prior to taking the factory course, the trainee is required to take a pre-test of his ability from *International Correspondence Schools* in Scranton, Pa. Any parts of the pre-test that show lack of fundamental training must then be studied before the trainee is certified to enter the factory course. If he has no knowledge of this subject, he must study a total of seven such lessons. All of these seven lessons relate specifically to the training a person needs on this subject.

The *Cincinnati Milling Machine Co.* benefits from this pre-test because the factory course can then be devoted totally to the specialized instruction needed rather than bring everybody up to date on fundamentals. We are sure that Mr. McGlynn can get further information on this useful seven-lesson course on numerical control systems from *ICS*.

ROBERT MITRIN
Norwood, Ohio

* * *

SUPERSENSITIVE COMMUNICATIONS

To the Editors:

Regarding the article "Supersensitive Communications Systems" in the February issue, I believe the author has erred in stating the performance of these amplifiers. The phase-lock technique allows much narrower bandwidths to be used and correspondingly higher signal-to-noise ratios, but the S/N ratio is still inversely proportional to the information bandwidth used.

It is true that at bandwidths on the order of 10 Hz there will be a great decrease in required received power. The information could be code, digital info, or greatly slowed voice modulation to be later played speeded up. The statement, "... the systems can carry voice modulation at signal levels that are impossible to detect with conventional approaches" is wrong in that it implies real-time voice modulation.

Fig. 1 shows the low-pass filter to be *after* the information detectors. As stated above, the S/N ratio will still be inversely proportional to the information bandwidth.

ARTHUR L. MARC
Cheyenne, Wyo.

Author Kyle's reply follows:

Mr. Marc's objection is typical of many which I have received in discussing phase-lock reception with professional communications engineers. I'll grant that the performance is "seemingly impossible," but the fact remains that systems of this type operating essentially as described are currently producing the performance described.

The particular statement (on page 43, just above "Typical Circuits") with which Mr. Marc takes issue as "implying real-time voice modulation was not intended as an implication; rather it was intended as a statement. These systems do carry voice in real time.

The contradiction between narrow bandwidth and voice modulation disappears when the first half of the statement is restored: "Information bandwidth rises rapidly with increase in signal strength." Note that no claim of voice modulation within a 10-Hz bandwidth is implied. The whole key to these systems' performance with wide-band modulation is that they automatically expand their information bandwidths to suit the strength of the received signal. Thus, a system which is capable of locking onto a signal at −200 dBm, for example, may not (probably will not) be able to recover wide-band modulation from this signal. Should signal strength rise to −160 dBm, however, wide-band signals could probably be carried easily. In contrast, a conventional receiving system would be hard put to find the signal at −160 dBm.

The arrangement shown in Fig. 1 is essential to the automatic widening of the information bandwidth. The information which passes *through* the low-pass filter is indeed restricted to very slow changes. That which does not see the filter, however, has no such restriction on its rate of change. Whenever this information is at least as strong as

(*Continued on page 12*)

1 Start Fast with NRI's New Remarkable Achievement Kit

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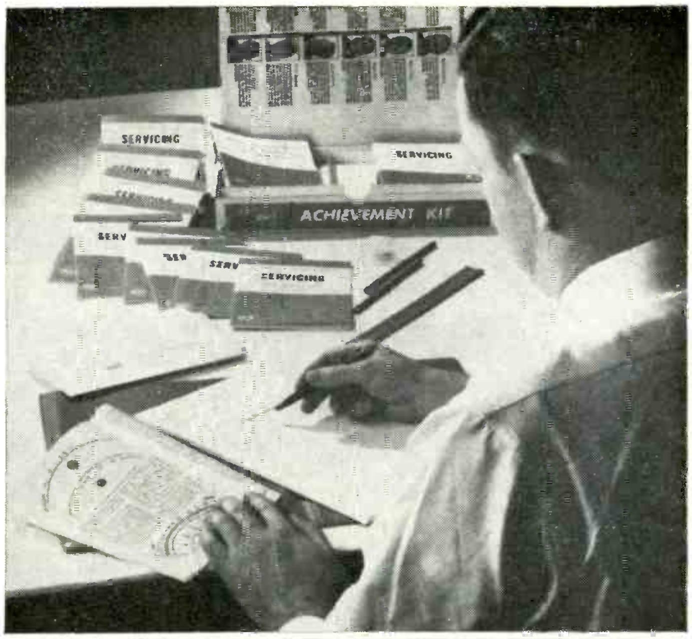

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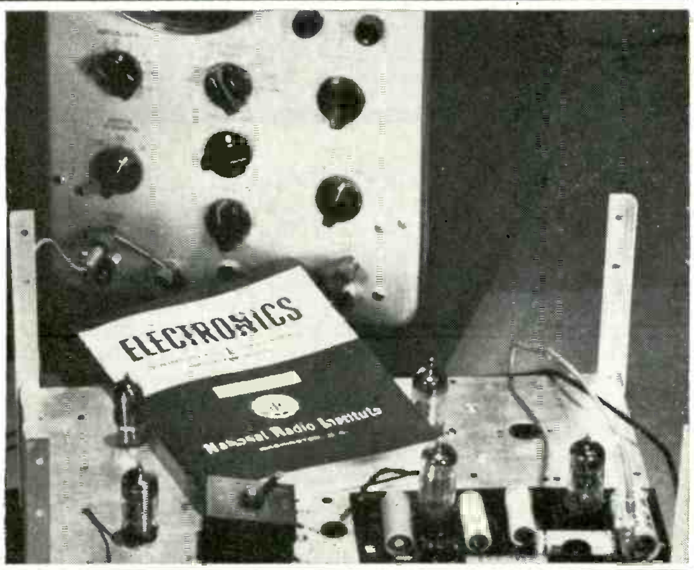

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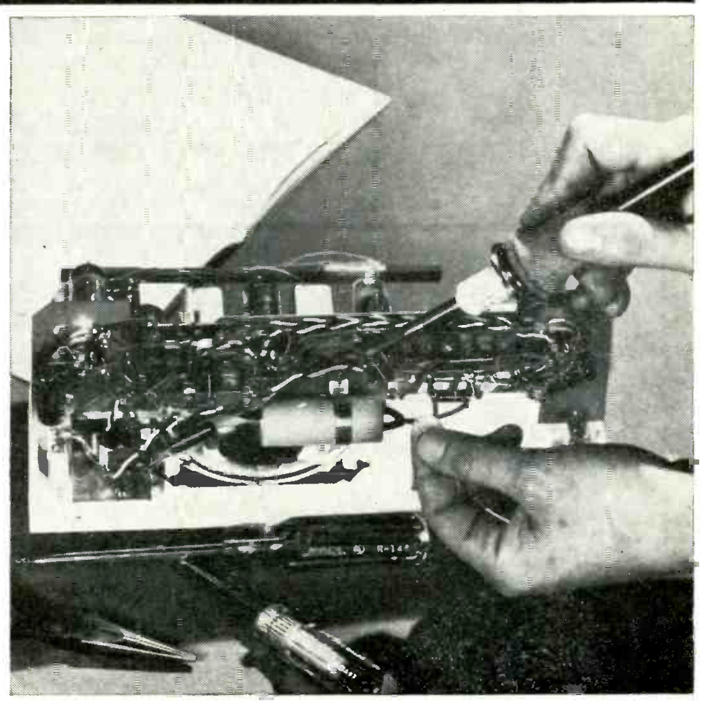

(*Continued from page* 6)

the noise surrounding it, it can be detected.

Jim Kyle
Oklahoma City, Okla.

* * *

OAO

To the Editors:

In the article "The Orbiting Astronomical Observatory" (March issue), Fig. 1 gives the impression that the OAO actually takes photographs of the stars under observation. Is this true, or is the OAO a complex spectrum analyzer?

David Freeman
Los Angeles, Calif.

Reader Freeman is correct. The OAO is a scientific analysis satellite and does not actually take photographs. However, when the data from a given area under OAO observation is compared with a conventional earth-based optical photograph of the same area, the effective results, it is hoped, will be as depicted.

Incidentally, the first OAO failed on April 10, just two days after its launch from Cape Kennedy. Three additional OAO's will be launched.—Editors

* * *

CHROMA DEMODULATION

To the Editors:

An otherwise excellent article, "Chroma Demodulation in Color Sets: RCA" by Walter H. Buchsbaum in Electronics World (May, 1966 issue), contains an obvious error and another less apparent.

1. In Fig. 4, curve (A) represents the grid coil response, while curve (C) represents the over-all chroma bandpass, *not vice versa*. As far as I can determine, coil *L2* (Fig. 3) is resonated at about 4 MHz. The peaked response curve shown at Fig. 4 (A) is the result of a combination of this 4-MHz peaking with the high-frequency roll-off of the i.f. response of the receiver.

2. The output of the chroma bandpass amplifier consists principally of 3.58-MHz sideband signals. The 3.58-MHz subcarrier is actually suppressed at the transmitter and only the major sidebands are transmitted. I believe, therefore, that it would be more correct to refer to the output of the bandpass amplifier as the "3.58-MHz signal" or the "3.58-MHz chrominance signal." The 3.58-MHz subcarrier is, in a sense, reinserted by the chroma demodulator. This is actually the signal labeled in Fig. 5 as the "color sync."

In spite of small errors, this and other articles in Electronics World are, as usual, top-notch. Keep 'em coming!

Raymond P. Ghelardi
Brooklyn, N. Y.

Actually, the figure itself is okay, but the captions for parts (A) and (C) have been transposed.—Editors ▲


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(WE MEAN BUSINESS)
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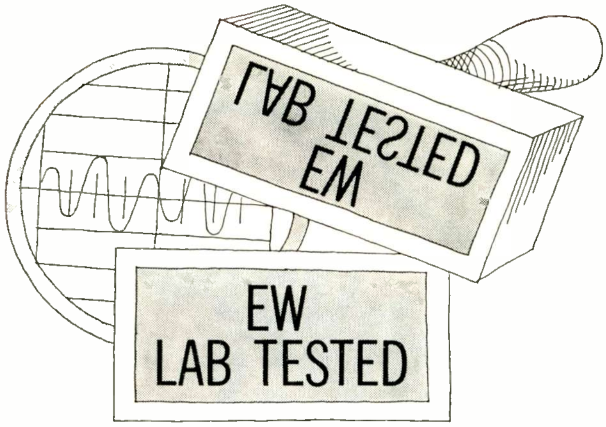


HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Heath AR-14 Integrated Stereo Receiver
"Knight" KN-2380 Speaker System

Heath AR-14 Integrated Stereo Receiver

For copy of manufacturer's brochure, circle No. 20 on Reader Service Card.

INTEGRATED stereo receivers, containing an FM multiplex tuner, preamplifiers, and power amplifiers on a single chassis, have proved to be one of the most popular components in the high-fidelity field. The reasons are obvious—no problems of compatibility between separate components, compact size, a minimum of interconnections, and the economy resulting from the elimination of duplicated metal work and power supplies.

Receiver prices have been dropping steadily for several years. Even in kit form, however, they were not to be had for less than \$150 to \$200—and they are among the most complex kits to assemble. This price barrier has been broken by the new *Heath* AR-14 solid-state receiver. Selling for only \$99.95, this easy-to-build kit offers good enough performance and flexibility to satisfy all but the most critical user.

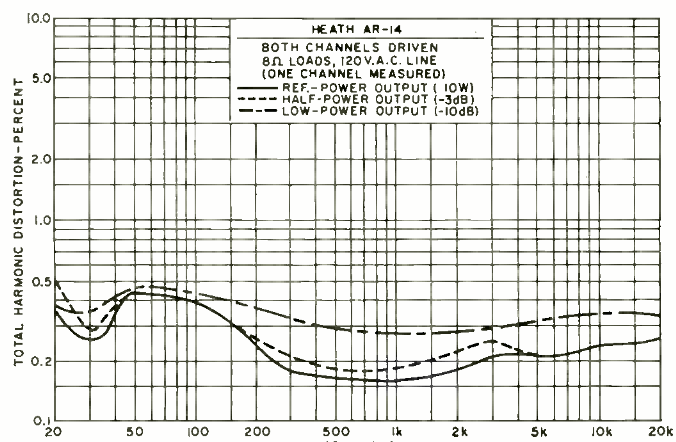
The FM tuner of the AR-14 has a pre-assembled and aligned front end, with a grounded-base r.f. amplifier, mixer, and oscillator. The a.f.c. is applied to the oscillator by a silicon diode capacitor. The FM i.f. amplifier and multiplex circuits are on a single large printed board. The four i.f. stages limit successively on strong signals, and are followed by a ratio detector.

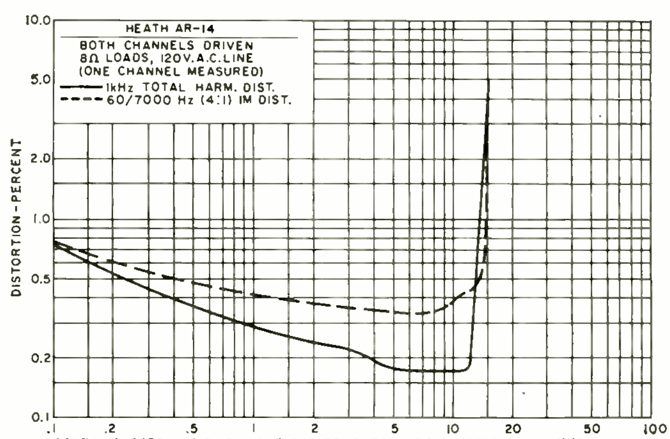
A 67-kHz SCA filter precedes the switching-type multiplex circuits. The 19-kHz pilot carrier, separated from the composite detected signal, locks a 38-kHz oscillator in the AR-14. The phase of the 19-kHz signal can be adjusted to optimize stereo separation by means of a front-panel control. Instead of the usual diode-balanced modulator, the AR-14 uses a two-transistor switching detector. The bases of the transistors are driven in opposite phase by the 38-kHz oscillator signal, while the composite detected signal (minus the 19-kHz pilot carrier) feeds the emitters in phase. The collector circuits contain the left- and right-channel programs, with de-emphasis supplied by printed, encapsulated filters.

The 19-kHz pilot carrier, when present, is amplified and used to light the stereo indicator lamp on the panel. FM mono/stereo switching is automatic, since the 38-kHz oscillator does not function without the pilot signal, and the switching detector acts as a pair of amplifiers for the mono signal in the absence of the switching signal.

All the audio circuits, except the output transistors, are on another large printed board. The preamplifiers are equalized for the RIAA phono characteristic. The six-position input selector switch provides for FM, phono, and external high-level "Aux" inputs. The same switch acts as a mode selector, since each input has both mono and stereo positions.

The tone controls are ganged for both channels. The concentric volume controls have slip clutches for balancing channel levels. The audio amplifier uses no transformers, large electrolytic block-





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Imagine.

Instant Movies in Sound (produce your own or tape them off the air)

The new Sony Videocorder® is a complete Home TV Studio™: a video tape recorder, built-in monitor, and optional camera outfit. Takes TV pictures and sound right off the air, and puts them on tape. And with the TV camera attached, and microphone plugged in, you can do the same with live action. When you're done—presto, switcho, rewind, playback! And there, on the TV monitor screen, is the same picture with the same sound, as easy as operating an ordinary tape recorder.

First Unit ever designed for the home. There's nothing really new about taping sight and sound. TV stations have been doing it for years. But the equipment costs tens of thousands of dollars. That's a long way from home.

But, when you can bring the complete system—recorder and monitor—down to under $1000, plus an optional $350 for the camera outfit, you're home. And that's exactly what Sony did. They achieved the most exciting home entertainment concept since television.

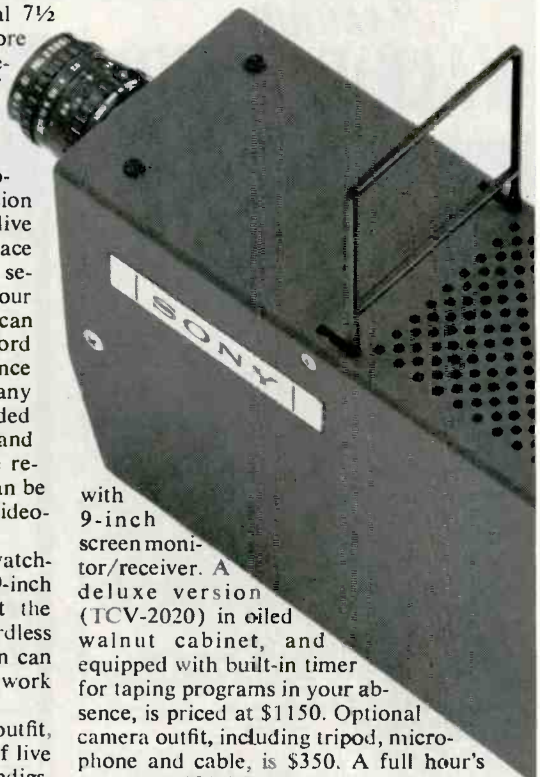
New recording/playback technique. Known as a pioneer in transistor developments, Sony is also one of the foremost producers of tape heads and tape transport mechanisms and the tape itself. Sony also manufactures TV picture tubes and vidicon tubes. Sony drew from this veritable storehouse of specialized experience to create this all-new, all-Sony TV tape system for the home. It was out of this same resourceful know-how that the ingenious idea of alternate-field recording and repeat-field playback was conceived. Combining it with helical tracking, it made possible the development of a unit that would use standard ½-inch video tape at conventional 7½ ips speed, yet capable of storing more than 60 minutes of program material on a 7-inch reel. The dream of a home TV tape recorder became a reality.

Unlimited applications. The Videocorder adds a thrilling new dimension to home entertainment. Want to relive some telecast event? Watch a space launch again? A ball game? Some selected program? Tape it with your Sony Home Videocorder. You can even use a timer attachment to record a program while you're out. For, once it's on tape, you can watch it at any time. And you can erase the recorded material, and reuse the tape over and over again. What's more, any tape recorded on one Sony Videocorder can be played back on any other Sony Videocorder.

Moreover, you're not limited to watching playback on the built-in Sony 9-inch screen monitor. You can connect the Videocorder to any monitor, regardless of size. A competent TV technician can even adapt your Videocorder to work with your TV set.

And with the optional camera outfit, you can record picture and sound of live events—family functions, social shindigs, community activities—you name it. You can also apply it to your business or profession or your hobby interests.

Now available. Prices start under $1000. The basic Sony Home Videocorder (TCV-2010) is priced at $995 complete with 9-inch screen monitor/receiver. A deluxe version (TCV-2020) in oiled walnut cabinet, and equipped with built-in timer for taping programs in your absence, is priced at $1150. Optional camera outfit, including tripod, microphone and cable, is $350. A full hour's tape costs $39.95.



Visit your Sony dealer today for an unforgettable demonstration. For free booklet describing the many uses for your Videocorder write: Sony Corp. of America, 580 Fifth Ave., N. Y., N. Y. 10036.

SONY® VIDEOCORDER®

ing capacitors isolate the speakers, which may be from 4 to 16 ohms impedance, from the output stages. The output transistors, which are mounted on the rear of the chassis, will not be damaged by brief short circuits of up to 30 seconds duration. However, their exposed position makes them vulnerable to accidental grounding when connecting the antenna wires, or if the chassis is pushed against a conducting surface. We understand that current AR-14 models are now supplied with insulating covers for the power transistors.

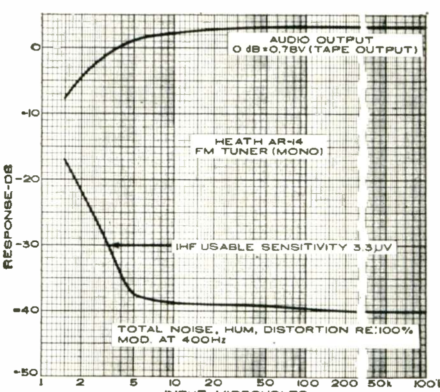
The new low price of the receiver was made possible by eliminating unnecessary or little-used features, such as tape-monitoring provisions, tuning indicator, or multiple-input sources. The absence of a tuning indicator is only briefly disturbing. The a.f.c. is strong and tuning for low distortion is non-critical. However, it cannot be switched off and sometimes it is not possible to receive a weak signal adjacent to a strong one because the stronger signal "captures" the a.f.c.

The power is switched on by pulling out the treble tone-control knob. Speakers are switched off, for headphone listening *via* the front-panel jack, by pulling out the bass tone-control knob. The FM pilot phase is adjusted by pulling out a knob which removes the main channel sound, leaving only the subcarrier information. It is turned for maximum volume and pushed in. Re-adjustment is rarely needed.

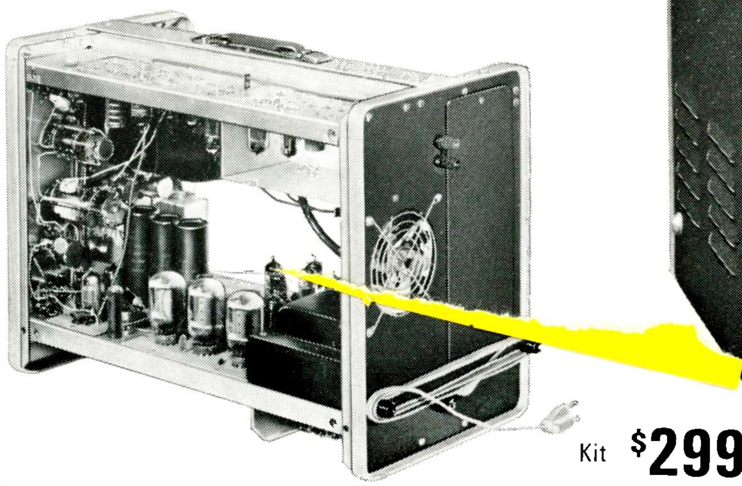
In our lab measurements, the receiver delivered its rated 10 watts per channel (continuous power) from 20 to 20,000 Hz, with less than 0.5% harmonic distortion. Over most of this range the distortion was less than 0.25% at full power. It was only slightly higher at lower power levels and never exceeded 0.5% even with 1-watt output.

At 1000 Hz, the harmonic distortion was about 0.75% at 0.1 watt, falling to 0.17% between 5 and 12 watts and climbing to 2% at about 15 watts. The IM distortion was similarly low, remaining under 0.5% from 0.5 to 13 watts, rising to only 1% at 15 watts. Frequency response was flat within ±1 dB from 20 to 20,000

(*Continued on page* 22)



New Professional DC 'Scope Heathkit® IO-14



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• A high stability 5" DC oscilloscope with triggered sweep • DC to 8 mc bandwidth and 40 nanosecond rise time • Vertical signal delay through high linearity delay lines—capable of faithful reproduction of signal waveforms far beyond the bandwidth of the additional circuitry • Calibrated vertical attenuation—from 0.05 v/cm to 600 volts P-P maximum input • Calibrated time base • 5X sweep magnifier • Forced air cooling • Input for Z axis modulation • Input for direct access to vertical deflection plates • Easy circuit-board construction & wiring harness assembly • Components are packaged separately for each phase of construction • Easy to align • Fulfills many production and laboratory requirements at far less cost than comparable equipment—particularly scopes capable of fast-rise waveform analysis • No special order for export version required—wiring options enable 115/230 volt, 50-60 cycle operation

Here Is A Truly Sophisticated Instrument . . . designed with modern circuitry, engineered with high quality, precision-tolerance components, and capable of satisfying the most critical demands for performance. The IO-14 features precision delay-line circuitry to allow the horizontal sweep to trigger "ahead" of the incoming vertical signal. This allows the leading edge of the signal waveform to be accurately displayed after the sweep is initiated.

The IO-14 Provides Features You Expect Only In High Priced Oscilloscopes. For example, switches are quality, ball-detent type; all major control potentiometers are precision, high-quality sealed components; all critical resistors are 1% precision; and circuit boards are low-loss fiber glass laminate. The IO-14's cabinet is heavy gauge aluminum. Its CR tube is shielded against stray magnetic fields, and forced air ventilation allows the IO-14 to be operated under the continuous demands of industrial and laboratory use.

Kit IO-14, 45 lbs. $299.00
Assembled IOW-14, 45 lbs. $399.00

IO-14 SPECIFICATIONS—(Vertical) Sensitivity: 0.05 v/cm AC or DC. **Frequency response:** DC to 5 mc, —1 db or less; DC to 8 mc, —3 db or less. **Rise time:** 40 nsec (0.04 microseconds) or less. **Input impedance:** 1 megohm shunted by 15 uuf. **Signal delay:** 0.25 microsecond. **Attenuator:** 9-position, compensated, calibrated in 1, 2, 5 sequence from 0.05 v/cm. **Accuracy:** ±3% on each step with continuously variable control (uncalibrated) between each step. **Maximum input voltage:** 600 volts peak-to-peak; 120 volts provides full 6 cm pattern in least sensitive position. **(Horizontal) Time base:** Triggered with 18 calibrated rates in 1, 2, 5 sequence from 0.5 sec/cm to 1 microsecond/cm with ±3% accuracy or continuously variable control position (uncalibrated). **Sweep magnifier:** X5, so that fastest sweep rate becomes 0.2 microseconds/cm with magnifier on. (Overall time base accuracy ±5% when magnifier is on.) **Triggering capability:** Internal, external, or line signals may be switch selected. Switch selection of + or — slope. Variable control on slope level. Either AC or DC coupling. "Auto" position. **Triggering requirements:** Internal; ½ cm to 6 cm display. **External:** 0.5 volts to 120 volts peak-to-peak. **Horizontal input:** 1.0 v/cm sensitivity (uncalibrated) continuous gain control. Bandwidth: DC to 200 kc ±3 db. **General** 5ADP31 or 5ADP2 Flat Face C.R.T. interchangeable with any 5AD or 5AB series tube for different phosphor characteristics. 4250 V. accelerating potential. 6 x 10 cm edge lighted graticule with 1 cm major divisions & 2 mm minor divisions. **Power supply:** All voltages electronically regulated over range of 105-125 VAC or 210-250 VAC 50/60 cycle input. (Z Axis) Input provided. DC coupled CRT unblanking for complete retrace suppression. **Power requirements:** 285 watts. 115 or 230 VAC 50-60 cps. **Cabinet dimensions:** 15" H x 10½" W x 22" D includes clearance for handle and knobs. **Net weight:** 40 lbs.

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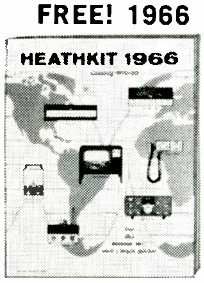

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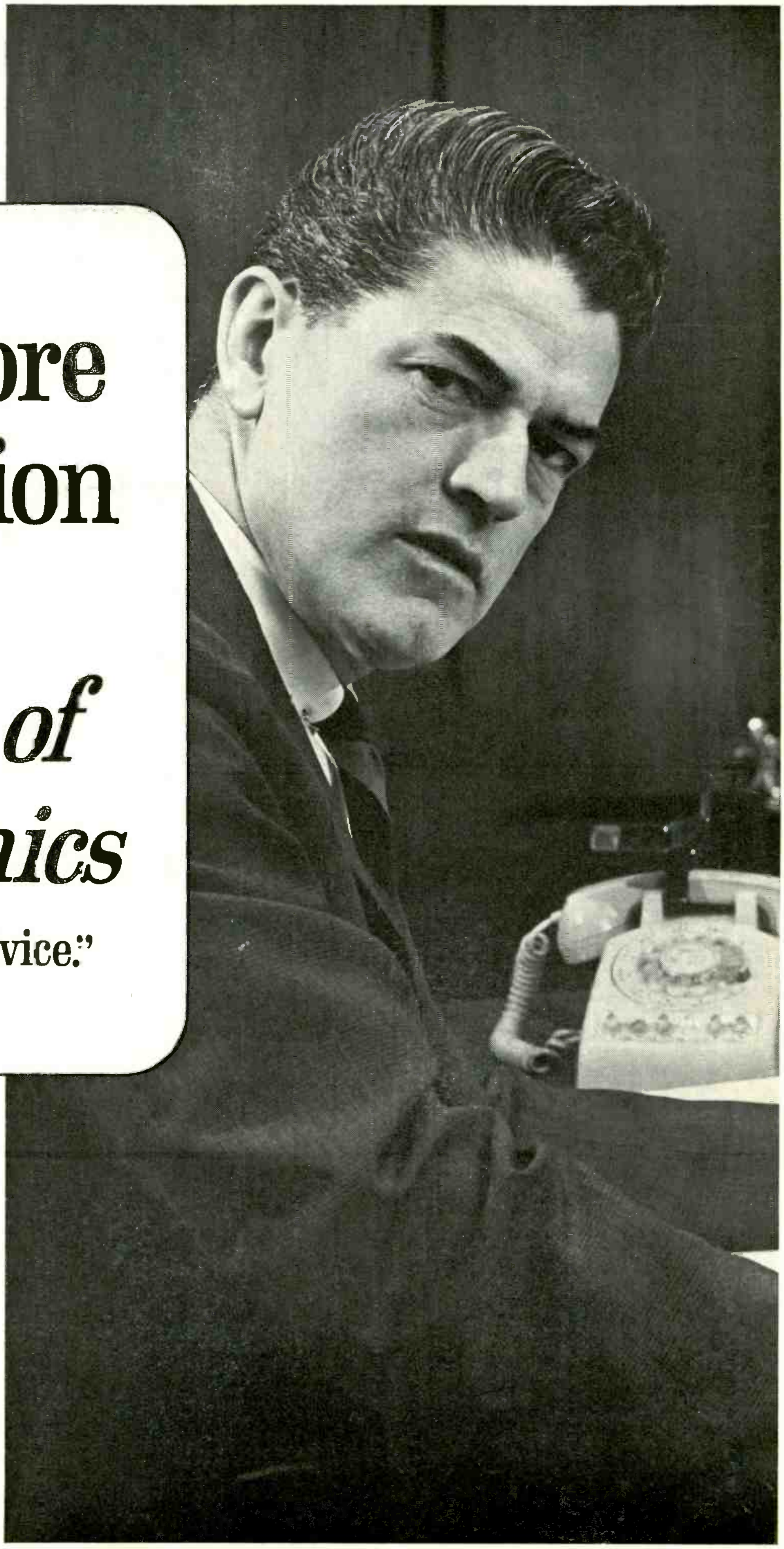
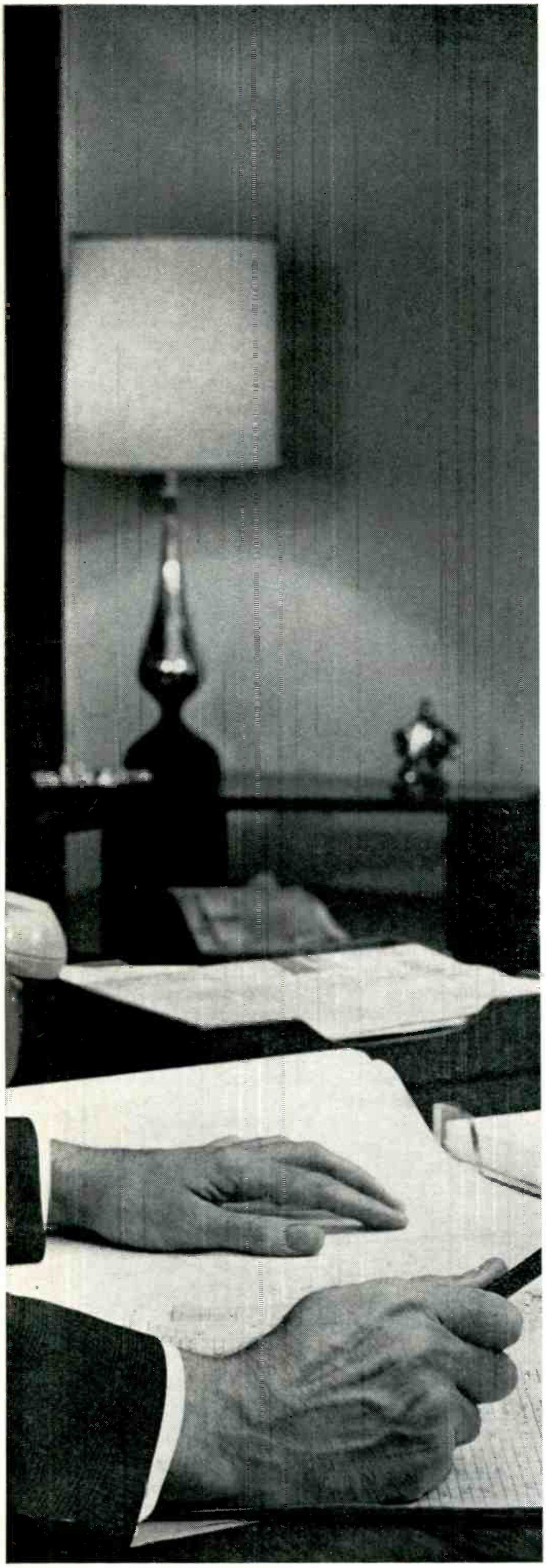
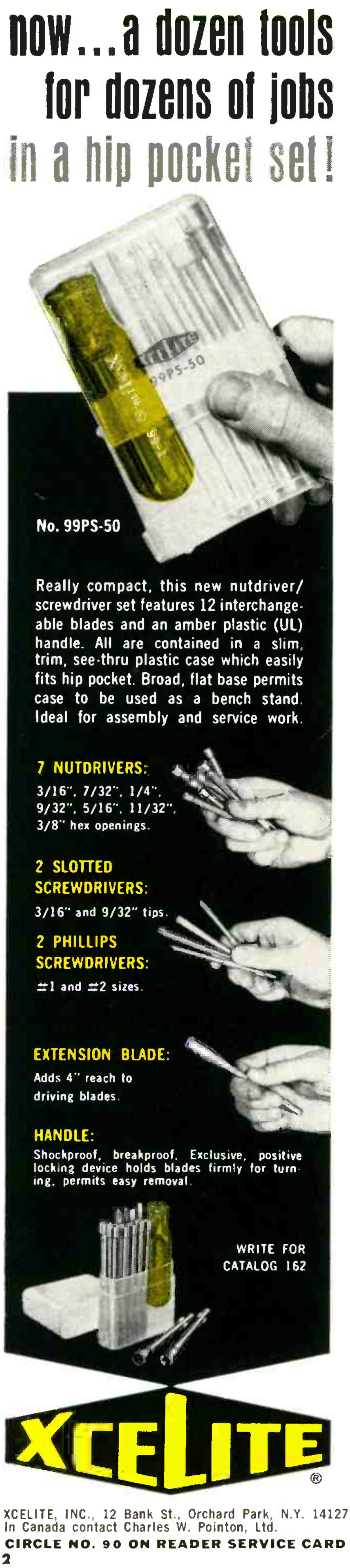






(*Continued from page* 16)

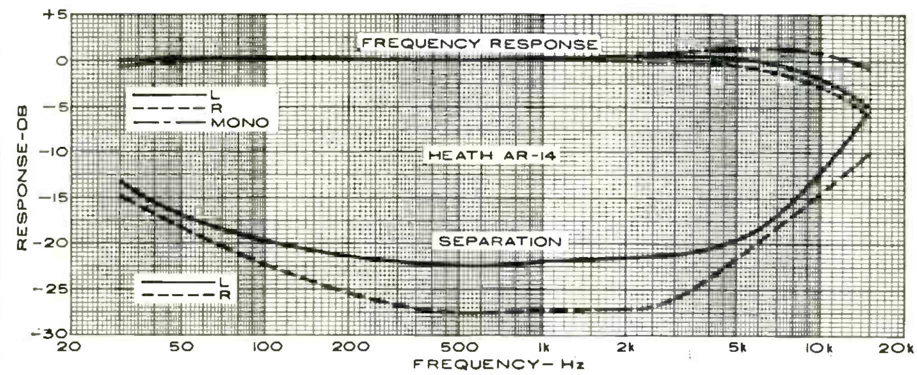
Hz. RIAA phono equalization was very accurate down to 100 Hz, falling off to a −5 dB error at 30 Hz.

The FM tuner is designed to be operable without an instrument alignment, since all coils are pre-aligned. Out of curiosity we checked tuner sensitivity without touching any of the alignment adjustments. We found it to be 20-μV IHF usable sensitivity. After the simple touch-up adjustments on interstation noise, as suggested in the manual, sensitivity improved to 7.5 μV. Instrument alignment further improved this to 3.3 microvolts, which is better than the rated 5 microvolts sensitivity.

FM-stereo separation was about 17.5 dB over most of the audio range prior to alignment. Aligning for maximum separation improved this to about 25 dB (rated 30 dB). Even in the unaligned state, the separation was more than adequate for good stereo performance, and we do not consider multiplex alignment by the user to be either necessary or desirable.

In every respect, this compact receiver proved to be an excellent performer. We did not feel hampered by any lack of flexibility. It sounded fine driving medium-efficiency speakers, although one cannot expect to play it at ear-shattering levels. It is interesting to note that in its general performance and distortion levels, each channel of the AR-14 is comparable to the famous Williamson amplifier of a decade ago.

With its construction simplified by extensive use of printed boards and its thoroughly satisfying and honest performance, we have no hesitation in recommending the receiver. It is hard to see how the manufacturer has managed to produce it for $99.95, but there has certainly been no sacrifice of performance. Cabinets cost $9.95 in walnut or $3.95 in beige metal. ▲



"Knight" KN-2380 Speaker System

For copy of manufacturer's brochure, circle No. 21 on Reader Service Card.

THE KN-2380 is the finest speaker system offered under the "Knight" brandname by *Allied Radio Corporation* of Chicago. It is a rather large three-way system, which can be mounted on a shelf or on the floor. A mounting base is supplied and can be used for either horizontal or vertical mounting.

The system measures 27" x 20½" x 14". The black satin-finished base is 3¼" high making the total height either 30¼" or 23¾", depending on whether vertical or horizontal mounting is used. The enclosure is made of ¾" hardwood with oiled walnut veneer on four sides. It has a tuned, ducted port for bass reinforcement.

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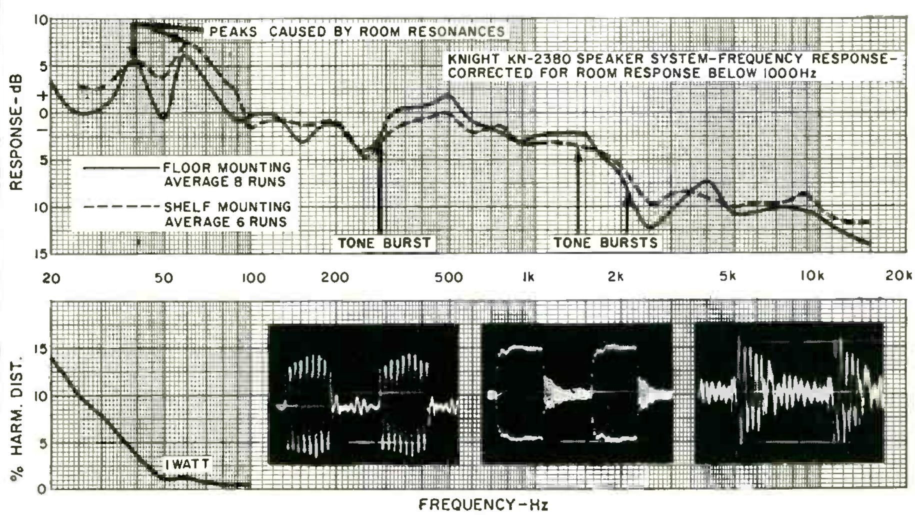
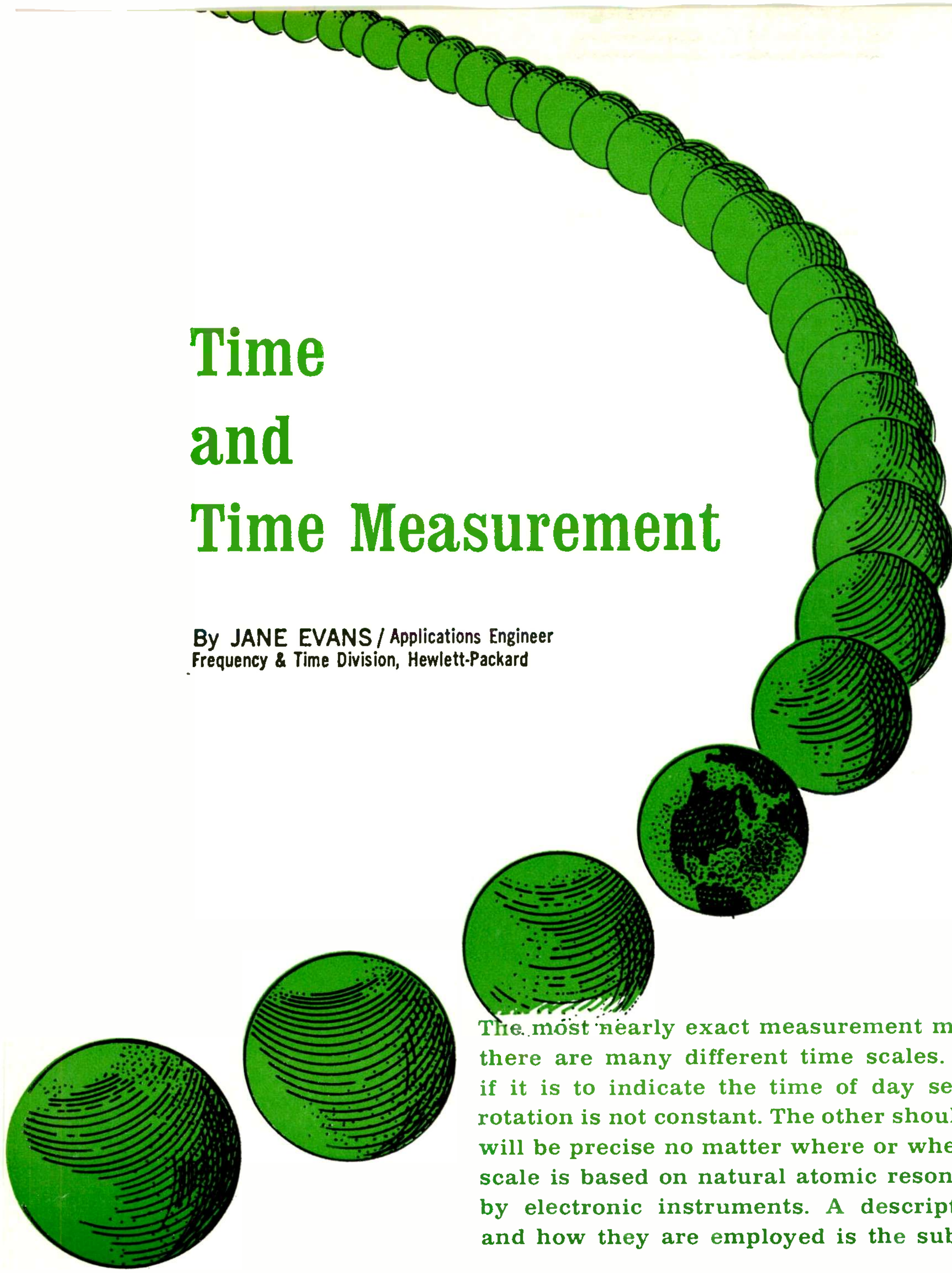




Time and Time Measurement

By JANE EVANS / Applications Engineer
Frequency & Time Division, Hewlett-Packard

The most nearly exact measurement man can make is of time, yet there are many different time scales. One of these must change if it is to indicate the time of day sensibly, because the earth's rotation is not constant. The other should be fixed so measurements will be precise no matter where or when they are made. The latter scale is based on natural atomic resonance and is accessible only by electronic instruments. A description of all the time scales and how they are employed is the subject of the following story.

HOWEVER mysterious may be the inner nature of time, its dimensions are measurable with more precision than we have yet achieved for any other fundamental physical quantity. Since every unit of measurement, including the familiar electrical ones like volts, ohms, and amperes, is ultimately referenced to mass, distance, and time, time measurements are basic to all science and engineering. Therefore, the precision with which time measurements can be achieved is an important element in man's understanding of his universe.

Our concern in measuring time, as in measuring other quantities, eventually comes down to agreement among ourselves on what we mean by the expressions we use and to establishing means of reproducing measurements precisely so that we come up with exactly the same numbers when we measure the same thing.

Much of science and engineering is concerned with measuring time intervals, as in determining the duration of pulses, the time to return a radar echo, or the period (duration) of a single cycle of a train of waves. To do this, we must first have a common agreement on the unit of measurement, in this case the second of time. It is only by agreement, evolved from hundreds of years of custom, that we assign 60 seconds to the minute and 60 minutes to the hour. These are in no sense "facts" which were "discovered," but rather agreements, that have been based more or less accurately on divisions of the length of the day and the year.

Seeking an Unvarying Reference

Some astronomers predict that the earth's momentum will be altered by eons of tidal friction and by meteorite collisions. As a result of this, it is felt that the earth must eventually circle inward and plunge into the sun. Hence, the length of the year can be presumed to be changing. This change, however, has thus far defied detection. We must agree, of course, on what we mean by a "day" and a "year."

Astronomers have agreed upon a kind of time called Ephemeris Time (ET), based on the motion of the earth about the sun. The International Committee on Weights and Measures in 1956 defined the second of Ephemeris Time as the fraction of 1/31,556,925.9747 of the tropical year for January 0 (Century Day), in the year we have agreed to call 1900, at the hour we have agreed to call 12 hours. The tropical year for that moment in time is the length of time the year (measured at the equator) would be if the sun continued to move at its then apparent instantaneous rate, corrected for the eccentricity of the earth's orbit and for the variations introduced by the nodding of the earth on its polar axis. It took many, many years of careful astronomical observation to collect data which, taken all together, established to perhaps 12 significant figures (parts in 10^{12}) that the earth's rate of rotation about the sun is unvarying.

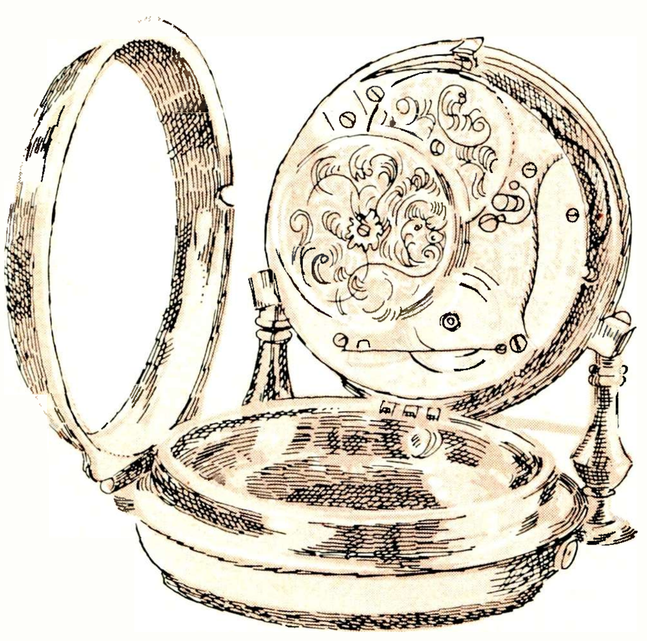
ET, then, appears to be a firm reference for measuring time intervals. Using it, celestial bodies will appear in repeatable astronomical relation to one another year after year. Insofar as this time scale is accessible to observers everywhere with the desired degree of precision, measurements of the same things will produce the same numbers. There, however, is the rub. Ephemeris Time, to many decimal places, is accessible directly only by very long astronomical observations. Furthermore, astronomers have reason to believe that the earth's orbital velocity eventually will show a change.

Time-Measuring Instruments

Convenient generators of time information (clocks and, in modern times, frequency standards) have been the object of much human endeavor from time immemorial. The story of sundials, waterclocks, and hourglasses has been told often. The development of fine clockworks made an immense improvement in the precision with which observers could agree on their measurements of time intervals, and this was a matter of great practical importance. The ultimate common reference for all of man's time measurements remained astronomical, though, until 1964, when the atomic scale was adopted.

The impetus to develop precise clockworks was the practical necessity of navigating accurately. The most practical way to determine longitude at sea is to compare the angle overhead of an astronomical body with the angle it is known *at the same moment* to be making at a known longitude. It is again a matter of agreement that Western observations are referred to a point near Greenwich, England. This involves carrying a clock which agrees, to the required precision, with Greenwich Time.

Back view of Harrison's timekeeper No. 4, constructed in 1759, shows its beautiful design and workmanship. Forerunner of the modern marine chronometer, the original version gained for Harrison 20,000 pounds offered by the British Parliament in 1714.



Navigation in early times was far from precise. In the early 18th century, missing a landfall by 90 miles was no scandal. The rate of the earth's rotation is the reference which navigators basically must clock accurately. What was needed was an artificial generator of time intervals, portable and easily read, which would either keep precisely in step with astronomical observations at Greenwich, or which would at least have a uniform rate of deviation so that Greenwich Time could readily be calculated from it.

No mechanical device or electronic oscillator itself generates unvarying time intervals, much less intervals which will stay indefinitely in step with the most nearly unvarying events we can observe (the bases of the Ephemeris and atomic time scales). A simple *difference* in the rate of a time-interval generator, in comparison with the agreed reference, is only an inconvenience if it is steady and known, since under these conditions the difference in their indications of time can be calculated. But all artificial time-interval generators *drift* in rate to some degree. Progress in measuring time intervals has consisted, then, in improving the precision with which this drift may be known or controlled.

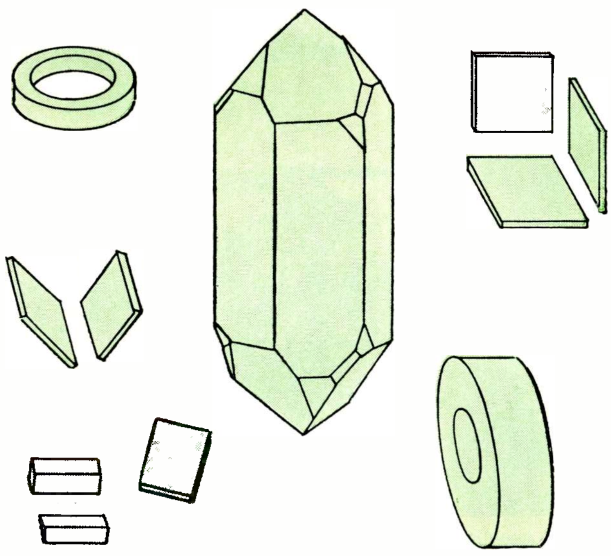
The degree of precision with which time intervals must be clocked to achieve safe navigation at sea can easily be seen. The British government, in 1714, offered to pay what was then a king's ransom, 20,000 pounds sterling, for any device that would determine the longitude within 30 minutes (2 minutes of time or 34 miles). It was the largest reward ever offered. The full amount was to be paid when a ship using the device sailed from Britain to a port in the West Indies without erring by more than the specified figure. Such a voyage, in those days, took about five months. To put the matter in the terms we commonly use today to describe the stability of time-interval generators, the British government, at the beginning of the eighteenth century, was calling for a device whose stability would be known or calculable to better than 1 part in 10^5!

This feat was accomplished and the prize finally paid, after years of haggling, to an uneducated Yorkshire carpenter named John Harrison. His magnificent marine chronometer had erred, at the end of a five-month voyage in 1761-62, by only 1 minute 53½ seconds! It was the product of a lifetime's labor and may be taken quite genuinely to have justified his biographer's words about it: "By reason alike of its beauty, its accuracy, and its historical interest, it must take pride of place as the most famous chronometer that ever has been or ever will be made." This instrument, made more than 200 years ago, performed at about the level we expect today of a moderately good crystal-controlled electronic time-interval counter. Only recently was there introduced a wristwatch, driven by a tuning-fork electronic oscillator, specified to drift no more than 1 minute per month (2.3 parts in 10^5). It appears typically to perform about twice that well, or at roughly the same level as the Harrison chronometer.

Significant further improvement in the stability of time-keeping devices came only in the 20th century with the invention of tuned *LC* electronic oscillators and, a little later, of quartz-crystal-controlled oscillators. These have gradually been improved to the point where some of the very best of the modern commercial quartz-controlled oscillators are specified stable to 5 parts in 10^{11} per day.

Stability vs Accuracy

It is important to realize that when we know the stability limits of a time-signal generator, we have only one of the facts we need to establish the *accuracy* of the signals which it generates. Indeed, it is meaningless to state accuracy *except with respect to a standard which is known to be unvarying* (and even here, we mean unvarying except within limits



Quartz crystals are widely used in accurate electronic clocks. Cuts of various sizes, shapes, and at different angles are obtained from the larger mother quartz crystal, which is either found naturally or grown artificially at high temperatures and pressures.

which are known to be too small to affect the comparison). We have seen that there is one such scale for comparison, the Ephemeris Time scale (ET).

If one of these superior modern quartz oscillators *could* be compared with ET on a given day, and if its rate were set so as to coincide exactly, we would know that, 24 hours later, its rate will not have drifted more than 5 parts in 10^{11}. There is an uncertainty, but we know its outside limits. We still can state with what *accuracy* the time-signal generator is delivering its signals at this later time because we know how long a time has elapsed since it was set correctly, and we know what its maximum drift is. At the end of two days, the limits of uncertainty are 1 part in 10^{10}; at the end of three days, 1.5 in 10^{10}; at the end of four days, 2.0 in 10^{10}; and so forth.

In real practice we cannot set an oscillator to coincide "exactly" with any outside source of time information, but only to coincide within known and quite acceptable limits. In real practice, too, a finely made quartz-crystal standard oscillator will rarely if ever drift (*i.e.*, alter its rate) in a single day as much as its specification will allow. Because of crystal aging, these oscillators typically drift slowly downwards or upwards, one or the other, over many days so that a trend can be recorded and their rate at any time predicted. The principle remains the same, however: all time-interval generators which are not referenced to any unvarying physical phenomenon, like the Ephemeris year, drift *in rate* and gradually become more or less accurate. Drift is the measure of stability and is given as a fraction (like 1 part in 10^{11}) per unit of time (like 24 hours). It is more conveniently stated mathematically, as $1 \times 10^{-11}/24$ hours. This becomes a statement of *accuracy* only if the time period is indefinitely long.

Epochal Time

We have dealt thus far only with measurement of time intervals and not with measurement of the time of day, such as 12 o'clock noon. This most certainly is purely a matter of agreement. The Western world for the most part has agreed to reference the time of day (in scientific circles it is called "epochal time") to observations made at the Greenwich Observatory in England. To keep a clock at any place in the world precisely in time with Greenwich Mean Time (GMT), we need yet another kind of time interval *which has a different length second* than the ET second. This is not an arbitrary matter related to the desire of some ancient British monarch but is really needed as the result of the instability or drift in the rate of the earth's rotation about its own axis.

Before that effect became apparent, however, those whose business it was to set up a time scale on which navigators could all agree had to take several other factors into account.

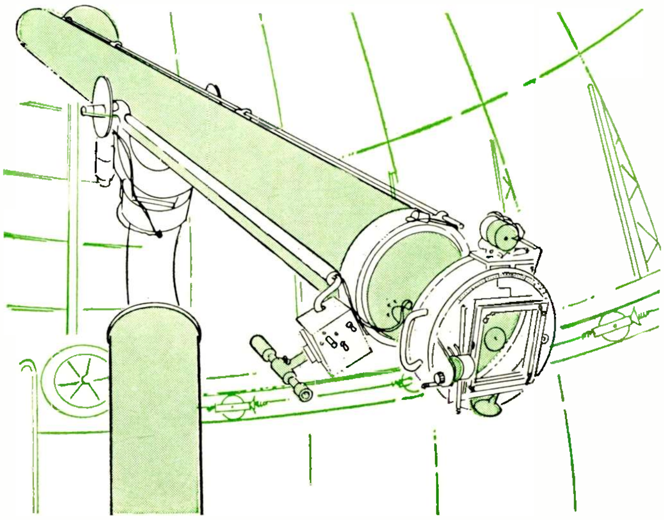
A unit of time derived from apparent motions of the sun will only be constant if the sun reappears over a fixed point of observation at uniform intervals. Measurements made with a sundial or sextant give apparent solar time. If the earth's orbit were a perfect circle, and if that orbit lay in the same plane as the earth's equator, then the length of an apparent day would remain constant throughout the year. The earth's orbit, however, is elliptical. For this reason, the earth moves faster along its orbit when it is closest to the sun. At this time of the year, even if the earth's rotation were uniform, the sun will appear to move through more angular degrees in the sky during a single rotation of the earth. Furthermore, the earth's axis is inclined with respect to its orbital path around the sun, and this produces further variation in the number of degrees through which the sun apparently moves during one complete rotation of the earth. These regular variations can, of course, be averaged, and a time scale can be set up so that navigators who know the date can correct their data by means of a chart.

It developed, however, as more stable time-interval collectors (clocks) were invented, that errors occurred. These could only be attributed to variations in the earth's rotational rate. Two subsequent Universal Time scales were invented, each more useful than its predecessor. The first (called UTI) recognized that the earth's pole is slowly shifting so that an uncorrected astronomical observation will give a slightly false reading of the earth's true angular rotation. The second scale, UT2, added a correction for seasonal variations in the earth's rotating rate which are apparently due to seasonal displacements of matter over the earth's surface, such as changes in the amount of ice in the polar packs.

This latter time scale is still in worldwide use as the scale by which epochal time is clocked. It is the time scale by which our daily lives are measured, which is collected and indicated by clocks, and which most usefully gives longitude information for navigators. Nevertheless, irregular changes in the earth's rotation rate, by no means all understood, necessitate a change in the agreed length of the UT2 second each year. This change has been as great as 1.5 parts in 10^8 in a single year; this surely makes it necessary, in scientific and engineering measurements of the highest precision to state what time scale is in use. If UT2 is used, then we must state in what year the measurement was made.

The trouble is that our earth does not revolve precisely the same number of turns about its own axis every time it makes one full orbit around the sun. The slowing is very

The Naval Observatory uses this dual-rate moon position camera telescope to observe the position of the moon with respect to background stars, thereby checking Ephemeris Time calculations.



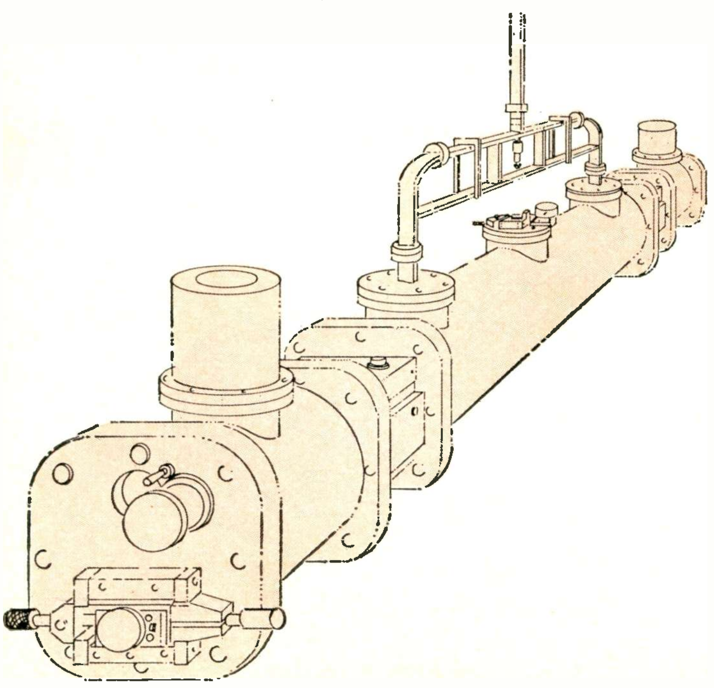
slight. In 200 years, not even a full second of difference has collected. We need, for ordinary living, a time scale which, when clocked, ticks off successive days and nights with precision. Navigators need a scale which will tell them with uncomplicated corrections at what angle a body will appear in the sky at a given (epochal) time. Such a time scale must be based on a unit whose length changes from time to time, since it must be based on the changing rotational rate of the earth. Scientists, however, need a time interval unit to which reference may be made at any time, without correcting the reading for the year in which the measurement was made. Science, furthermore, needs a time scale to which reference may easily and conveniently be made and not one which takes years to define. It would be helpful, especially to astronomers in correlating measurements recorded over long periods, if this time scale were in near-perfect agreement with the one astronomical scale (Ephemeris Time) which thus far seems to be invariable. Astronomers, physicists, and electronic scientists have contributed to devise such a scale.

Atomic Time

During this century it has been learned that within an atom the electrons may assume various orbital arrangements which may be described in quantum mechanical rules that have been worked out. Some arrangements have more energy than others. During a transition from a higher energy configuration to one of lower energy, the surplus appears as electromagnetic radiation. Each transition has its own characteristic frequency, defined by a constant of nature which appears to be invariable. There are many such transitions. To be useful as a reference, the one chosen should be of a kind that is easily observed, and its characteristic frequency should be very high (in the microwave region) so as to increase the resolution with which comparisons may be made to it in a conveniently short space of time.

One such transition occurs in cesium 133. In the middle of this century, physicists invented a practical device, the cesium beam tube, which makes it possible to observe the characteristic frequency of that transition. The national laboratories of several countries have constructed splendid models of this device. Extremely careful comparisons have been made among them. To something on the order of a few parts in 10^{12}, they are known to be in agreement in rate. Such tiny differences as do exist are due to perturbations within the tubes and not to variations in the atomic reference.

The National Bureau of Standards cesium beam atomic frequency and time standard, which is the primary standard for the measurement of time. Device operates at 9192.63177-MHz frequency.



Home of Greenwich Mean Time at Herstmonceux, near Greenwich, Eng.

Many considerations must be taken into account in designing such tubes for minimum perturbation. Length tends to reduce error and some of the standards used by national laboratories are many feet long. Recent developments have made it possible, however, to achieve agreement in the region of parts in 10^{11} or 10^{12} with instruments which can be fitted into a standard rack cabinet. They may even be battery-powered and transported about easily. What is exciting to scientists and engineers about these devices is that *they do not drift*. They continue to function within these very narrow limits indefinitely. They may, therefore, be used individually to *define* time intervals, without other reference. Thus they are *primary* standards.

The first atomic oscillator to serve as a precise standard was constructed at the British National Physical Laboratory in June, 1955 by L. Essen and J. V. L. Parry. It was of the cesium beam type.

The atomic transition exploited by the cesium beam tube has now been adopted as the international standard of time interval. In 1964, the Bureau International de l'Heure, a multi-nation standardizing body headquartered in Paris, reached this agreement and declared it. W. Markowitz and R. G. Hall at the U.S. Naval Observatory with L. Essen and J. V. L. Parry of the British National Physical Laboratory established in 1958 that the frequency of the chosen transition is 9,192,631,770 cycles per Ephemeris second, ±20 cycles. The international standard of time interval is defined to be 9,192,631,770 periods of the natural electromagnetic oscillation occurring during that transition of cesium 133 which is designated $(F=4, m_F=0) \leftrightarrow (F=3, m_F=0)$. The two parts of this expression simply define two discretely different energy states which may be taken by the orbiting electrons in an atom of cesium 133, between which transitions may occur and during which electromagnetic radiation of a constant frequency is emitted.

By electronic arithmetic, as in frequency synthesizers, any desired frequency can be derived from the unwieldy number given above. With suitable care in the circuitry, a 100-kHz (kilocycles per second) standard frequency can be derived (or one of any other desired frequency), and it can be known to be steady with virtually the same certainty as the reference. This can be used to drive a clock, where absolute accuracy is then known. Other needed time scales, such as UT2, can be generated by appropriate arithmetic circuits. The difference is given as an offset, described in parts per 10^{10} and issued yearly by international agreement.

Correlating Time Standards

The precision with which time intervals can be compared, using Atomic Time (A_1) as a reference, is equal to atomic-controlled oscillators' demonstrated long-term agreement (parts in 10^{11} or 10^{12}). The precision with which clocks in various places will agree on the time of day (epochal time) is another matter, however. Greenwich Mean Time, or any other nationally established standard, may be taken as the reference. Every means, including reference to astronomy and atomic standards, is used to keep national standards running together at the same *rate* so that the *difference* in their indicated time of day at any given moment will remain substantially constant. Differences among timekeeping centers on indicated time of day (epochal time) have been shown to be many milliseconds.

There are some modern purposes for which exact knowledge of these differences is important. One, for example, might be determination of the exact position or velocity of an interplanetary space vehicle by comparison, at two widely separated known points on earth, of the exact time at which the same signals from the vehicle arrive at each. In space and at microwave frequencies, the velocity of signal transmission may be taken as constant so that such a measurement would make sense if agreement on time of day on earth were sufficiently exact.

The uncertainty in our knowledge of the difference among timekeeping centers on the time of day can be narrowed only to a certain degree by ordinary radio means because the speed with which radio waves propagate over the horizon through long distances is variable, depending mainly on ionospheric conditions. The uncertainty in our knowledge of these differences, even after many radio comparisons, was at least 50 microseconds.

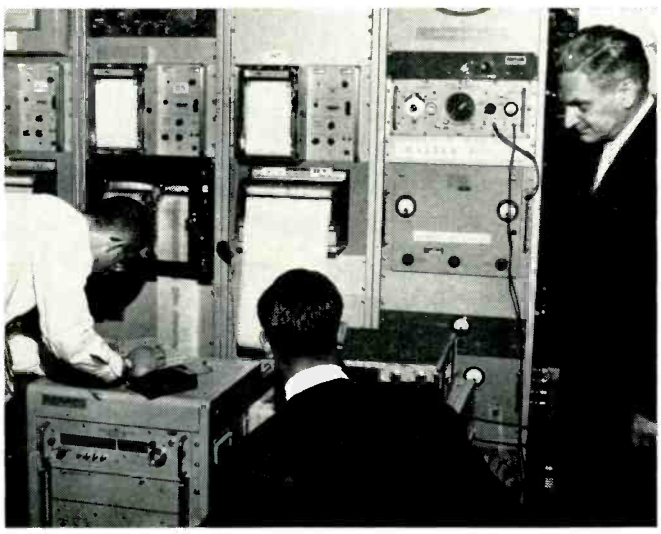
Two ways have been used in recent years to narrow the uncertainty. Each has been useful to check the other. One is by microwave communications *via* satellite relay, whose transmission time is much less subject to ionospheric variation than long-distance l.f. or h.f. transmission. This was accomplished between England and the United States in 1962 with government facilities and the *Bell Telephone Company's* Telstar II. It was accomplished again in 1965 between the United States and Japan, using the U.S. Navy facilities in the Mojave Desert of California, NASA's Relay II satellite, and the Radio Research Laboratories of Japan. On this occasion a cross-check was made by the second method, the "flying clock."

Cesium-controlled atomic clocks were synchronized at Mojave and at Washington, D.C. with the U.S. Time Stardard. These clocks, the first of their kind to be sufficiently compact to fly conveniently in ordinary passenger airliners, were then flown to Japan where comparison was made with the Japanese timekeeping center. Uncertainty over the offset between the two time-of-day standards was reduced to a few microseconds by these two kinds of measurement.

The same clocks were flown among 21 timekeeping facilities in 11 countries in 35 days, including centers in Canada, England, France, Switzerland, Germany, Denmark, and Sweden. Similar reductions in the uncertainty over time differences were made with each stop, and valuable information was gained on the exactness with which standards of time interval agree.

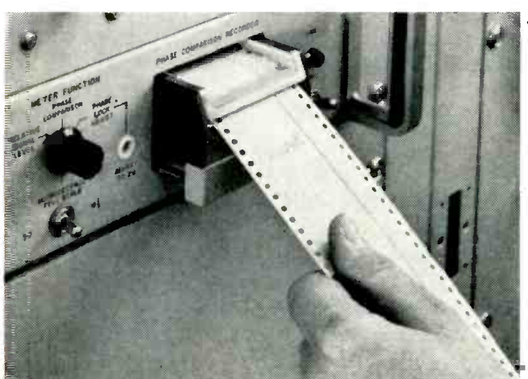
Techniques of Modern Timekeeping

In engineering and science, time interval is the most commonly wanted time measurement. Frequency measurements are, of course, measurements of cycles (which can be totaled, one by one) per second of time interval. Electronic counters which measure frequency, therefore, either have built-in time bases or are connected to external time bases. These are stable oscillators, (*Continued on page* 84)



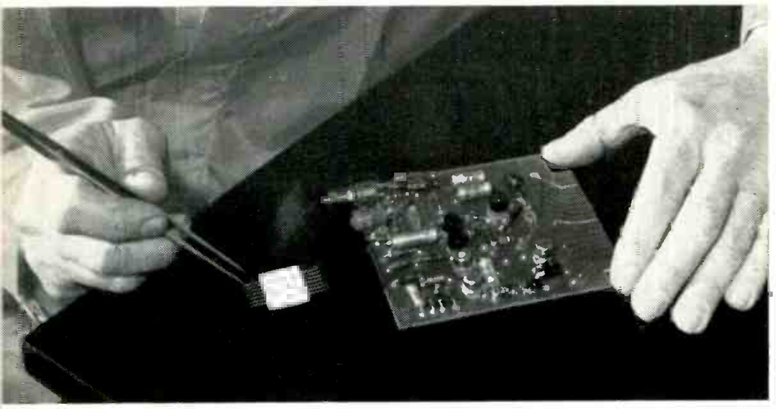
The U.S. Naval Observatory, home of U.S. standard on time of day (epochal time). W. Markowitz, right, observes time comparison by flying clocks. Markowitz and R.G. Hall, along with Essen and J.V.L. Parry, established in 1958 the precise frequency of the atomic transition used in primary time standard.

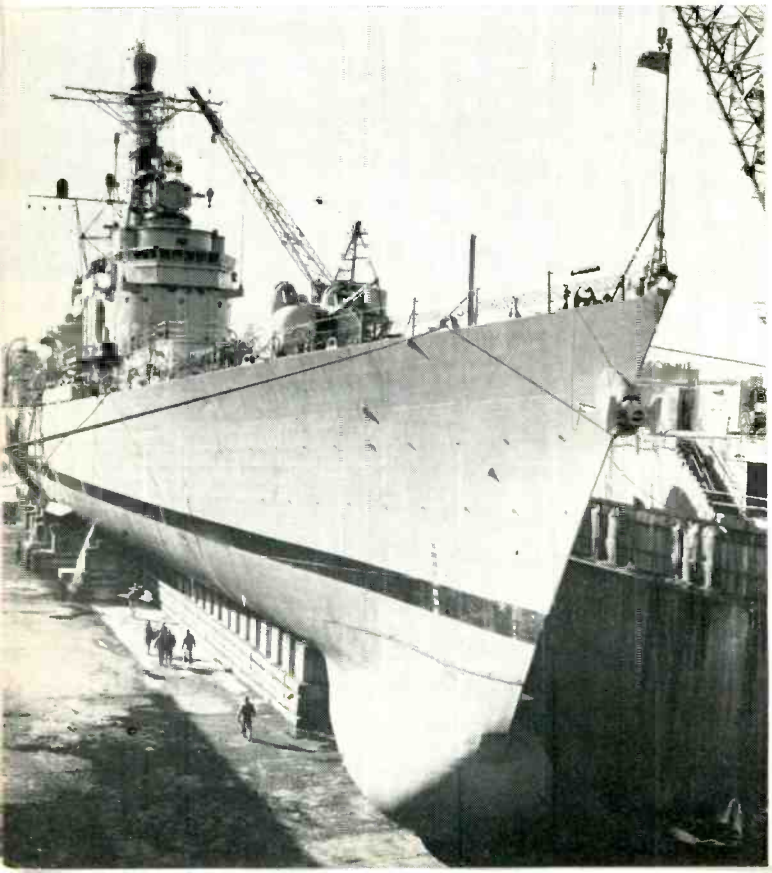
Lathare N. Bodily, co-designer of atomic standard which gives the flying clocks their accuracy, adjusts his instruments.



Comparison between local standards and NBS are conveniently made by automatic recording. Phase of the received 60-kHz NBS transmission is continuously compared with that of the local standard. Here a local atomic standard is compared to the NBS transmission. Since the local atomic standard is known to coincide with the NBS transmission within a few parts in 10^{12}, the measurement being taken is actually of the differences caused by propagation between the transmitter in Boulder, Colo., and the receiving point which, in this case, is located in Palo Alto, Calif.

Dr. L. Essen examines atomic clock in England.





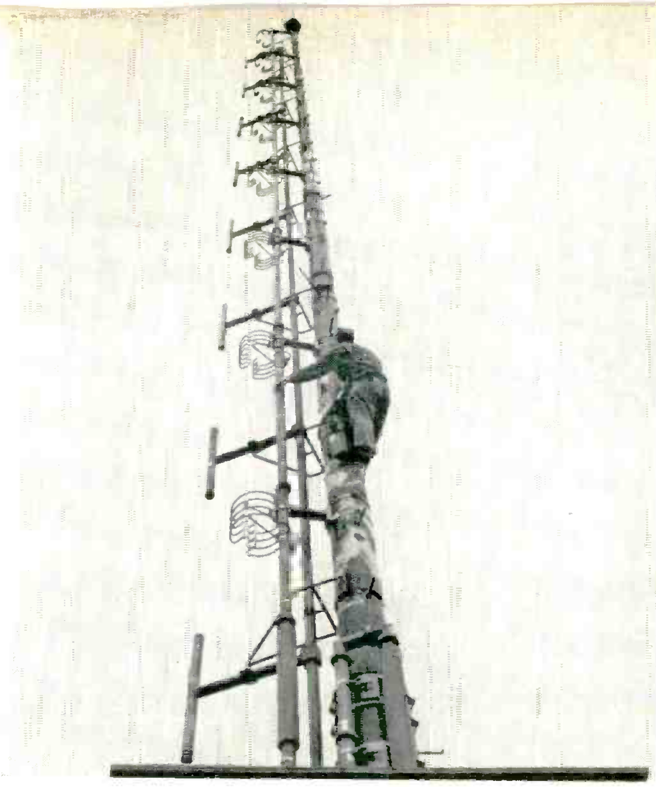
RECENT DEVELOPMENTS IN ELECTRONICS

Computer Does Homework. (Above) A group of six New York City high-school students are finding it easier to do their homework these days, thanks to the use of an IBM computer located some fifty miles away. The only extra equipment in the students' homes is an accessory "pad" connected to their telephones to provide touch-tone dialing. The student first dials the special number which connects the computer to his line. Then he enters the numerical values and operations applying to his problem by means of the "pad." The computer gives him an immediate answer to the problem over the phone. Although the computer's voice is that of an expressionless young lady, the fact that the computer talks to the student makes the system very effective. If a mistake is made in entering the problem, the computer's voice tells the student that he has made an error. The student must set up the problem properly; the computer does the calculations. The program is an experimental one conducted jointly by the Catholic Schools Diocese of Brooklyn and IBM. The computer manufacturer foresees the use of centrally located computers that will share time with a large number of users in homes, engineering and professional offices.

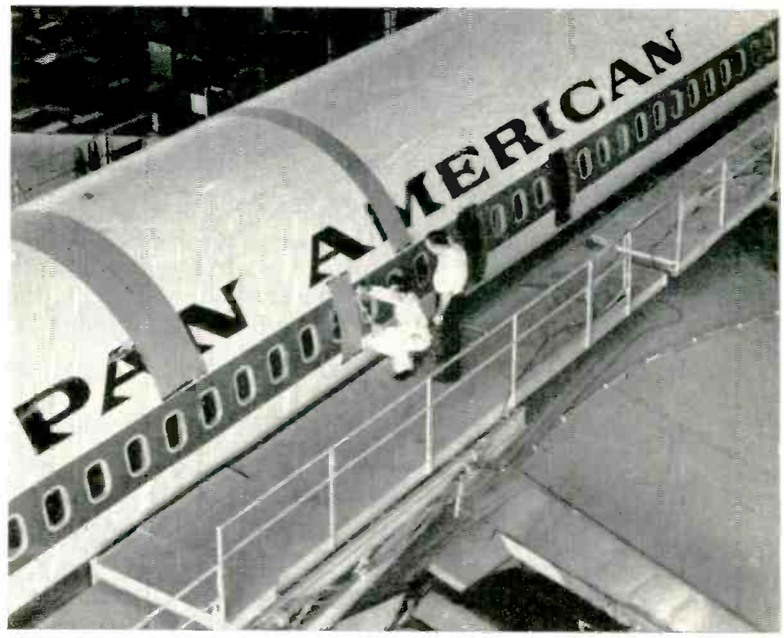
Integrated-Circuit Test Equipment. (Center) A tunnel-diode voltmeter on the circuit board at the right has been shrunk to a chip-sized integrated circuit by Boeing engineers as part of the MITE (Microelectronic Integrated Test Equipment) program. The idea is to build test equipment right into subsystems used in jet airliners or space vehicles, so that these assemblies can be made self-checking. The circuits sample mechanical or electrical action and convert it to voltage readings. Should the voltage fluctuate beyond certain limits, bells will ring, red lights will flash, or a computer will be told that the unit is in trouble. So far in the works, in addition to the tunnel-diode voltmeter, are "go/no-go" detector, chopper, converter (frequency standard and gate), and reference voltage generator.

Giant Sonar Bow Dome. (Left) The large bubble at the bow of U.S. Navy destroyer Willis A. Lee is a nine-ton molded rubber sonar bow dome. It is used to protect sensitive sonar equipment housed below the ship's water line. Inch-thick reinforced rubber walls have acoustical properties similar to those of sea water, permitting sound to pass through with minimum distortion for efficient submarine detection. The dome is the largest product ever molded from rubber, according to B. F. Goodrich Aerospace and Defense Products, the manufacturer. The dome is 20-feet wide, 10-feet high, and 37-feet long and can withstand over 11,500 pounds pressure per square foot. It is pressurized internally with sea water to withstand high speeds and pressures. Streamlining is required to reduce the turbulence of the water that would otherwise produce noise.

Dual-Polarized FM-Stereo Antenna. (Right) A new dual-polarized transmitting antenna, located 590 feet above the ground on Chicago's Field Building, is now being used by WEFM of that city. The eight circular bays provide the usual horizontal polarization, while the eight vertical dipoles provide vertical polarization. By using this dual polarization, the FM broadcast station expects to improve its coverage, particularly for motorists with FM radios and for listeners using radios with line-cord or hank antennas.



Wrap-Around Radiograph Checks Fuselage. (Center) Technicians are shown laying out film for a full 360-degree fuselage radiograph of a jet Clipper. The x-ray unit is inside the plane and is lined up with the film. Exposure time is about one minute for the full 360 degrees. After 5000 flight hours, a jet liner is inspected and repaired in compliance with rigid requirements. Using new x-ray equipment and long rolls of x-ray film, the previous 1500 man-hours required to open and inspect the plane visually has been reduced by as much as approximately 80 percent.



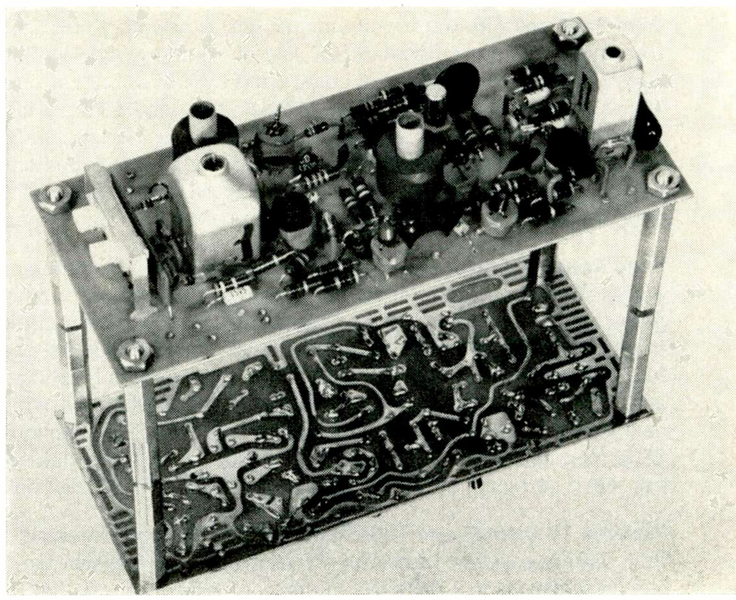
Portable TV Camera and Tape Recorder. (Below left) The world's first battery-powered transistor TV tape camera is shown here. The new device will tape 30 minutes of broadcast-quality TV with on-location sound. Seven-pound camera head permits the operator to see and control TV picture and sound as he shoots. The brief-case sized recording unit (on shoulder strap) weighs only 23 pounds complete with rechargeable nickel-cadmium batteries and magnetic tape. The tape recorder uses one-inch wide magnetic tape driven at 10 ips around a three-section inverted mandrel. The whole midsection, which houses the single recording head, rotates against the tape. The entire system is made by Westel Co., Redwood City, Calif, and sells for about $10,500.

Laser-Guided Tunnel Borer. (Below right) The 280-ton tunnel borer in the photo maintains direction with a unique laser-beam guidance system. The giant machine, built by Hughes Tool Co., moves forward in 5-foot steps as rotating cutting head bores into stone face. Cuttings are removed by a bucket system on the rotary head. An overhead conveyer belt carries the rock to the back of the machine for removal. The use of the laser permits the machine to cut 21-foot diameter tunnels with a single pass and with a high degree of straightness and accuracy. The laser is a small, rugged helium-neon unit which produces a straight, bright beam of red coherent light. This light source is set up at a distant survey station point and the light is made to fall on two photocell targets, each containing a grid of about 400 cells. One target is mounted at the front and the other is at the rear of the tunnel borer. Corresponding lights are made to glow on a display panel in view of the machine operator, who is then able to correct for any deviations that may occur.

AUTOMATIC STEREO MULTIPLEX DEMODULATOR

By DANIEL R. von RECKLINGHAUSEN
Chief Research Engineer, H.H. Scott, Inc.

Design of a transistorized circuit for use in hi-fi FM tuners in which demodulator diodes perform wholly automatic switching from mono to stereo.



Automatic demodulator subassembly is pictured placed over a mirror in order to show its printed circuitry.

EVER since the Federal Communications Commission authorized the broadcasting of stereophonic sound from FM stations, a number of circuits have been developed to demodulate the composite stereophonic signal into left and right audio signals. A number of these circuits were described by the author at that time and further developments have since been made.

The circuit we have found to be the most satisfactory has been a switching circuit where the multiplex demodulator alternately switches the composite signal from the FM detector to the left and right audio outputs. Usually this involves the use of an amplifier between the FM detector and the demodulator so that sufficient signal will be available for demodulation. Furthermore, it also involves the use of two audio amplifiers where the differential gain between the two audio amplifiers is adjusted to obtain the best separation.

All of the previous multiplex circuits had to be switched from monophonic to stereophonic operation by connecting the two audio amplifiers to either the stereo demodulator diodes or to a separate network connected directly to the detector of the composite signal amplifier. This required at least the equivalent of a double-pole, double-throw switch.

In order to have such circuits switch automatically from monophonic to stereophonic operation, double-pole, double-throw relays, or at least four diodes were used for this purpose, adding further to the complexity of the circuit.

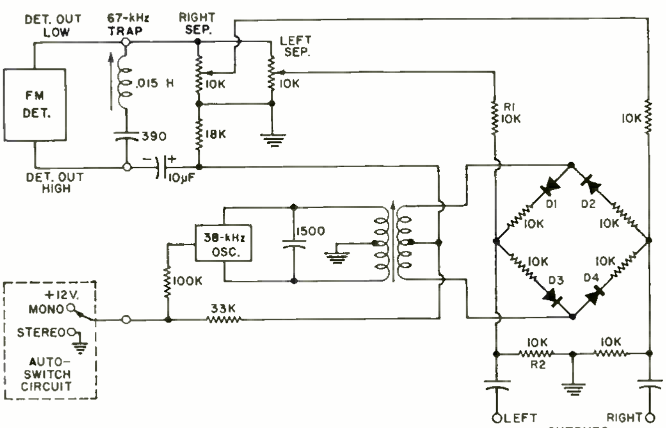
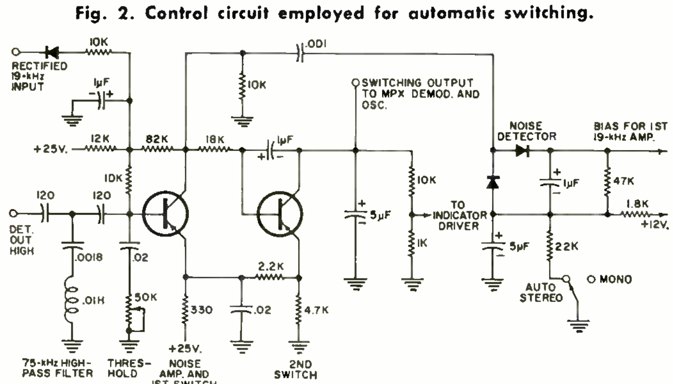


Fig. 1. Simplified circuit of the multiplex demodulator.

Fig. 2. Control circuit employed for automatic switching.



Basic Circuit Operation

Investigation and further development over the years showed that the multiplex demodulator diodes themselves could also perform the function of switching from mono to stereo operation. Fig. 1 shows such a circuit. Here, the FM detector is of the conventional wideband variety, except that the detector circuit itself is floating and not grounded, so that two terminals are available. Across the output of the detector is a trap circuit tuned to 67 kHz to remove any background music signal usually centered at this frequency. This signal would cause undesirable audible whistles when listening to FM-stereo if the station did broadcast such a service.

The FM detector circuit is grounded with two groups of resistors, an 18,000-ohm fixed resistor and the two 10,000-ohm separation potentiometers. In this way a "high" and a "low" output of opposite phase is obtained. The "high" output is also connected to the center-tap of the secondary of the 38-kHz oscillator transformer. Here, the oscillator voltage is, in effect, connected in series with the composite signal and applied in opposite phase to two sets of detector diodes.

At the moment the upper portion of the detector oscillator secondary has a positive voltage, diodes *D1* and *D3* will conduct to permit the composite signal from the "high" output of the detector to pass through the secondary of the 38-kHz oscillator transformer to the two 10,000-ohm resistors to the left output terminal. Whenever the polarity of the 38-kHz signal is reversed, the opposite pair of diodes, *D2*

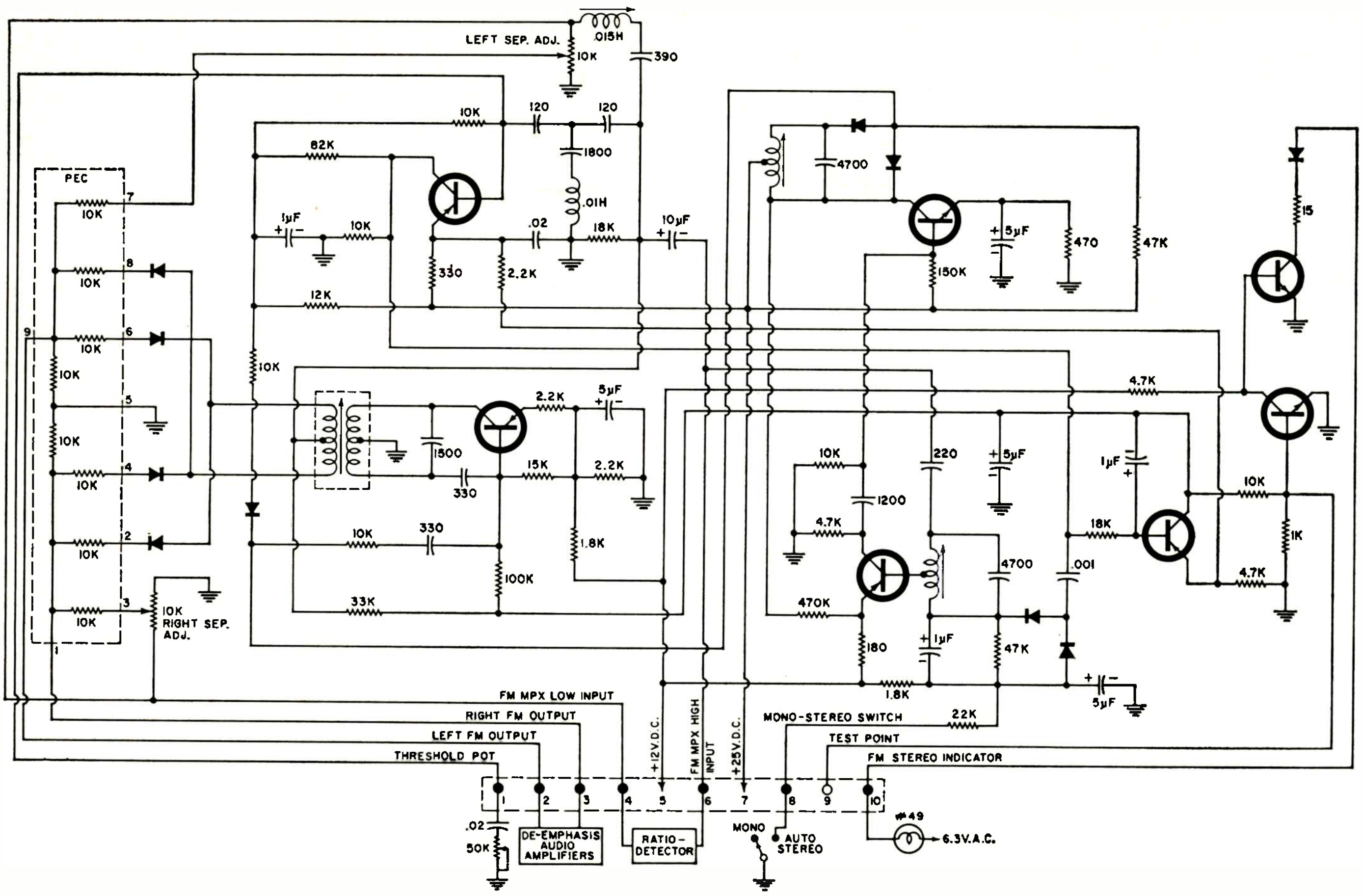


Fig. 3. Complete circuit diagram of the automatic switching stereo demodulator used in current Scott FM tuners.

and *D*4, will conduct and permit the signal to pass to the right output.

Since the switching efficiency for stereo demodulation is not 100%, the composite signal is also fed to the left and right outputs, but in opposite phase from the "low" detector output. Here, the two 10,000-ohm separation potentiometers feed the opposite phase signal through two 10,000-ohm resistors to the left and right outputs, respectively. Hence, the stereo separation at the left and at the right outputs can be adjusted separately. These outputs are, of course, connected to de-emphasis circuits and to further audio amplifiers which also have very sharp cut-off 15-kHz filters to prevent any ultrasonic component from being recorded as a whistle when employing a tape recorder.

The Switching Function

Whenever the FM station does not broadcast stereo, it is desirable to switch the multiplex circuit to monophonic operation, as shown in Fig. 1. In stereo operation, the switch is, in effect, grounded and bias is applied to the 38-kHz oscillator to permit it to function. The 38-kHz oscillator is synchronized by the 19-kHz pilot signal from the FM station.

In order to switch the multiplex circuit to mono, the switch is connected to a positive voltage of approximately 12 volts. The voltage first biases the 38-kHz oscillator in reverse and thereby prevents a 38-kHz output. Next, this positive voltage applied to the 33-kΩ resistor will also be applied to the center-tap of the secondary of the oscillator transformer. This allows both direct and signal current to flow through diodes *D*1 and *D*4 and their associated resistors. The d.c. control current flows to ground partly through the left separation control and partly through 10,000-ohm resistors *R*1 and *R*2. Diodes *D*2 and *D*3 will be reverse biased.

Since in stereophonic operation the diodes conduct at only alternate half-cycles, signal current from the FM detector will appear at the left and right outputs only half the time, but flowing through two 10,000-ohm output resistors in parallel. In mono operation, it will flow at all times through only one 10,000-ohm output resistor. Audio output level remains constant in mono and stereo.

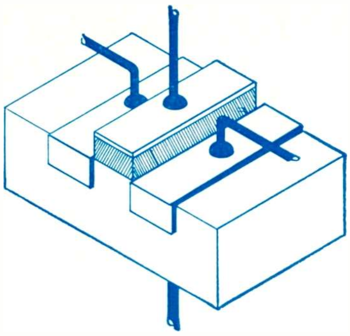
In order to have automatic switching from mono to stereo, a control circuit is required, the schematic of which is given in Fig. 2. Here, two transistors are arranged in a switching circuit. In normal mono operation, the first switching transistor conducts to some degree, and the second transistor is fully turned on with a voltage drop from collector to emitter of almost zero.

When a multiplex signal is received, the 19-kHz pilot signal from the FM detector is amplified in a separate two-stage amplifier (not shown), and the output of this 19-kHz amplifier is partially rectified to obtain a negative control voltage with respect to the 25-volt supply. This relatively negative voltage is then fed through the two 10,000-ohm resistors to the base of the first switching transistor, causing it to conduct more current. The voltage drop across its 10,000-ohm collector resistor increases and reduces the base current of the second transistor, thereby reducing its collector current. In order to have this second transistor switch off, positive d.c. feedback is applied from its emitter through the 2200-ohm resistor to the emitter of the first transistor, thereby causing the first transistor to conduct more and turning the second transistor off. Therefore, the voltage drop at the collector of the second transistor has now decreased from 12 volts to almost zero volts.

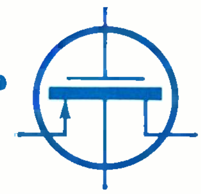
The decrease in collector current of the second transistor changes the voltage drop across the 1000-ohm series collector resistor which is used to turn on additional transistors (not shown), causing a stereo indicator light to operate.

Further Refinements

These circuits could be used, without any further modification, to switch auto- (*Continued on page* 83)



The Insulated Gate Transistor



By DONALD E. LANCASTER

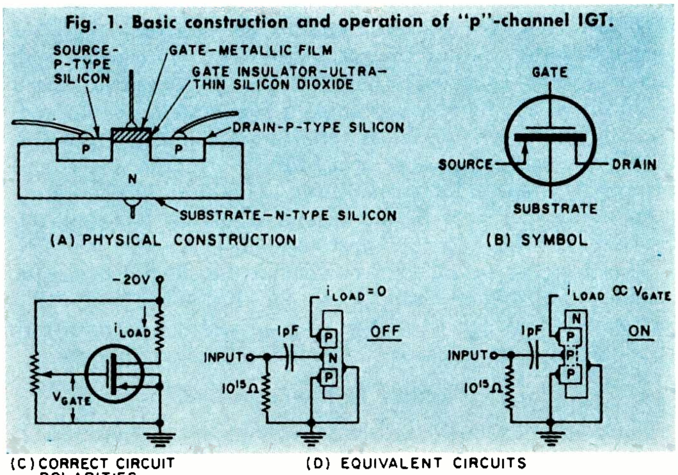
This new semiconductor, also called MOSFET, IGFET, or MOST, has an input impedance much higher than most vacuum tubes, simple geometry leading to inexpensive fabrication, high current gain, and very small size.

THERE is a new type of semiconductor with such remarkable properties that it promises to advance the electronic art as significantly as did the junction transistor itself. This is the *insulated gate transistor* (IGT), with an input impedance much higher than most vacuum tubes, a simple geometry inherently cheaper to fabricate than a junction transistor, essentially infinite current gain, and extremely small size.

Various designations for the device include the IGFET (insulated gate field-effect transistor), the MOSFET (metal-oxide silicon or semiconductor field-effect transistor), and the MOST (metal-oxide silicon or semiconductor transistor). All these devices are similar and simply represent the different nomenclature each company has chosen for its particular device. The IGT is *not* an ordinary junction field-effect device since it differs significantly in operating principle, biasing, and performance from the ordinary junction FET.

The most prominent feature of all IGT's is the fantastic input impedance which is typically 10^{15} ohms. The addition of leads and a glass header drops this to a mere 10^{13} ohms (that is 10 million megohms!). Considering surface conduction, ions, and grid current in vacuum tubes, this input impedance is much higher than any but special electrometer tubes. As an example, a 2-picofarad capacitor has enough charge to keep an IGT running at constant output current for several hours. This extreme input impedance opens new vistas for electronic circuits, particularly in ultra-sensitive electronic instruments; timing, monitoring, and holding circuits; and various types of logic circuitry.

Fig. 1. Basic construction and operation of "p"-channel IGT.



Operating Principles

An IGT consists of three terminals, the *drain*, the *source*, and the *gate*. Between the gate and the rest of the transistor is a nearly perfect insulator of ultra-thin silicon dioxide (typical thickness = 1500 Å). This is the key to the extremely high input impedance of the IGT. A voltage applied to the gate of an IGT allows a current to flow between source and drain. Any change in input voltage is reflected as a change in output current.

Fig. 1 shows a typical IGT and the bias polarities required. The device consists of an *n*-type substrate into which two identical *p*-regions have been diffused. Contact is made to these two *p*-regions, forming the source and drain terminals. Between the two *p*-regions, a capacitor is formed out of the *n*-type substrate, the silicon-dioxide insulator, and a metallic gate terminal.

We connect the source and the substrate to ground and bias the drain negatively, perhaps by -20 volts. In the absence of a negative gate voltage, no current will flow between source and drain because of the *n* substrate which forms a reverse-biased junction and prevents conduction.

Suppose a negative voltage is applied to the gate terminal. This places a negative charge on the gate terminal end of the gate capacitor. Consequently, a *positive* charge must be built up on the substrate end of the gate capacitor. The substrate started out as *n*-type material. The presence of the positive charge makes the material less and less *n*-type, until there is more positive charge available than there are excess electrons in the *n*-type material. At this instant, a portion of the substrate changes from an *n*-type to a *p*-type, forming a *p*-*p*-*p* junction or simply a connection of all *p* material between source and drain.

Down to a certain threshold level, perhaps less than -5 volts, the input gate voltage has little effect and very little output current flows (Fig. 1D). At inputs more negative than the threshold voltage, the output current between drain and source is a linear function of the negative gate voltage. The threshold level is that point at which a portion of the substrate switches from *n*- to *p*-type.

This type of operation is called "enhancement mode" for

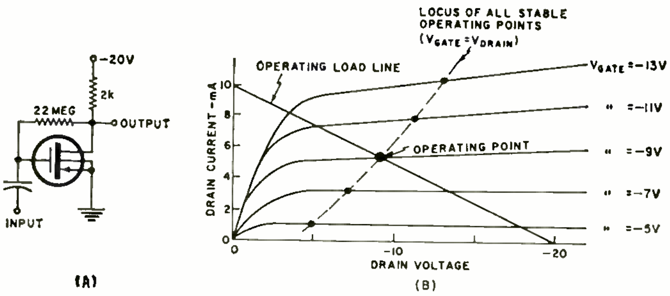


Fig. 2. Single resistor biasing of IGT. Since no gate current is drawn in the absence of an input, there is no drop across the 22-megohm biasing resistor, and the gate voltage equals the drain voltage. A stable operating point may be chosen on the curves anywhere the gate voltage equals the drain voltage. The bias point is stable because a slight increase in negative gate voltage produces an increase in source-drain current and decreases the drain voltage. This, in turn, decreases the gate voltage, returning to a stable operating point. Similarly, a slight decrease in gate voltage decreases drain current, increasing the drain and gate voltages, and returning the IGT to a stable point. By proper choice of load resistance, temperature drift of gate-to-source voltage can be made negligible. In this figure, operating point is chosen where $V_{gate} = V_{drain} = -9$ V. Using a -20 V supply, we can construct load line between operating point and supply axis. This intersects current axis at 10 mA, dictating load resistance of 2000 ohms.

Amelco Semiconductor 1300 Terra Bella Ave. Mountain View, Calif.	Motorola Semiconductor Box 955 Phoenix, Arizona 85001
Crystalonics Inc. 147 Sherman Street Cambridge, Mass. 02140	Radio Corporation of America Electronic Components and Devices Harrison, New Jersey
Fairchild Semiconductor 313 Fairchild Drive Mountain View, Calif.	Raytheon Company Semiconductor Div. 350 Ellis Street Mountain View, Calif.
General Instruments Semiconductor Products 600 West John Street Hicksville, New York	Silconix Incorporated 1140 West Evelyn Ave. Sunnyvale, Calif.
General Microelectronics Inc. 2920 San Ysidro Way Santa Clara, Calif.	Texas Instruments Inc. P.O. Box 5012 Dallas 22, Texas
KMC Semiconductor Corp. Parker Road, RD #2 Long Valley, N.J. 07853	TRW Semiconductors Inc. 14520 Aviation Blvd. Lawndale, Calif.
Union Carbide Corporation 365 Middlefield Road Mountain View, Calif.	

Table 1. Directory of insulated gate transistor manufacturers.

no output current flows unless a large enough input voltage is present. As the gate voltage rises and falls, the charge on the gate-to-substrate capacitor changes in proportion which, in turn, causes a proportional change in output current. Notice that no gate current is ever drawn. All the input voltage has to do is charge up or discharge a nearly perfect capacitor having a capacitance as low as 0.2 picofarad.

Some interesting features of the IGT should now become apparent. There is only one diffusion required to simultaneously put down both *p* regions into the *n* substrate, compared with a minimum of two diffusions required for any junction device. Thus, fewer steps are required to build an IGT, making it inherently cheaper than junction devices. In one specific instance, 130 processing steps are required for a junction-type device, while only 38 are required for a similar IGT device.

The IGT can be made quite small. Typical designs require only two square mils for an IGT whose equivalent junction device would take up forty-eight mils. In this example, 24 IGT's can, in theory, be put in the space of a single conventional transistor.

In the "on" (conducting) state, the IGT essentially consists only of *p*-type material. There are no semiconductor junctions, and no offset voltage is produced. The IGT will easily switch signals as low as 1 microvolt without any offset problem. The applied polarity doesn't really matter as long as the gate is biased negatively with respect to the substrate. Because of this, the IGT is bipolar and can accommodate either polarity of output current.

Most devices are symmetrical and it makes no difference which lead is called the source and which the drain.

The type of IGT we are describing and using in all the diagrams is called a *p-channel* device because in the "on" state the equivalent circuit is a single bar of *p*-material. Just as we have *p-n-p* and *n-p-n* junction transistors, *n*-channel IGT's which operate from opposite polarities are available.

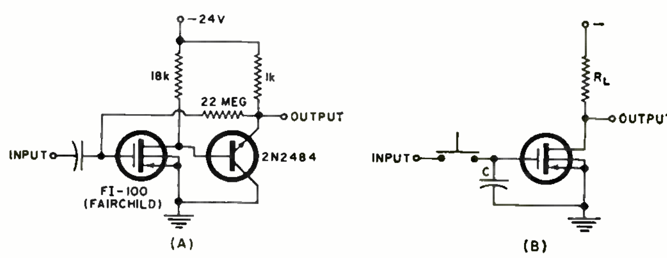
Biasing Considerations

Only a single resistor is needed to bias an IGT compared with several resistors and an electrolytic capacitor frequently used for an ordinary junction transistor. Further, by the correct choice of operating current, the biasing may be made largely independent of temperature. Fig. 2 shows how a biasing resistor is added from drain to gate. This resistor may be any value as long as it is small compared to 10^{13} ohms, and is chosen to be large enough to not significantly load the input signal. A value of 22 megohms is typical.

For a given gate voltage, the IGT allows a certain current to flow. If this current produces a drain voltage equal to the gate voltage required for that current, the bias point is stable. If not, the IGT quickly shifts to the correct bias point. Optimum values of bias and load depend upon the IGT. They are determined in exactly the same way as operating load lines of a pentode are determined, as detailed in Fig. 2.

IGT's have voltage gains from 1 to 15 or more. These figures are bound to improve with newer devices. The optimum load resistor for an IGT is usually between 1 and 20,000 ohms. When a lower output impedance is needed, the IGT may be cascaded with an ordinary emitter-follower, as in Fig. 3A. The voltage gain of this circuit is around five, while the current gain is around one million as the input impedance is 22 megohms and the output impedance is around 22 ohms. The resultant power gain under optimum conditions is 5,000,000—quite a respectable figure for a two-stage amplifier.

Today, the IGT is available in three forms, a single device in a TO-5 or TO-18 can, matched pairs on the same substrate



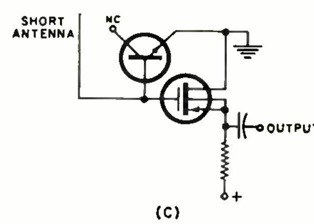
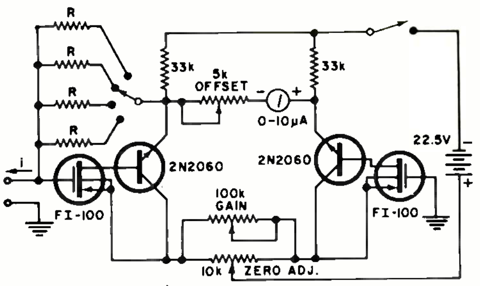


Fig. 3. (A) Adding an emitter-follower results in low output impedance. (B) "Catch and hold" circuit. (C) Proximity alarm.



i FULL SCALE	R
0-1µA	100k
0-100nA	1MEG
0-10nA	10MEG
0-1nA	100MEG
0-100pA	1000MEG
0-10pA	10kMEG
0-1pA	100kMEG

TRANSISTORS AND IGT'S MUST BE MATCHED PAIRS

Fig. 4. Circuit of extremely sensitive d.c. picoammeter.

in a similar package, or as the active elements in completely integrated circuits. Prices for a single unit range from $4 to $20, depending upon the manufacturer and the performance specs. The pricing trend is downward and much less expensive IGT's should be readily available within a very few months.

Table 1 lists a number of IGT manufacturers. Data sheets, application notes, and prices are available from most of these sources upon written requests on company letterhead.

Applications

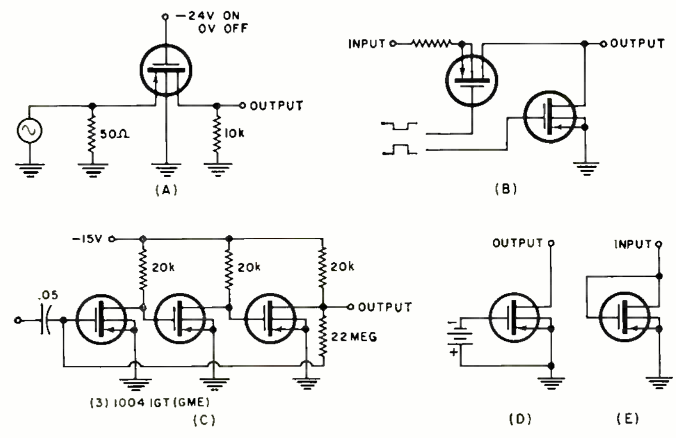
The IGT applications fall naturally into two groups, those using integrated circuits and those using discrete devices. Using IGT's as the basic transistor in integrated circuits has many interesting advantages, especially the small size, low current operation, and ease of manufacture.

Two problems always of interest in logic circuits are the "fan in" and the "fan out" of each logic element, be it gate, a flip-flop, a register, or an inverter. The fan in is simply the number of inputs available to a circuit. When using IGT's, multiple inputs are easily obtained in small space by paralleling as many IGT's together as there are inputs. Fan out is the number of circuits a given element can drive. With the extremely high input impedance of the IGT, a single device can drive hundreds, or even thousands, of similar circuits. This is a most significant advantage of the IGT in computer and logic circuitry.

Some integrated-circuit units are already available using IGT's. One is a shift register that counts to 21 and uses over 100 IGT devices. A second shift register counts to 100 and contains 612 IGT's. Both units fit easily inside a TO-5 can. We can soon expect to see entire IGT *systems* integrated into single large substrates, such as complete counting chains of flip-flops, decade counters with internal decoding, binary adders, entire logic circuits, and others.

Turning to the discrete-component applications, Fig. 3B shows an IGT with a capacitor between gate and source. An input signal momentarily applied will charge the capacitor to some value, producing some output current. Removing the input signal leaves the charge on the capacitor

Fig. 5. (A) R.f. switch. (B) Series-shunt chopper. (C) Audio amplifier. (D) Constant-current source. (E) Constant-R load.



and so does the 10^{13} ohm leakage path through the IGT. The IGT will "remember" the magnitude of the input voltage and produce the same output current for days after the signal has gone. This is called a "box car" or a "catch and hold" circuit, useful for sampling and averaging out a varying waveform, or catching a brief impulse and keeping its value long enough so that it may be easily measured. Even with no external capacitor, the internal gate-to-substrate capacitance, usually 0.2 to 10 picofarads, will hold the value of the input signal for several hours after the signal has disappeared.

Timing and delay circuits are an obvious extension of the basic hold circuit. A resistor from a reference voltage is used to charge a capacitor whose voltage is IGT monitored. When the capacitor voltage reaches the turn-on voltage of the IGT, an output is produced, and the timer reset. Precision saw-tooth and ramp voltages are generated in the same manner, with the IGT output being a low-impedance "copy" of the charge voltage on the capacitor without any loading effects.

Fig. 3C shows a proximity detector. Here a high-quality silicon transistor is used as the biasing resistance for the IGT. This provides a very high input impedance, yet protects the IGT should the gate actually be touched. The gate terminal of the IGT is extended to include a small antenna. A moving hand brought near the antenna will change the capacitance to ground without altering the charge present. This lowers the IGT gate voltage and produces a change in output current which is easily monitored. Only a slight amount of additional capacitance is required. For an IGT with a 1-picofarad gate-to-source capacitance, only 0.1 picofarad of additional capacitance will produce a 10% change in the output current. This makes the circuit extremely sensitive.

An interesting proximity application is alarms. Unlike practically all other alarm circuits, no energy is transmitted and there is no light beam, ultrasonic signal, or other detectable energy available that can either reveal the location of the alarm or even the fact that an alarm is present at all. (*Continued on page* 64)

HANDLING PRECAUTIONS FOR IGT DEVICES

The extremely high input impedance of the IGT is a two-edged sword, for a careless moment in handling can result in immediate and permanent damage to the component.

The culprit is static electricity which can easily build up several hundred volts of potential on the gate and puncture the silicon dioxide insulator between gate and substrate. As an example, the insertion of an IGT into a block of Styrofoam will almost certainly ruin the device as this generates over 200 volts of static electricity.

Engineers and technicians working with IGT's should strictly adhere to the following precautions:

1. The IGT comes with all four leads shorted together. Do not untwist the leads until ready for use.
2. Before untwisting the leads, wrap a layer or two of aluminum foil or fine wire securely around all four of the leads directly at the can.
3. Ground the tip of the soldering iron to the substrate lead before soldering the gate lead in place. Do not use a soldering gun.
4. Do not remove the aluminum foil or fine wire until all four leads are secure.

Once the circuit is permanently connected to the IGT, there is no further danger, as the input and biasing components will protect the IGT.

If sockets are used, always hold the IGT by the can and contact first the substrate lead and then the remaining three. Do not release the IGT until it is in the socket.

SPECIAL SECTION: SOLID-STATE DIODES

Rectifier Diodes

By FRANK GIFT / Chief Engineer, International Rectifier

Semiconductor diodes are now widely used to convert a.c. to d.c. at currents up to hundreds of amperes. Here are the most important parameters to consider in making a proper selection.

POLYCRYSTALLINE semiconductor materials (first magnesium copper sulfide and copper oxide, later selenium) were developed into practical power rectifiers long before monocrystalline (*e.g.*, silicon). Because of significant improvements in blocking (reverse) voltage capability, efficiency, size, and weight, selenium rectifiers displaced the oxide and sulfide types in all except very-low-voltage power supplies, where copper oxide, with an inherently lower voltage drop, is still attractive.

With germanium power rectifier diodes, designers realized an increase in current density, a reduction in forward voltage drop, and a moderate increase in blocking voltage with reduced reverse current, resulting in increased efficiency together with a reduction in size and weight.

As technological problems were solved, silicon diodes almost completely replaced germanium for use as rectifiers because of substantially superior reverse voltage capabilities, higher allowable junction temperatures, and an overall lower cost per kW of power rectified. Table 1 indicates a typical spectrum of available silicon rectifier diodes.

There is still an important segment of the business served by selenium, however. Because of its reverse voltage characteristic, which draws high reverse current at voltages in excess of rated, together with its relatively high capacitance and its ability to heal itself if broken down by voltages in excess of its dielectric strength, selenium can be used in applications where frequent voltage transients are likely to occur. In fact, an important class of selenium assemblies is designed primarily for voltage transient suppression. In applications of moderate current and voltage, selenium rectifiers offer a cost advantage over silicon.

A "rating" is a *limiting condition* of usage specified for the device by the manufacturer, beyond which catastrophic failure or impairment of serviceability may occur.

A "characteristic" is a *measurable property* of the device. Thus, "maximum peak reverse voltage" is a rating; "maximum reverse current at peak reverse voltage" is a characteristic.

The system most often used by the diode makers is known as "Absolute Maximum Rating," wherein the equipment maker should design so that throughout the life of his unit no specified maximum rating will ever be exceeded, even under the worst probable operating conditions.

Forward Current Parameters

Average forward current (I_o or $I_{F(AV)}$): The average forward current is used as a basic rating of a rectifier diode. It is defined as the maximum full-cycle average value of forward current allowable when operating in a half-wave circuit with resistive or inductive load (180° conduction), associated with a specified ambient temperature (or case temperature for devices designed to be mounted on external heat exchangers). Derating is required for higher temperatures and for other values of conduction angle (Fig. 2). For very short conduction angles (capacitive load, for example), manufacturers often include, as part of their ratings, data giving the *maximum peak repetitive current, $I_{FM(rep)}$*.

When specifying a particular device, or comparing one maker's rating with another's, current rating curves should be examined. A study of these curves will often show that two different tables are really describing the same device.

Forward voltage drop: The main characteristic associated with the forward current rating is the forward voltage drop. Among the more common methods used for specifying the forward voltage drop are:

1. Maximum peak forward voltage drop (V_{FM}) at specified average rectified forward current.
2. Maximum d.c. forward voltage drop (V_F) at specified pure direct current (not rectified d.c.).
3. Maximum average forward voltage drop ($V_{F(AV)}$) or the full-cycle average forward voltage drop at specified average rectified forward current.

Because of the nonlinearity of the diode forward voltage characteristic curve, a sine-wave-shaped current through the diode does not produce a sine wave of forward voltage drop. For comparison and to calculate forward losses for odd waveshapes or various values of current, many companies supply curves of instantaneous forward voltage drop *vs* instantaneous forward current (Fig. 1).

The forward voltage drop values are temperature-sensitive, with a negative temperature coefficient in the normal operating range. Therefore, any specification of forward voltage drop must also include temperature as a condition.

Maximum Allowable Peak Surge Current ($I_{FM(surge)}$): The surge current rating in many applications is more important in determining the device to be selected than is the maximum average forward current rating. In case of a short circuit magnitude of resultant current flow will be limited by the composite effect of power-supply elements, primarily the transformer impedance. The duration of the surge current will be determined by the protective devices used. The rectifier diodes must be able to conduct the fault current, with no degradation, for a time sufficient for the protective devices to interrupt the current flow.

A value of *maximum allowable peak surge current* ($I_{FM(surge)}$) is often listed on rating sheets, usually defined as the maximum permissible value of peak current applied as a non-recurrent half-cycle of a 60-Hz sine wave of current superimposed at elevated temperature on maximum rated current and voltage. This value is useful only as a comparison between devices and most makers also provide a curve of maximum allowable surge current *vs* number of cycles duration (Fig. 3).

The so-called I^2T constant (sub-cycle surge-current rat-

The author, chief engineer for International Rectifier, has been with that company since 1949, holding at various times supervisory positions in the testing, production, and engineering departments. He has a BSEE from California Institute of Technology, is a member of IEEE. He directs and supervises engineering personnel, reporting to the Vice-President, Engineering.

$V_{RM(rep)}$						$I_{F(AV)}$ @ 150°C (Amps)		MAX. $I_{F(AV)}$	TEMP. @ MAX $I_{F(AV)}$ °C	JEDEC PACKAGE OUTLINE
200V	400V	600V	800V	1000V	1200V	T_A	T_C	Amps		
1N645	1N647	1N649				0.150		0.400	25A	DO-7
1N2069	1N2070	1N2071						0.750	25A	DO-27
1N538	1N540	1N547	1N560	1N561		0.250		0.750	50A	DO-1
1N3189	1N3190	1N3191				0.500		1.00	100A	DO-13
1N1124A	1N1126A	1N1128A	1N3649	1N3650			1.0	3.3	50C	DO-4
1N1344B	1N1346B	1N1348B					6.0	6.0	150C	DO-4
1N1202	1N1204	1N1206	1N3671	1N3673			12	12	150C	DO-4
1N3618	1N3620	1N3622	1N3623	1N3624			16	16	150C	DO-4
1N1186	1N1188	1N1190	1N3766	1N3768			35	35	150C	DO-5
1N2131A	1N2135A	1N2138A					60	60	150C	DO-5
1N3289	1N3291	1N3293	1N3294	1N3295	1N3296		75	100	130C	DO-8
1N3086	1N3088	1N3090	1N3091	1N3092			150	150	150C	Mod. DO-8
1N3263	1N3267	1N3269	1N3271	1N3273	1N3274		120	160	125C	DO-9
1N3736	1N3738	1N3740	1N3741	1N3742	1N3743		200	250	130C	DO-9

Table 1. Typical silicon rectifier diodes. The abbreviations "A" and "C" employed refer to ambient and case, respectively. Some typical values of contact thermal resistance with DC-200 grease are: for DO-4 package, 0.9°C/W; for DO-5, 0.39; for DO-8, 0.15; for modified DO-8, 0.14; and for DO-9, 0.11°C/W.

ing) is not really a constant for diodes and should only be used for very rough comparisons. Manufacturers publish a curve of peak current *vs* sub-cycle pulse duration as in Fig. 4. The purpose of this curve is for comparison with the interrupting current curve of the fuse under consideration. The total clearing time of the fuse should be used in this comparison, not simply the melting time.

Reverse Voltage Parameters

Reverse Voltage Rating: Reverse voltage ratings are often described by one or more of the following values (over the entire operating temperature range):

1. Maximum allowable repetitive peak reverse voltage ($V_{RM(rep)}$) is that which may be applied to the device on a repetitive basis, including all repetitive voltage transients. This voltage should never be exceeded except in cases where a transient voltage rating is also specified.
2. Maximum transient peak reverse voltage ($V_{RM(non-rep)}$) is the value that may be applied to the device on a non-recurrent basis, for the conditions specified (usually a maximum pulse width).
3. Maximum continuous d.c. reverse blocking voltage (V_R), that which may be applied to the device in the reverse direction. Often the rating of V_R is identical to the rating of $V_{RM(non-rep)}$ for a given device.
4. Maximum r.m.s. input voltage ($V_{I(r.m.s.)}$) is the maximum that may be applied to the input of a rectifier circuit (implied single-phase half-wave). This rating is often misleading since $V_{RM(rep)}$ is the determining rating.

Reverse Current: Reverse (leakage) current can be specified in a number of different ways as described below.

1. Maximum peak reverse current (I_{RM}) at a specified temperature with specified peak reverse voltage applied (usually the rated peak reverse voltage).
2. Maximum average reverse current ($I_{R(AV)}$), usually specified during an operating test where the device is conducting rated average forward current, at rated peak reverse voltage, at a specified temperature in a half-wave resistive load circuit.
3. Maximum d.c. reverse current (I_R) measured when a pure d.c. voltage is applied in the reverse direction, at a specified temperature. Usually the value of d.c. voltage is specified as the rated repetitive peak reverse voltage.

Reverse current in a silicon diode is normally so low that it is unimportant to the operation of most rectifier circuits. However, it is of value in determining the relative "health" of a device after it has withstood environmental stresses such as long-term storage, operation, temperature cycling, etc. If the leakage current after such stress is appreciably greater than before stressing, it may be a sign of surface contamination or junction strain.

Temperature & Thermal Resistance

Temperature Rating: Subjecting the device to temperatures below the specified minimum may result in a catastrophic failure because of excessive strain on the silicon wafer caused by the differences of coefficient of expansion of associated bonding materials. Exceeding the high-temperature limit may incur excessive deterioration or catastrophic failure. The operating temperature range normally implies no derating of reverse voltage, only rerating of forward current in accordance with the current derating curves.

Thermal Resistance: The maximum thermal resistance junction-to-case (θ_{J-C}) or junction-to-ambient (θ_{J-A}) is defined as the value of temperature rise of junction above case or ambient divided by the power loss in the junction under d.c. steady-state conditions, in units of °C per watt. An approximation of the average junction temperature rise above case temperature during operation may be obtained by multiplying θ_{J-C} by the average power loss in the forward direction. Power loss values may be obtained from power loss curves, such as the one shown in Fig. 5.

Table 2 lists various parameters for rectifier diodes.

In general, the lower current rated devices (under 3 amperes) are designed with two external leads while devices rated above 3 amperes generally are designed for use with external heat exchangers, such as cooling fins.

Stud-mounted rectifier diodes are normally rated with respect to case (*i.e.* base) temperature. Good design practice requires consideration of two thermal resistance values external to the diode: thermal resistance of the contact between base and heat exchanger, and thermal resistance of heat exchanger to ambient.

To minimize contact thermal resistance:

1. Make sure the mounting surface of the heat exchanger is flat and smooth.
2. Apply a thin film of thermally conductive lubricat-

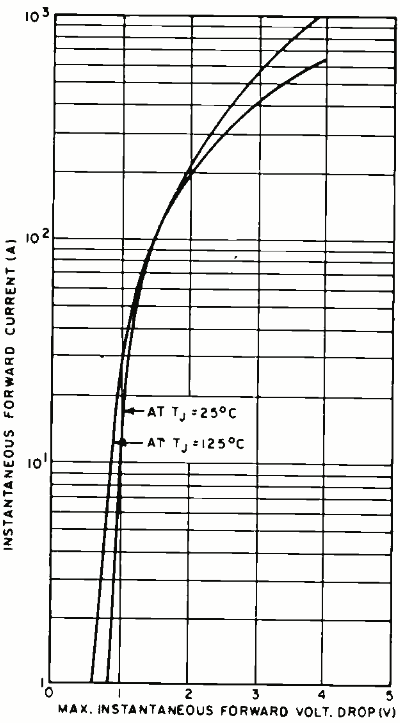


Fig. 1. Forward voltage drops for various currents for two junction temperatures, +25 and +125°C.

Fig. 2. Maximum allowable forward current vs case temperature, showing derating.

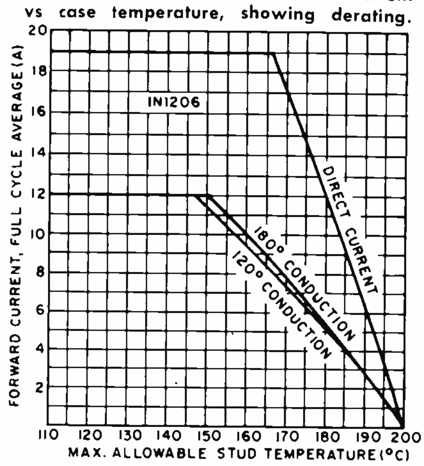
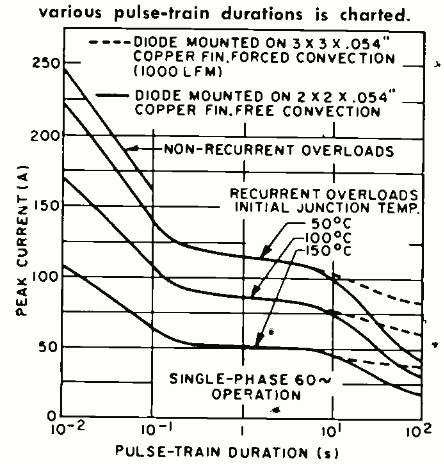


Fig. 3. Maximum overload current for various pulse-train durations is charted.



ing grease between the mating surfaces.

3. Use a torque wrench.

In some cases it may be desirable to mount the device in such a manner that it is electrically insulated from the heat exchanger. Insulating washers made from thin films of high-dielectric-strength materials such as mica (0.003-inch thick) or Mylar (0.001-inch thick) may be used. The contact thermal resistance will be doubled or tripled over the non-insulated mounting. This method of mounting is generally not recommended for diodes operating at currents in excess of 50 amperes.

The thermal resistance of the heat exchanger-to-ambient which is required by a particular application may be determined from the rating curves. First the total maximum allowable thermal resistance from diode case to ambient is determined by dividing the average power to be dissipated at maximum load (from the power *vs* current curve) by the maximum allowable temperature rise of the base (rated case temperature at desired load current minus maximum expected ambient temperature). By subtracting the contact thermal resistance from the case-to-ambient thermal resistance, a value of heat exchanger thermal resistance is derived.

Pitfalls

Current Rating: When comparing the current rating of various rectifier diode types, don't stop at the single value of current shown on the rating sheet. Examine the entire current-temperature derating curve, and also note whether the temperature reference is "ambient" or "case."

When paralleling rectifier diodes, don't fail to provide for closely balanced current division through the use of such means as paralleling reactors or inductively symmetrical diode arrangement, unless provision is made to derate the diodes by more than 20% for each parallel path.

When determining the optimum size of rectifier diode for a given application, don't consider only the steady-state current rating. The surge current rating is the limiting consideration for many small installations and most large ones. It may be more economical to install a larger diode which can be protected from overloads and fault currents by conventional methods rather than a smaller diode whose overload protection requires more expensive high-speed fuses or circuit breakers.

In comparing one diode with another, examine the *complete* forward voltage drop *vs* forward current curves or power loss curves, in particular noting temperature and basis of presentation.

Voltage Rating: Don't fail to consider the probability of voltage transients created either in switching or from external sources. Voltage transients of several thousand volts have been recorded on 120-volt a.c. distribution lines. Protection methods include low-voltage zener diodes for clamping voltage below 50 volts, selenium transient limiters for voltages to 1000 volts, controlled voltage spark gaps for very high operating voltages, and capacitors.

	PARAMETER	SYMBOLS EIA	SYMBOLS MIL	UNITS	CONDITIONS ASSUMED	CONDITIONS STATED	SUPPLEMENTARY CURVES
RATINGS	Maximum allowable average forward current	$I_{F(AV)}$ or I_O	I_o	A d.c.	Single-phase ½-wave, res. load (180° cond.)	Temperature (ambient or case)	Derating for temp. conduction angle
	Maximum repetitive peak forward current	I_{FM} (rep)	i_f	A peak	—	Temperature	—
	Maximum allowable peak surge current	I_{FM} (surge)	i.f. (surge)	A peak	Non-rep. superimposed on rated operation	Number & shape of surge pulses	Current vs time; current vs no. of cycles of 60 Hz
	Maximum allowable repetitive peak reverse voltage	V_{RM} (rep)	V_{RM} (wkg)	V peak	No derating over operating range	—	—
	Maximum allowable transient peak reverse voltage	V_{RM} (non-rep)	v_r	V peak	Non-recurrent	Maximum pulse width	—
	Maximum continuous d.c. reverse blocking voltage	V_R	V_R	V d.c.	—	—	—
	Maximum r.m.s. input voltage	$V_{r(r.m.s.)}$	—	V r.m.s.	—	—	—
	Storage temp. range	T_{stg}	T_{stg}	°C	Non-operating	Maximum Minimum	—
	Operating temp. range	T_A or T_C	T_{op}	°C	Current derating no volt. derating	Maximum Minimum	—
	Mounting torque range	—	—	lb-in	No lubricant on threads	Maximum Minimum	—
CHARACTERISTICS	Maximum peak forward voltage drop	V_{FM}	v_f	V peak	—	Junction temp. forward current	Peak forward voltage drop vs forward current
	Maximum d.c. forward voltage drop	V_F	V_F	V d.c.	No temp. rise during test	Forward current	—
	Maximum average forward voltage drop	$V_{F(AV)}$	—	—	180° conduction	Forward current	—
	Maximum peak reverse current	I_{RM}	i_r	mA peak	—	Temp. peak voltage	—
	Maximum average reverse current	$I_{R(AV)}$	I_{RO}	mA d.c.	180° conduction	Temp. forward current, reverse voltage	—
	Maximum d.c. reverse current	I_R	I_R	mA d.c.	Pure d.c.	Temp. reverse voltage	—
	Thermal res. steady-state	θ_{J-A} or θ_{J-C}	θ_{J-A} or θ_{J-C}	°C/W	d.c. value unless otherwise stated	—	Transient thermal res. vs time
	Forward power loss curve	—	—	—	—	Junction temp.	Av. forward power loss vs average forward current

Table 2. A summary of the common ratings and characteristics. See text.

Fig. 4. Maximum surge current for various square-wave pulse durations.

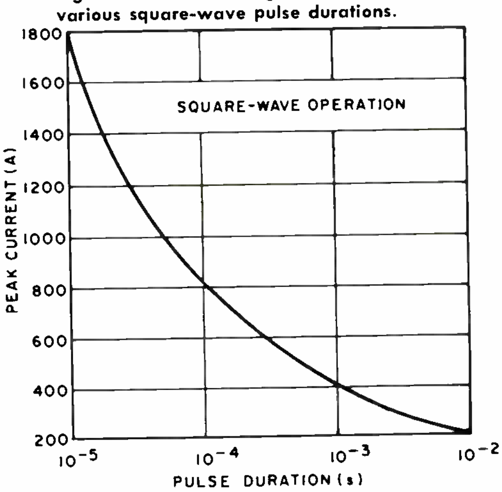
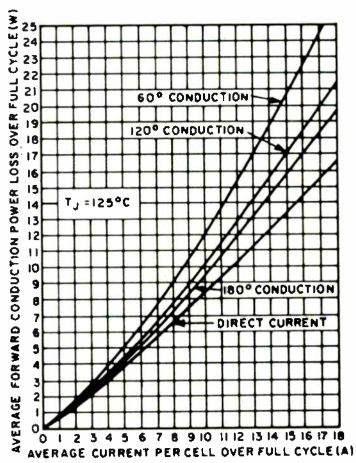


Fig. 5. Forward current power loss for various conduction angles.



Diodes which have a true bulk avalanche voltage breakdown can dissipate a surge of power in the reverse direction and make transient voltage protection simpler. The penalty for depending on the diode for self-protection must be to derate in the forward-current mode in order to provide an allowance for junction temperature rise during transient voltage suppression. The data sheet for such a device must show a rating of maximum allowable reverse power *vs* time, for various temperatures; a curve showing "typical reverse voltage characteristic" is of no value.

In determining the appropriate voltage rating of a rectifier diode for a given application, don't depend on the rating of maximum allowable r.m.s. voltage. Instead, work from the maximum allowable peak reverse voltage rating. For example, in a single-phase half-wave rectifier circuit with resistive load, the ratio of peak reverse voltage across the diode to r.m.s. input voltage is 1.4. By adding a capacitor to the load the ratio can change to 2.8.

Don't apply diodes in series without consideration being given to equal voltage division. The recommended method of voltage balancing is by means of resistance and capacitance shunting of each diode. The value of resistance should be chosen to conduct at least three times the highest anticipated diode reverse current, while the capacitor value should be determined on the basis of diode capacitance, diode recovery charge, and physical layout of the diode string with respect to distributed capacitance to ground.

Mounting: Never mount a stud-mounted rectifier diode without using a torque wrench; observe the manufacturer's limits. Limits are usually given with the assumption that the threads will be dry. If they are lubricated, the value of rated torque should be reduced by 25%.

In using lubricating grease, be careful of some of the new "improved" materials which use additives to further reduce thermal impedance. If these additives are solid materials, they may inhibit good mating of the contact surfaces and, after a period of operation, they may cause deterioration of contact thermal resistance.

Reliability: Where high reliability and long life are desired, never operate rectifier diodes to the limit of their current and temperature ratings, and always provide protection against catastrophic failures resulting from voltage transients or surge currents. The failure rate of silicon diodes in a well-protected system is very markedly affected by operating junction temperature (as a rule of thumb, reliability can be increased by as much as 250% by a 20°C reduction of junction temperature).

Silicon as a basic material for rectifier diodes appears to be nearly ideal and its displacement by new materials does not appear likely in the near future. ▲

LIGHT-SENSOR DIODES

By DON R. ABEL, Texas Instruments Inc.

FOR years light sensors have been used in such novelty applications as headlight dimmers, burglar alarms, bowling foul detectors, and light meters. Today, a new breed of light sensors is finding wide application in card readers, punched-tape readers, rotational counters, position indicators, character-recognition devices, proportional controllers, and differential amplifiers.

Generally, light sensors are divided into two types: **photovoltaic** and **photoconductive**. A photovoltaic cell develops a voltage across its terminals when illuminated. Photovoltaic cells are power converters; they convert light energy into electrical energy and are used primarily as solar cells. Current capability is proportional to the area illuminated. No external bias is required, but the light-gathering area is usually one or two orders of magnitude larger than that of photoconductive devices, to supply sufficient current for most applications.

The fundamental process in photoconductive devices, on the other hand, is the modulation of the conductivity of a "p-n" junction or of a bar of semiconductor material. Photoconductive cells can be thought of as variable resistors, the amount of resistance varying with the quantity of light incident upon the cell. The greater the light, the lower the resistance. When properly biased, a photoconductive cell will provide a higher output for a given barrier area than a photovoltaic unit. Table 1 compares silicon photovoltaic and silicon photoconductive light sensors.

Less amplifier gain is necessary (or even the elimination of an amplifier stage) when the photoconductive light sensor is used instead of the photovoltaic type. Table 2 compares typical photoconductive devices. For punched-card and tape readers, digital uses, etc., the ratio of light current to dark current is important. It is necessary to maintain a large voltage differential between the "off" and "on" conditions to insure noise immunity and provide for temperature variations. Equipment capability and system speed may well be limited by rise and fall times of the sensor.

Prices for the light sensors shown in Table 2 are: for the LS-400, $13 each in under 100 quantities; for the 7223, $2 each; and for the 605-T or CL403, $4 each.

	Photovoltaic	Photoconductive
Applications	Solar energy source	Photo switching
	Servo systems	Card or tape readers
	Galvanometers	Character recognition
	Card or tape readers	Differential amplifiers
	Sound pickup	Lamp controls
Comparative Characteristics	No power source required	Requires power source
	More stable	More sensitive
	Low noise	Small size
	Low output	
	Less versatile	

Table 1. Comparison of the two types of silicon light sensors.

Structure	n-p-n	p-n	p-n
Material	Si	Ge	CdS/CdSe
Typical Types	TI LS-600	7223	605-T CL403
Voltage	30 V d.c.	50 V d.c.	300 V a.c./d.c.
Typical Sensitivity (μA/ft candle)	7.0	0.2	5.0
Typical Dark Current (@ 25°C)	0.01 μA @ 30 V	35 μA @ 50 V	———
Temperature Range (—°C)	—65 to 150	—40 to 50	—50 to 75
Light Current/Dark Current Ratio (@ 25°C)	100,000	150	5000
Pulse Rise Time (μsec)	1.5	6	1000
Pulse Fall Time (μsec)	15	35	6000
Length (inches)	0.091	0.520	Plastic 0.25, Glass 1.0
Diameter (inches)	0.0625	0.083	Plastic 0.25, Glass 0.25
Case Material	Kovar/ceramic	Glass	Plastic/glass

Table 2. Typical photoconductive light sensors, characteristics.

Table 3. Consumer, industrial, and military applications for various types of light-sensor diodes.

	Se	CdS	CdSe	Silicon Photo-voltaic	Silicon Photo-conductive	InAs	InSb	GaAs Emit-ters	InAs Emit-ters	Ge:Hg	Ge:Cu
CONSUMER											
Camera exposure controls		X	X								
Automotive light dimmers		X									
Light meters	X										
Lamp controls		X		X	X						
INDUSTRIAL											
Card & tape readers				X	X			X			
Encoders, decoders				X	X			X			
Character recognition & mark-sensing					X			X			
Sound pickup					X						
Counters & position indicators				X	X			X			
IR medical analysis							X			X	X
MILITARY											
IR sensing & detection				X	X	X	X		X	X	X
Fire control systems				X	X	X	X			X	X
Mapping						X	X			X	X
Peripheral tape, card, document, character sensing					X						
Solar energy converter				X							

The author received his B.S. in Chemical Engineering from Newark College of Engineering in 1952. Prior to joining RCA in 1959, he worked at the U.S. Army Signal Corp's Fort Monmouth, N.J. installation doing development work in the fields of reinforced plastics and thin films. At RCA he worked on the development of thin-film resistors until 1960 when he was assigned to Project Lightning for the development of high-speed tunnel diodes. Since 1963 he has continued working with tunneling devices and developed the tunnel diode for the C-band microwave amplifier used in the RCA CW-60 system. He is currently Project Leader of the Special Diodes group.

Tunnel Diodes

By ROBERT M. MINTON
Radio Corp. of America, Electronic Components and Devices

Employed in amplifier, oscillator, and switching circuits because of its voltage-controlled negative-resistance characteristics, this diode operates on the principle of quantum mechanical tunneling.

THE voltage-controlled negative-resistance characteristic of the tunnel diode has led to its widespread use in amplifier, oscillator, and switching circuits. While earlier devices such as the tetrode vacuum tube, the thyraton, and the *p-n-p-n* transistor also displayed a negative resistance, the tunnel diode is unique in that it operates on the principle of quantum mechanical tunneling. This phenomenon is responsible for the high-frequency capability of the device.

Fig. 1 compares the typical characteristics of a conventional *p-n* junction diode and a tunnel diode. The major physical differences between the two are the impurity densities of the materials used in fabrication and the width of the depletion region. In conventional (or rectifying) diodes, the low doping levels used result in wide depletion regions, and conduction can occur only by injection of minority carriers over the junction barrier. In tunnel diodes, a high doping density is used to create an extremely narrow depletion region through which electrons in the conduction band can "tunnel" to equivalent energy levels in the valence band. It is this tunneling action that gives the tunnel diode its characteristic curve at a small forward bias. At a bias greater than 300 to 400 mV, a tunnel diode conducts as a conventional diode.

In addition to being used in the forward direction, low-peak-current tunnel diodes are useful as low-voltage rectifiers when biased in the reverse direction. Used in this manner, the tunnel diode is referred to as a tunnel rectifier or back diode. The characteristics of such a device are shown in Fig. 1C, with the first and third quadrants reversed. Another use for the tunnel rectifier is for nonlinear biasing of tunnel diodes in high-speed switching and memory applications.

Tunnel-Diode Parameters

The parameters commonly used in specifying tunnel diodes, their corresponding symbols, and the applications in which each parameter is significant are given in Table 1. Figs. 1A and 2A define these parameters.

Five of the first six current and voltage parameters relating to the forward *I-V* characteristics have obvious definitions. The exception is the forward voltage (V_F, V_{FP}, V'_F), which can be specified at either V_F, the voltage corresponding to actual peak current (I_P), or at V'_F, the voltage for which the current is equal to the maximum allowable peak current ($I_{P\,max}$). Refer to Fig. 1A.

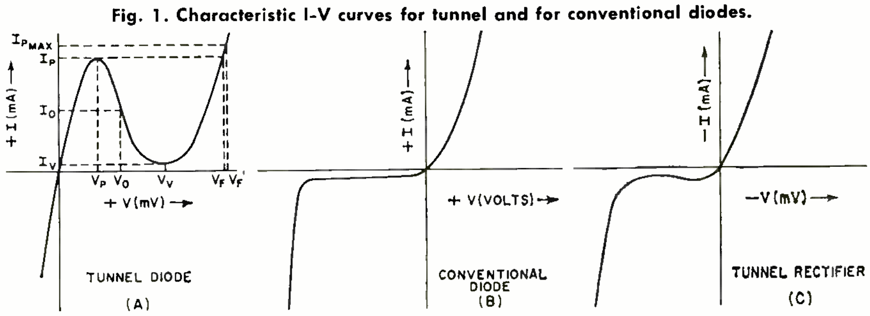
The capacitance parameters are all related, with the valley-point terminal capacitance or total capacitance (C_V, C_T, C) being the sum of the junction capacitance (C_j)

PARAMETER	SYMBOL	APPLICATION*
1. Peak current	I_P	S, O
2. Valley current	I_V	S, O
3. Peak-to-valley current ratio	I_P/I_V	S,A,O
4. Peak voltage	V_P	S,O
5. Valley voltage	V_V	S,O
6. Forward voltage	V_F, V_{FP}, V'_F	S
7. Valley-point terminal cap.	C_V, C_T, C	S
8. Package capacitance	C_P	A,O
9. Junction capacitance	C_j	A,O
10. Series resistance	r_S	A,O
11. Negative resistance	R, $-$R, R_N	A,O
12. Negative conductance	G, $-$G	A,O
13. Series inductance	L_S	S,A,O
14. Peak-current-to-cap. ratio	I_P/C	S
15. Rise time	t_r	S
16. Resistive cut-off frequency	f_{ro}, f_r	A,O
17. Self-resonant frequency	f_{xo}	A,O
18. Noise constant	$20\ I_oR_N$	A
19. Inflection current	I_I, I_o	A
20. Inflection voltage	V_I, V_o	A

* S=switching; A=amplifier; O=oscillator

Table 1. Tunnel-diode parameters, symbols, and applications.

Fig. 1. Characteristic I-V curves for tunnel and for conventional diodes.



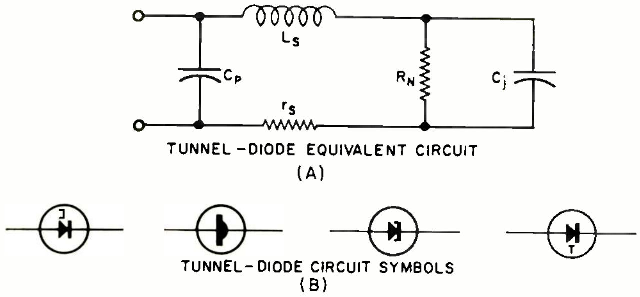


Fig. 2. Tunnel-diode equivalent circuit and circuit symbols.

and the package capacitance (C_P). The total capacitance is applied in switching-circuit calculations, and the junction capacitance is used in calculating the resistive cut-off (f_{ro}, f_r) and self-resonant (f_{xo}) frequencies. The package or case capacitance (C_P) is used in obtaining the junction capacitance (C_j); it is usually an average value of measurements made on electrically open-circuited diodes.

The series resistance (r_s) is that portion of the small-signal terminal resistance which is external to the junction and is normally measured in the reverse direction. For amplifier and oscillator diodes, the measurement is usually made under pulsed conditions at very large reverse currents. This technique results in minimum values of series resistance and, therefore, maximum cut-off frequency for the diode.

The negative resistance (R, $-R$, R_N) and negative conductance (G, $-G$) are determined by the slope at any point on the tunnel-diode curve between the peak (V_P) and the valley (V_V) voltages. These parameters are difficult to measure, particularly on low-capacitance diodes, and the following approximations have been derived for the value of the negative resistance: $-R = 120/I_P$ for germanium, $220/I_P$ for silicon and gallium arsenide, and $60/I_P$ for gallium antimonide, where I_P is in milliamperes and $-R$ is in ohms.

The series inductance (L_S) can be considered as the lead inductance of the package in which the tunnel diode is mounted because the diode inductance is negligible. Very often L_S becomes the limiting parameter in very-high-frequency applications.

The peak current-to-capacitance ratio (I_P/C) is a figure of merit used to indicate the switching speed of the tunnel diode.

The rise time (t_r) is that time required for the tunnel diode to switch from a low-voltage state to a high-voltage state; for constant-current load-line switching, it can be approximated by $t_r \approx [(V_F - V_P)/(I_P - I_V)]C_V$. For germanium, an approximate value is given by $C/2I_P$. If C is in farads, and I_P is in amperes, the rise time is in picoseconds.

The resistive cut-off frequency (f_{ro}, f_r) and the self-resonant frequency (f_{xo}) are also figures of merit. The former is the frequency at which the net negative resistance of the diode becomes zero, and the latter is the resonant frequency of the inductive and capacitive reactances of the diode.

The noise constant ($20\ I_O R_N$) is also a figure of merit

PARAMETER	GERMANIUM	GALLIUM ARSENIDE	GALLIUM ANTIMONIDE	SILICON
I_P (mA)	0.025-1000	0.025-1000	0.025-3.0	0.100-100
I_P/I_V	4/1-8/1 min.	8/1-12/1 min.	12/1 min.	2.5/1-3.6/1 min.
I_P/C (mA/pF)	25/1 max.	16/1 max.	5/1 max.	0.02/1 max.
f_{ro}(GHz)	50 max.	20 max.	50 max.	<1
$20 I_O R_N$(mV)	1.35-1.50 min.	—	0.85-0.95 min.	—

Table 2. Limits for commercially available tunnel diodes.

Table 3. Representative JEDEC switching tunnel diodes.

JEDEC TYPE NO.	MATERIAL	I_P (mA)	I_P (% tol.)	I_P/I_V (min.)	C_T (max.)	VOLT. TOL.	COST
1N3716	Ge	4.7	±10	4/1	50 pF	Typical	Inexpen.
1N3848 1N3149	Ge	10	±10	6/1	30 pF	Min-Max. or typical	Low
1N3859	Ge	20	±5	8/1	10 pF	Min-Max.	Medium
1N3860	Ge	50	±5	8/1	12 pF	Min-Max.	High

for the tunnel diode and is a function of the slope of the negative-resistance region. It is related to the noise figure of the tunnel diode, and the minimum value is limited by the diode material.

The inflection current (I_I, I_O) and inflection voltage (V_I, V_O) refer to the point where the minimum negative resistance occurs. It is at this point that maximum gain can be achieved. The inflection point usually occurs at approximately $I_P/2$ and corresponds to a bias voltage slightly less than that at which the minimum noise figure can be obtained.

The parameter limits for commercially available tunnel diodes are shown in Table 2. The range of values include data for special types which in many cases are low-yield devices and very expensive. Table 3 shows representative JEDEC types available in production quantities. (Only switching types are listed because there are no amplifier or oscillator tunnel diodes with JEDEC registration.)

Test circuits for measuring tunnel-diode parameters have been independently designed by the many diode users and manufacturers. Several documents of standards relating to tunnel diodes and their test circuits are available: *IEEE* No. 253 "Standard Definitions, Symbols, and Methods of Test for Semiconductor Tunnel (Esaki) Diodes and Backward Diodes": *DOD* MIL-S-19500D "General Requirements for Semiconductor Devices Used in Military Equipment" and MIL-STD-750A "Methods for Testing Semiconductor Devices, Including Mechanical, Environmental, Physical, and Electrical Tests."

Materials Employed

There are four semiconductor materials from which all commercially available tunnel diodes are fabricated: germanium (*Ge*), gallium arsenide (*GaAs*), gallium antimonide (*GaSb*), and silicon (*Si*). For switching applications, gallium arsenide, germanium, and silicon are used. Amplifiers utilize gallium antimonide and germanium, while the only acceptable material for oscillators is gallium arsenide.

For high-speed switching, only gallium arsenide and germanium are used because the high capacitance and poor peak-to-valley current ratio (I_P/I_V) obtained with silicon restrict its use as a very-high-frequency device. Silicon, however, is capable of operating up to 150°C and is primarily useful when high ambient temperatures are encountered and when high speed is unimportant.

Gallium-arsenide diodes provide a voltage swing twice that of germanium diodes. Because the power output at a fixed impedance level varies as the square of the voltage swing, the power output of a gallium-arsenide diode is about four times that of a germanium diode having the same negative resistance. However, when speed, cost, or reliability is an important consideration, germanium is selected over gallium arsenide. Germanium switching diodes are superior to gallium-arsenide diodes in both speed and cost by a factor of two or three. Gallium-arsenide diodes offer poor reliability because they can experience serious peak-current degradation when operated at high forward current levels. An empirically established limiting condition of 0.5 mA/pF must be satisfied to insure the safe d.c. operation of diffused gallium-arsenide tunnel diodes.

The only two materials capable of meeting the frequency and noise-voltage requirements of a low-noise microwave amplifier are gallium antimonide and germanium. Although germanium has a slightly higher noise constant, germanium diodes offer a more stable gain with respect to temperature and a higher cut-off-frequency capability.

Gallium-arsenide diodes are used almost exclusively in tunnel-diode oscillators because all other materials are incapable of delivering enough power to warrant their consideration.

The commercially available tunnel-diode materials with their respective properties are tabulated in Table 4 for comparison.

Mechanical Considerations

For high-speed switching and microwave applications, tunnel-diode packages must be designed for low inductance and low capacitance. The package capacitance is usually in the order of 1 pF or less and, in many cases, may be neglected or absorbed in the other circuit elements. Lead length is the prime contributor to the series inductance, and special short-lead package designs are required to obtain high self-resonant frequency diodes.

Tunnel diodes can be permanently damaged by overheating or electrostatic discharge unless precautions are taken while they are being assembled or tested. Manufacturers' instructions should be closely followed when diodes are soldered into a circuit. Microwave diodes in the pill and prong packages are extremely sensitive, and mechanical contacts should be made to these devices whenever possible. Also, their low impedance makes microwave amplifier diodes extremely vulnerable to electrostatic discharge; to prevent damage to the unit (especially during winter months), anyone handling the device should use a ground strap.

Selecting the Right Diode

Although the tunnel diode is a relatively simple device, selecting the right one for a given application can be difficult. The applications engineer or technician working on an assignment involving tunnel diodes is confronted with the problem of (1) selecting the proper diode from the large variety on the market, or (2) writing his own specification. Because amplifier, oscillator, and switching circuits each require a different type of diode, the selection has to be based on the specific application.

Amplifier: For a tunnel diode to operate as a linear amplifier, it must be made unconditionally stable at a bias point somewhere in the negative-resistance region (Fig. 3A). To fulfill this stability requirement, the following conditions must be met:

(1) $r_s<R_N$ where $f_{xo}=1/2\pi R_N C_j(R^2_N C_j/L_s-1)^{1/2}$
(2) $f_{xo}>f_o<f_r$ where $f_r=1/2\pi R_N C_j(R_N/r_s-1)^{1/2}$
(3) $L_s<r_s R_N C_j$ where f_o = operating frequency

One other important consideration for the tunnel-diode amplifier is the noise figure. At high gain, it is given by $F=(1+20\ I_o R_N)/[1-r_s/R_N][1-(f_o/f_{ro})^2]$.

To minimize this value, it is necessary to keep the f_o/f_{ro} ratio small, a practical value being ⅓ for most high-frequency operations. The value of $I_o R_N$ and r_s/R_N ratio are essentially constant for a given design and are fixed by the material and peak current of the diode, respectively. Of all the available semiconductor materials, only germanium and gallium antimonide are capable of meeting the low-noise requirements of a microwave amplifier.

Oscillator: The operation of a tunnel diode in most oscillator applications requires biasing in the negative-resistance region (Fig. 3A). As a relaxation oscillator, the diode can also be biased monostably or bistably (Figs. 3B and 3C). Unlike amplifiers, oscillator circuits are designed to assure self-starting oscillations. Because oscillations can occur above and below the f_{xo}, depending on whether the external circuit is inductive or capacitive, it is important that the tunnel diode have an f_{ro} greater than the operating frequency. This condition is also necessary because as the oscillation frequency approaches the f_{ro}, the amplitude of oscillation approaches zero and thus reduces the power output.

In the selection of tunnel diodes for oscillator applications, the major design considerations are the frequency stability, the resistive-cut-off frequency, and the power output. Frequency stability is primarily a circuit design and environmental problem because the tunnel diode R_N is voltage- and temperature-sensitive, and the C_j is voltage dependent. In addition, circuit loading can also affect the oscillator frequency. The f_{ro} and the power-output considerations are interrelated, and the device is limited in trying to achieve maximum power and maximum frequency simultaneously. Because higher peak-current diodes are used to obtain higher power output, minimizing both the series inductance (L_s) and the series resistance (r_s) becomes a problem. Conventional packages contribute too much inductance; therefore, more sophisticated methods have to be used for mounting diodes in the circuit.

Switching: For switching applications, the tunnel diode is biased for monostable or bistable operation, as shown

PROPERTY	GERMANIUM	GALLIUM-ARSENIDE	GALLIUM ANTIMONIDE	SILICON
Reliability	Excellent	Poor	Poor	Good
Temp. stability	Good	Good	Poor	Good
Freq. capability	Excellent	Good	Good	Poor
Noise constant	Good	Poor	Excellent	Poor
Power output	Poor	Excellent	Poor	Poor

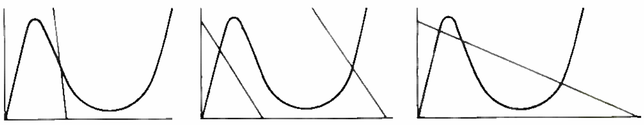
Table 4. Comparison of tunnel-diode material properties.

in Figs. 3B and 3C, respectively. Regardless of the operation mode, the most difficult problem in choosing a switching diode is that of selecting *practical* current and voltage tolerances consistent with the required peak-current-to-capacitance ratio of the diode. Because the tolerances of all the system components are related, a balance between the tunnel diodes and other components should be made with respect to cost and reliability. Very tight tolerances or limits, for example, will only result in increased cost.

The device engineer has limited control over the diode characteristics. The only parameter over which he has direct control is the peak current (I_P). The voltage characteristics are primarily a function of the base wafer resistivity. Although the range appears fairly wide, the I_P/C requirements of high-speed diodes (I_P/C greater than 2 to 1) limit the spread of usable resistivities. The I_P/I_V ratio is primarily a function of the material and the resistivity; for high-speed germanium diodes, a minimum ratio of 8 to 1 is reasonable. Ratios of 9 to 1 and 10 to 1 are available strictly on a selection basis.

The r_s, in itself, is not usually a problem, but it can adversely affect the peak voltage, especially as the diode speed is increased. See Fig. 4.

Radiation and temperature dependence should also be considered in design with tunnel diodes. Compared to other semiconductor devices, tunnel diodes are relatively immune to nuclear radiation because conduction is by majority carriers and doping levels are high. The parameter most affected by radiation is the valley current (I_V), but significant changes do not occur until integrated neutron flux densities of 10^{16} or 10^{17} neutrons per square centimeter are experienced.



(A) ASTABLE (B) MONOSTABLE (C) BISTABLE

Fig. 3. Biasing modes that are employed for tunnel diodes.

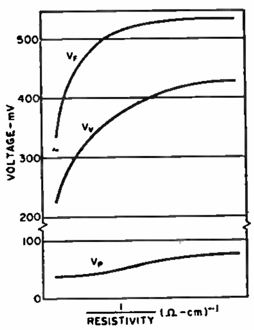
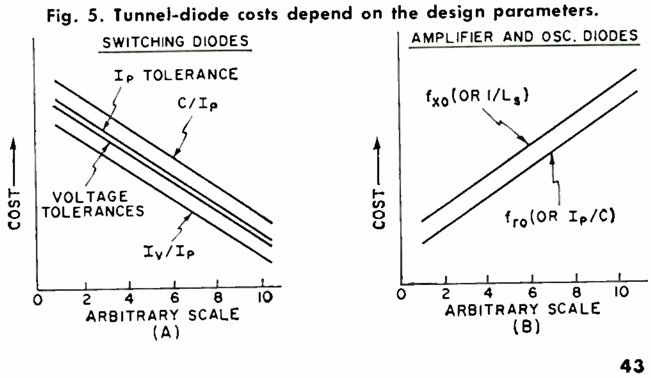


Fig. 4. Variation of tunnel-diode voltages with resistivity. These voltages are only averages and do not include the Ir_s drop across the diode. For higher speed diodes, the r_s as well as its distribution is increased, and tight voltage tolerances are more difficult to achieve in high yield. The I_P/C ratio is the parameter around which most high-speed switching tunnel diodes are designed and is a function of the base-wafer resistivity and the processing temperatures used in forming the "p-n" junction. Practical limits are about 10 to 1; at greater I_P/C ratios, power dissipation becomes a problem and reliability can be seriously affected. (For an I_P/C ratio of 10 to 1, junction diameters are 100 millionths of an inch or less.

Fig. 5. Tunnel-diode costs depend on the design parameters.



Valley current is also greatly affected by temperature, increasing by as much as 20 percent at 75°C. The peak, valley, and forward voltages have negative-temperature coefficients of about 0.1, 0.8, and 1.1 mV/°C, respectively, while the negative resistance decreases at the approximate rate of 0.4 ohm/°C. The change in peak current with temperature is a function of the resistivity and can vary from negative to positive values. For very high speed (I_P/C greater than 2 to 1), the doping level is optimum and an average maximum change in peak current of about ±4 percent occurs over the temperature range from −20°C to +75°C. Whenever tight temperature specifications are placed on tunnel diodes, 100-percent testing is required in order to guarantee that the specification will be met.

Cost: Because cost is usually uppermost in the selection of tunnel diodes, it is very important not to overspecify any of their parameters. Very often, tight tolerances or limits which invariably result in a higher cost are unnecessarily specified. An automatic etch machine has been developed just to control the peak current of a tunnel diode to within a tolerance of ±1 percent.

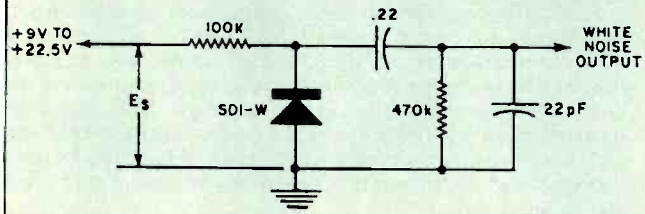
The graphs in Fig. 5 illustrate the effect of the more important design parameters on the cost of tunnel diodes. In some cases, the reciprocals of the parameters were plotted for convenience. Also, an arbitrary scale of 10 was selected for the horizontal axes of the graphs. ▲

NOISE DIODES

RANDOM noise sources are finding ever-increasing use in the testing of audio and r.f. systems. Random noise is used to generate random numbers to test computers, simulate cosmic noise, calibrate astronavigational and tracking systems, provide a reference level for determining the sensitivity of receivers, and often to activate shaker tables for testing components and assemblies.

White noise is a special type of random noise having a uniform energy distribution and neither the instantaneous energy of a particular frequency, nor the time of its appearance can be determined, as both are random. However, in terms of statistical probability, the long-term energy per bandwidth can be accurately predicted.

Fig. 1. As E_s is increased, the noise diode generates white random noise across audio-frequency range (20 Hz to 20 kHz).



White noise is being used in many ways in modern technology. Properly shaped, it provides the "waterfall" sound for audio analgesia. It can provide constant-level sound against which hearing ability can be measured, or it can be used as a mask against unwanted sounds.

Although some types of vacuum and gas diodes have been used as noise sources, modern electronic systems are using special types of semiconductor diodes. Typical of these is the *Solitron* SD1-W, a double-diffused, silicon junction diode designed for the 20-Hz to 20-kHz spectrum. When the reverse voltage applied to the circuit shown in Fig. 1 is gradually increased, the diode produces an increasing amount of random, non-white voltage. At one particular applied voltage level, the diode suddenly goes into zener or avalanche operation with a resulting generation of reasonably white noise. As E_s is increased above this point, the output level drops but the signal becomes "whiter." This diode circuit is equivalent to a high-impedance generator and should not be used across a load much smaller than 100,000 ohms. A transistor amplifier is usually used to raise the level and match impedances.

Typical diodes have an output ranging from 500 to 2500 μV r.m.s. per 20-kHz bandwidth. Other types of noise diodes are available to cover the range from 1 Hz to 500 MHz. ▲

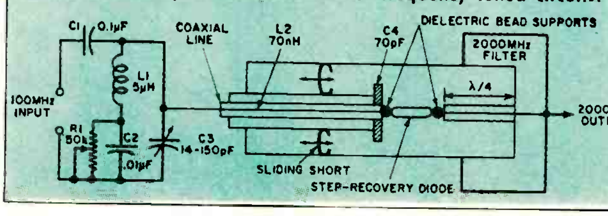
STEP-RECOVERY (CHARGE-STORAGE) DIODES

ALL *p-n* junction diodes have charge storage during current flow in the forward direction. Holes and electrons are injected into the base region and stored by diffusion. The charge thus stored by the forward current must be removed by reverse current, or recombination, before the diode can be turned off, or reversed biased into its high-impedance state.

In the design of frequency multiplication circuits using variable-reactance semiconductor diodes (varactors), the principal effect used is the variation in depletion layer capacitance with reverse bias variation. The storage of charge under forward bias has been neglected or avoided.

By contrast, step-recovery diodes are optimized for maximum charge storage under forward current with controlled release of the stored charge at reverse current, and fast transition from reverse current conduction to the normal diode reverse bias condition. Although the capacitance of the step-recovery diode does vary with reverse bias, this effect is small compared with the difference in charge stored between forward and reverse polarities. By using step-recovery diodes to optimize the forward storage and recovery transient, as opposed to optimizing the reverse bias capacitance variation, the user can construct efficient harmonic generators of orders of two to 30 without resonant tank circuits at any intermediate frequencies. The simplicity and freedom from spurious outputs obtained by omitting the idler networks is the principal advantage of the step-recovery diode, compared with the varactor. Another important advantage is the relatively low conversion of AM noise to phase noise.

Fig. 1. Frequency multiplication circuit using a step-recovery diode requires no intermediate-frequency tuned circuits.



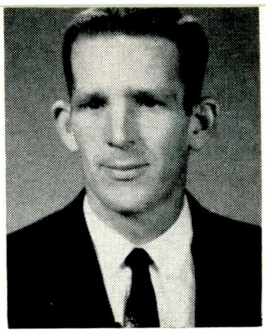
A typical 20 times frequency multiplication circuit, having 10% efficiency has been developed by *Hewlett-Packard Associates* and is shown in Fig. 1. This circuit accepts a 100-MHz input at 45 mW and delivers a 2000-MHz output at 4 mW.

The input signal is fed through a coupling capacitor C1 which in conjunction with choke L1 and bypass capacitor C2, are used to separate the input power from the bias voltage developed across variable resistor R1. The input impedance is matched by a network consisting of variable capacitor C3, inductor L2, and bypass capacitor C4, which also decouples the higher harmonics from the input. The input impedance of 50 ohms is matched down to a range of 5 to 15 ohms to couple efficiently into the diode.

The step-recovery diode is placed in series with the input resonator which is of the shorted type. The only adjustment of the diode reactance and microwave circuit impedance required is by the use of the sliding shorts shown in Fig. 1. The 2000-MHz output filter is a six-resonator interdigital structure with a bandwidth of 20 MHz and a 2-dB insertion loss. The estimated total losses of this circuit are approximately 2.5 to 3 dB.

Operation of the circuit is simple. The tuning only requires that R1 and C3 be adjusted for the best input match and the sliding short be positioned for maximum power.

The controlled lifetime and fast transition of the step-recovery diode makes it very useful for a variety of other high-speed circuit applications. ▲



The author has been associated with Texas Instruments since 1960. During that time he has worked in device characterization and tests on diodes and light sensors. He has served as product engineer on planar phototransistors, as engineering section head for computer diodes, and as a device applications engineer. Presently, he is an engineering section head and is responsible for device applications as well as module and integrated diode array development. He was formerly with Hughes Aircraft and served as a missile instrumentation engineer for the Air Research and Development Command of the U.S. Air Force. He was graduated from Texas Technological College with BSEE and MSEE and is a member of the IEEEE.

Reference and Regulator Diodes

By JAMES W. CLIFTON/ Manager, Applications Engr. Section
General Products Dept., Texas Instruments

How to choose the proper zener diode for maintaining constant voltage output at varying load current and operating temperature.

ONE of the most interesting, and certainly most useful, of all the tools which the advent of semiconductor technology has placed in the hands of the electronic circuit designer is the reference or regulator diode. The flexibility of this component with regard to voltage ranges and power-handling capability has allowed this element to surpass its older equivalent, the gas regulator tube.

In design and construction, the semiconductor regulator diode is almost identical to a rectifier. It can, in fact, be used this way. The key difference is in the nature of application which requires a tight control over the avalanche or breakdown voltage level. The voltage regulator is designed to operate in the reverse current direction (cathode positive). Operated in this direction, the device will exhibit a relatively high impedance until either zener or avalanche breakdown is reached. Once in this region, the device will exhibit a relatively constant voltage for wide variations in current.

Two mechanisms are observed and utilized in manufacturing voltage regulator diodes, these are the zener effect and the avalanche effect. The mechanism of zener breakdown is caused by internal field emissions due to tunneling and occurs in the voltage range below 6 volts. Avalanche breakdown, on the other hand, is generated by electron multiplication quite similar to breakdown in gaseous dielectrics. One note regarding the temperature characteristics of the above physical mechanisms: the zener breakdown voltage decreases with increasing temperature (negative temperture coefficient), the avalanche breakdown voltage increases (positive temperature coefficient).

The terms *reference* and *regulator* are at times used interchangeably when speaking of voltage-regulator diodes. As a good rule of thumb, however, a unit which by use is intended to maintain a relatively constant voltage at some fixed current over a changing temperature range is called a reference unit, and one which by use is intended to hold a relatively constant voltage level over a varying current and temperature range is called a regulating diode.

Reference elements may be a single junction or may be made up of multiple junctions to achieve a near zero temperature coefficient. Practically all reference diodes are classified by power dissipation (typically 400 mW or less), breakdown voltage and temperature at some fixed current, and range of operating temperature. Reference elements are typically used as voltage standards in power supplies, comparators, and level-sensing devices.

Regulating devices are used in power-supply regulation, meter-surge protection, relay arc suppression, and numerous other areas where a relatively constant voltage is required over a range of input voltages and output currents. They are available in power ratings up to 50 watts and voltage ranges up to 200 volts.

A special case of the regulator diode is the so-called *double-anode unit*. This unit, as the symbol indicates, is two regulator diodes with cathodes common as shown in Fig. 1.

The double-anode unit is usually a single silicon chip with cathode material being common and with two anode areas. The electrical characteristic which distinguishes this type of unit is symmetry of breakdown voltage. Double-anode regulators are commonly used in a.c. circuits for voltage clamping and in protective circuits where both positive and negative overloads may occur.

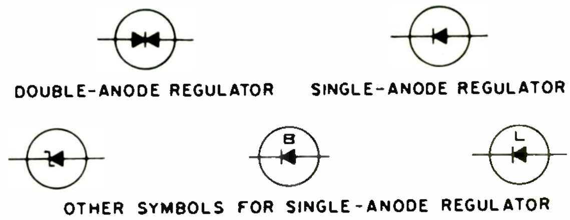
Comparison of the voltage-regulator solid-state diode with the voltage-regulator tube points out many advantages of the former. In addition to the customary advantage of smaller size and weight, the regulator diode enjoys the advantage of being able to regulate at almost any voltage level from 2 to 200 volts in a single device, and as high as desired in multiple unit stacks. Power-handling capability of up to 50 watts far surpasses that available with tubes, and problems such as drift, noise, and limited lifetime are markedly reduced with the semiconductor element. The circuit design engineer will also discover that the regulator diode will be price competitive and almost always more economical than the gas tube equivalent.

The many types of reference and regulator diodes which are presently available are far too numerous to outline in detail here, but a representative listing of standard JEDEC voltage regulator diodes, military parts, and voltage tolerances are included in Tables 1, 2, and 3.

Parameters and Symbols

In order to understand and effectively use any compo-

Fig. 1. Symbols for single-ended and double-ended zener diodes. Other symbols that are being used show the cathode shaped like the letter Z (for zener), the letter B (to indicate breakdown diode), or what looks like an L (representing the V-I curve).

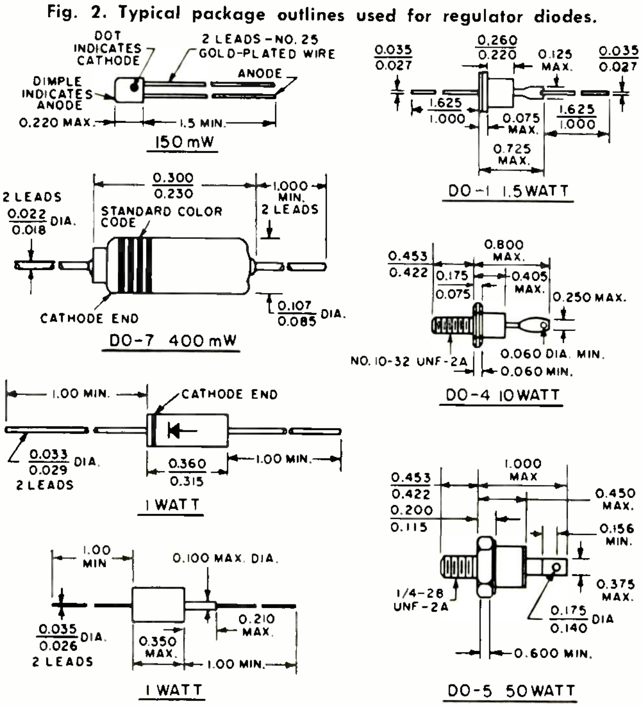


Nominal Voltage	JEDEC Registration Dissipation Available (watts)			
	0.4	1.0	10	50
2.4	1N4370			
2.7	1N4371			
3.0	1N4372			
3.3	1N746	1N3821		
3.6	1N747	1N3822		
3.9	1N748	1N3823	1N3993	1N4557*
4.3	1N749	1N3824	1N3994	1N4558*
4.7	1N750	1N3825	1N3995	1N4559*
5.1	1N751	1N3826	1N3996	1N4560*
5.6	1N752	1N3827	1N3997	1N4561*
6.2	1N753	1N3828	1N3998	1N4562*
6.8	1N754	1N3016	1N2970	1N2804
7.5	1N755	1N3017	1N2971	1N2805
8.2	1N756	1N3018	1N2972	1N2806
9.1	1N757	1N3019	1N2973	1N2807
10	1N758	1N3020	1N2974	1N2808
11	1N962	1N3021	1N2975	1N2809
12	1N759			
12	1N963	1N3022	1N2976	1N2810
13	1N964	1N3023	1N2977	1N2811
15	1N965	1N3024	1N2979	1N2813
16	1N966	1N3025	1N2980	1N2814
18	1N967	1N3026	1N2982	1N2816
20	1N968	1N3027	1N2984	1N2818
22	1N969	1N3028	1N2985	1N2819
24	1N970	1N3029	1N2986	1N2820
27	1N971	1N3030	1N2988	1N2822
30	1N972	1N3031	1N2989	1N2823
33	1N973	1N3032	1N2990	1N2824
36	1N974	1N3033	1N2991	1N2825
39	1N975	1N3034	1N2992	1N2826
43	1N976	1N3035	1N2993	1N2827
47	1N977	1N3036	1N2995	1N2829
51	1N978	1N3037	1N2997	1N2831
56	1N979	1N3038	1N2999	1N2832
62	1N980	1N3039	1N3000	1N2833
68	1N981	1N3040	1N3001	1N2834
75	1N982	1N3041	1N3002	1N2835
82	1N983	1N3042	1N3003	1N2836
91	1N984	1N3043	1N3004	1N2837
100	1N985	1N3044	1N3005	1N2838
110	1N986	1N3045	1N3007	1N2840
120	1N987	1N3046	1N3008	1N2841
130	1N988	1N3047	1N3009	1N2842
150	1N989	1N3048	1N3011	1N2843
160	1N990	1N3049	1N3012	1N2844
180	1N991	1N3050	1N3014	1N2845
200	1N992	1N3051	1N3015	1N2846

*Indicates not available for military use.

Table 1. Listing of regulator diodes by voltage and power.

Fig. 2. Typical package outlines used for regulator diodes.



ALL DIMENSIONS IN INCHES

nents, one must first acquire familiarity with the vocabulary which applies to that component. The terminology applied to regulator diodes is quite similar to that used with all semiconductors, yet some uniqueness of parameters does exist. Certain parameters are, of course, more significant to the user than others and these are usually specified as either minimums or maximums on the manufacturer's data sheet. Other parameters which are of interest, but not of controlling dominance are given as typical values and are not specifically guaranteed on a standard part. In Table 4 regulator diode parameters are discussed. Measurement techniques for regulator diodes are common to all manufacturers and are standardized by JEDEC registrations and on military parts in MIL-S-750A. Circuits which are not standardized must usually be worked out with the individual manufacturer.

Materials Employed

Practically all regulator diodes are manufactured with silicon as the starting semiconductor material. Silicon is selected in preference to germanium due to its superior thermal properties. Sensitivity of germanium devices to temperature extremes limits their usability to junction temperatures of 100°C compared to 200°C for silicon. Both from the standpoint of power handling capability and minimum reverse leakage current, silicon has the obvious advantage.

Three basic processes are utilized in manufacturing silicon regulator diodes. Each has certain advantages over the other two and also certain disadvantages.

The *alloy process* is used extensively in fabrication of low-voltage diodes. The primary advantage of the alloy process is that it allows one to obtain the very abrupt junction which is required for a sharp breakdown characteristic at lower voltage. The alloy device will typically exhibit less noise than its diffused counterpart. Major limitation on the alloy technique is the restriction on power-handling capability of the device. This power limitation arises out of the limitation on junction size due to mechanical considerations of matching the alloy material to silicon. Reliable devices of 1 watt are possible, and devices up to 10 watts have been fabricated for restricted usage. A second aspect of the alloy device, which acts as a minor disadvantage, is the absence of passivation over the exposed junction. This may tend to make the devices less reliable in some environments.

The *diffused* approach to regulator fabrication is limited to voltages above 6 volts and also has the exposed junction that is typical of the alloy unit. It tends to be somewhat more noisy in comparison to the alloy process. It has the advantages of being able to sustain large amounts of power and to allow construction of higher voltage units.

An extension of the diffused process is the use of the *planar technique* which utilizes an oxide passivation to cover the junction. This passivation makes the planar unit typically more reliable than either alloy or diffused types. The planar unit experiences the same low-voltage limitation as the diffused unit and is typically more noisy than either alloy or diffused. It has inherently much lower reverse leakage current and a sharper breakdown characteristic. Power-handling capability is superior to alloy construction and comparable to the diffused device.

As pointed out before, each process has certain strong and weak points, and selection of proper type is simply a function of end use of the product.

One of the most difficult and certainly most important aspects of fabricating a regulator diode is in providing some sort of housing or package for the device. The functions which the devices package must provide are: protection of the device from environment, removal of heat from the junction, good electrical paths to the external circuit, and simply as a carrier for the silicon chip.

Good package design requires a knowledge of the electrical conductivity, thermal transfer capability, and thermal expansion characteristics of the materials used. All device packaging schemes will require at least two insulator-to-metal seals. Common insulators are glass or ceramic. Metals may be Kovar, molybdenum, Dumet, or other alloys. The seal may be either a fused glass-to-metal oxide seal or a thermo-compression seal. Expansion coefficient of metal and insulator must be closely matched over the device's operating temperature range. Typical package outlines are shown in Fig. 2.

The 10-watt and 50-watt packages are supplied with a threaded stud and power rating is based on mounting the device to an external heat sink. Fig. 3 shows typical sizes of heat sinks which can be utilized for device mounting. Derating of device power from rated power at 25°C to 175°C with allowable power being 0 at 175°C. Many elaborate heat sinks are available in industry and the specific one to use can be dictated only by the application involved.

Selecting the Right Diode

In selecting the proper diode, the first item to be considered is the application. Requirements of the application will define the approximate voltage range to be used as well as the power-handling requirements. With these two pieces of information in hand, the design engineer is equipped to select the proper device.

Consideration should be given to what tolerance is allowable on the nominal voltage selected. Devices are available as ±20%, ±10%, ±5%, and ±1%. Obviously, the tighter the tolerance required, the more the unit will probably cost; therefore, one should specify only that tolerance which is actually required. When possible, the standard nominal voltage should be specified as cost will again be affected. If the device must operate under wide temperature excursions as a reference voltage, it will be necessary to specify the temperature coefficient. Specify only to the extent required to do the job adequately. An application across wide temperature variations will also require careful analysis of the power-handling capabilities of the device and of the mounting technique to be used.

Applications of the regulator device in power supplies for regulation will require consideration of the B_V characteristic and the zener impedance, to assure that the required percent regulation can be maintained over the range expected in input voltage and output current. If the device is to operate as a transient suppressor or clamping device, careful attention should be given to maximum surge current ratings. In those applications where high-gain amplifiers are to be used, consideration must be given to the

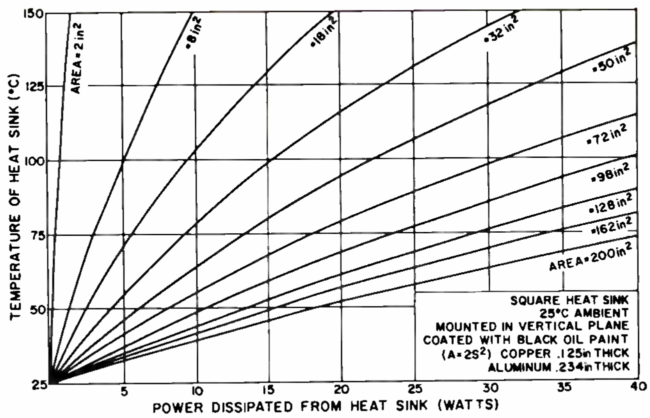


Fig. 3. Power-dissipation characteristics of square heat sinks.

DISSIPATION	VOLTAGE RANGE	DEVICE NUMBERS	APPLICABLE MIL-SPEC
400 milliwatt	2.4-3.0	1N4370A-1N4372A	MIL-S-19500/127
	3.3-12	1N746A -1N759A	MIL-S-19500/127
	11-200	1N962B -1N992B	MIL-S-19500/117
1.0 watt	3.3-6.2	1N3821A-1N3828A	MIL-S-19500/272
	6.8-200	1N3016B-1N3051B	MIL-S-19500/115
10 watt	3.9-6.2	1N3993A-1N3998A	MIL-S-19500/272
	6.8-200*	1N2970B-1N3015B	MIL-S-19500/124
50 watt	6.8-200**	1N2804B-1N2846B	MIL-S-19500/114

*1N2978, 1N2981, 1N2983, 1N2987, 1N2994, 1N2996, 1N2998, 1N3006, 1N3010, 1N3013 not available for military applications.

**1N2812, 1N2815, 1N2817, 1N2821, 1N2828, 1N2830, and 1N2839 are not available for military applications.

Table 2. Applicable MIL-Specs for various regulator diodes.

TOLERANCE

5%	10%	20%
1N4370A-1N4372A	1N4370 -1N4372	
1N746A -1N759A	1N746 -1N759	
1N962B -1N992B	1N962A -1N992A	1N962 -1N992
1N3821A-1N3828A	1N3821 -1N3828	
1N3016B-1N3051B	1N3016A-1N3051A	1N3016-1N3051
1N3993A-1N3998A	1N3993 -1N3998	
1N2970B-1N3015B	1N2970A-1N3015A	1N2970-1N3015
1N2804B-1N2846B	1N2804A-1N2846A	1N2804-1N2846

Table. 3. Regulator diodes grouped according to voltage tolerance.

Table 4. A summary of the important zener-diode parameters along with their significance.

PARAMETER	SYMBOL	HOW SPECIFIED	SIGNIFICANCE OF PARAMETER
Breakdown voltage	B_V (volts	Nominal ± tolerance at some current I_{Zt}.	Voltage at which the unit controls or regulates. Most important parameter.
Forward voltage	V_F (volts)	Maximum at specified current (I_F).	Defines forward voltage characteristic, usually of only minor importance.
Reverse current	I_R (μA)	Maximum	Specified at some voltage below avalanche or zener point. Represents the pre-breakdown leakage current of the device and helps to define the degree of sharpness of voltage breakdown point. Especially important in meter protection, relay arc suppression, or transient overload protection.
Test current	I_{Zt} (mA, by general usage)	Nominal	Current at which breakdown voltage or temperature coefficient are measured as applicable. Usually this is the current at which the regulator should be designed to operate.
Voltage regulation	B_V (volts)	Maximum	Voltage change between two different currents. Defines large-signal dynamic impedance of the regulator. Particularly important in defining how well a device will regulate over a range of input voltages and output currents in power-supply applications.
Small-signal dynamic impedance	Z_Z (ohms)	Maximum at some test current I_Z.	Defines change in regulator voltage for small changes in input current about the test current I_Z. Measured with a.c. superimposed on d.c. I_Z current. Particularly important in voltage regulators, level-sensing devices, and reference devices. Controls regulator sensitivity to ripple in input d.c. supply.
Temperature coeff.	TC (%/°C)	Typical at some I_{Zt}. (May be maximum on special device types)	Particularly important in reference applications. Defined as the percent change in regulator voltage per degree change in temperature. $TC = [(V_{ZT1} - V_{ZTZ})/(V_Z\ 25°C)] \times [100/(T_Z - T_1)]$.
Noise voltage	N (μV)	Maximum at some current and some frequency band.	Noise voltage is particularly important where the noise is likely to feed into high-gain amplifiers. Noise measurement circuits are usually special with each manufacturer.
Power dissipation	P_D (W or mW)	Maximum at 25°C.	Defined as the power required to raise the junction to its maximum operating temperature (165°C to 200°C) with the diode case at 25°C. Power is usually derated linearly for temperatures above 25°C.
Knee imp.	Z_K (ohms)	Maximum measured at I_K.	Impedance at the regulator knee.
Surge current	I_{RM} (A)	Maximum	Maximum reverse surge current, important in clamps, clippers, or protective applications.

noise level in the particular device that is to be used.

Over-all, the selection process, simply stated, is one of specifying only those criteria which are necessary to proper device operation. Specific problem situations can often be handled for the user by a manufacturer's application engineering group in the most economical as well as the most efficient manner.

Future Developments

As with all semiconductor products, improvements are a day-to-day thing in production techniques for reference and regulator diodes. Improved control procedures in manufacturing processes will result in better parameter control, hence lower cost. Better surface passivation techniques in the planar process are greatly reducing the failure rate observed on these devices. New materials are being evaluated with regard to increased power-handling capability and lower noise. The use of the punch-through effect in reference construction will probably yield reference units with nominal voltage below 2 volts while monolithic approaches will yield multiple devices in the same package which are much more closely matched with respect to breakdown characteristics than is now possible with discrete devices.

Improved materials handling techniques and simplified packaging schemes will bring both greater economy and greater reliability to the user. Device manufacturers stand ready to help the user with his present or future design requirements. ▲

Hot-Carrier Diodes

Using a metal-to-semiconductor junction, this new device has nearly ideal diode characteristics. It can be used as an ultra-fast detector; very-low-noise, high-conversion-efficiency mixer; and very fast switch.

THE hot-carrier diode is a new semiconductor rectifying device that offers a number of advantages over conventional *p-n* junction or point-contact diodes. Compared with *p-n* junctions, the hot-carrier diode has a much higher frequency capability. Compared with point-contact devices, it has improved electrical performance and mechanical ruggedness. It has nearly ideal diode characteristics; consequently, its conversion efficiency in mixer applications is higher than other types of diodes. It also has very low noise and a large square-law range.

Hot-carrier diodes are distinguished from the more conventional semiconductor devices in that the junction consists of a metal and a semiconductor, rather than two dissimilar semiconductor types. Although the metal-on-semiconductor concept goes back several decades to the time of Schottky, this idea was not pursued until recently because of technological limitations. As a result of research in this area, *hp associates* (an affiliate of *Hewlett-Packard*) produced the first hot-carrier diodes last year.

The metal-semiconductor junction of the hot-carrier diode (Fig. 1A) is made to be rectifying instead of ohmic through a choice of materials with suitably related work functions.

In the diodes thus formed, current flow occurs mainly by means of majority carriers (usually electrons in practice rather than holes because of the higher mobility of the electron). When the diode is forward biased, the majority carriers are injected into the metal at a much higher energy level than that of the metal's existing free electrons—hence the name "hot-carrier" diode.

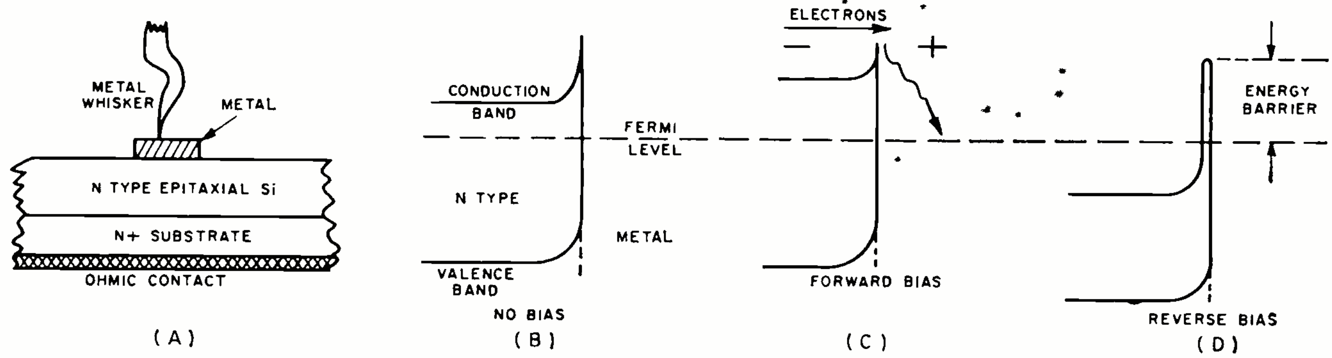
In the *p-n* junction, holes are injected from the *p* to the *n* side and exist there as minority carriers. Similarly, electrons are injected from the *n* to the *p* side. Although the existence of these minority carriers is necessary for current to flow, their presence becomes troublesome when it is desired to have a rapid response in junction conditions to a change or reversal of the bias. If the polarity of the bias is reversed, for example, current will flow easily in the reverse direction until the minority carrier density is reduced either by removal or recombination. The flow of reverse current lowers rectification efficiency if the diode is used as a detector, or increases the reverse recovery time if the diode is used as a switch. The time constant for the reduction of the minority carrier density is the lifetime.

In the hot-carrier diode, there exists at the metal-to-semiconductor interface an energy barrier known as the Schottky barrier, which occurs because of the difference in work functions of the two materials (see Fig. 1B). This barrier is decreased by a forward bias as shown in Fig. 1C and increased by a reverse bias as shown in Fig. 1D. Hence, the barrier results in a rectifying diode. In the forward bias condition, the majority carriers (electrons) are injected from the semiconductor into the metal where they initially have an energy level substantially above that of the metal's free electrons. In the metal, the hot electrons give up their excess energy in a very short time, about 100 femtoseconds (one femtosecond equals 10^{-15} second), after which they become part of the sea of free electrons in the metal.

The electron flow from semiconductor to metal occurs with virtually no flow of minority carriers in the reverse direction. Consequently, the response to a change in bias in the hot-carrier diode is much faster than in *p-n* junctions. Even the slowest hot-carrier diodes have majority carrier lifetimes of less than 200 picoseconds while the faster ones have lifetimes too short to be presently measurable. In addition, the low minority carrier density means that there is less stored energy in the junction. This, in turn, reduces the drive requirements when the diode is operated as a switch.

Hot-carrier diodes have some drawbacks. They are still undergoing laboratory refinements to reduce their inherent barrier capacitance and series resistance, which may be as low as 1 pF and 10 ohms respectively. Also, development is under way to improve their packaging to make them interchangeable with conventional *p-n* types. Manufacture is presently restricted to a few companies and the prices are still fairly high. ▲

Fig. 1. (A) Construction of a hot-carrier diode. (B) Energy diagram without bias. (C) With forward bias. (D) With reverse bias.



Switching Diodes

By JOHN BROWN
Head, Applications Engineering, Fairchild Semiconductor

How to select these devices which are characterized by certain maximum reverse recovery times for high-speed switching uses.

SWITCHING diodes are designed for rapid switching from either the forward or reverse state to the opposite state with minimal transient behavior. Unfortunately, ordinary rectifying junctions do not immediately exhibit a high impedance when switched to a reverse-biased state from a forward-conducting one. Instead, they conduct freely for a brief time interval.

The time from the instant of switching until the device exhibits a satisfactory high impedance is the *reverse recovery time* (t_{rr}). When switched from a reverse-biased to a forward-conducting state, the diode exhibits a high impedance in the forward direction. The time from the instant of switching until the device reaches low impedance is the *forward recovery time* (t_{fr}). Of these two parameters, reverse recovery time is normally far larger.

Even though a manufacturer employs all the tricks of his trade, he cannot entirely eliminate forward and reverse recovery times. The user may, however, optimize operation by employing as low a forward current level as possible for the "on" state and driving to as high a reverse current as possible when switching to the "off" state.

The largest number of switching diodes currently sold are types such as the 1N3600 and 1N914. Both these devices offer switching speeds (t_{rr}) of less than 4 nsec, reverse leakages less than 100 nA, and reverse breakdown voltages of 80 V or greater. The forward voltage drop is less than 1.0 V at $I_F = 200$ mA for the 1N3600 and at $I_F = 20$ mA for the 1N914.

Faster devices (less than 0.75 nsec t_{rr}) are available, such as the 1N4376, at a sacrifice in breakdown voltage and conductance. Medium-speed (less than 50 nsec) devices, such as the 1N3070, with higher breakdown (over 150 V) voltage and high conductance are also available. All the devices mentioned can be obtained as MIL qualified types. Manufacturers in the commercial and consumer markets may now purchase low-priced devices from reputable manufacturers to the barest of specifications with no fear of device failures presenting a problem.

Switching Diode Parameters

MIL-STD-750 is perhaps the best single reference for device parameters and their measurement. Table 1 lists the parameters commonly used in specifying switching diodes. The first eight (V_F, I_F, V_R, I_R, V_{BR}, I_{BR}, t_{rr}, and C) are almost always specified. The next two (V_P and t_{fr}) are appearing more frequently on users' specifications.

The remaining parameters listed are not normally given although their behavior must be taken into account in circuit design. However, the variations in these parameters from one device to another is not significant enough to warrant a required test by the manufacturer or else the parameter is strongly dependent on one of the eight major parameters already specified. These parameters are usually described in sufficient (for designers' purposes) detail by curves included on data sheets supplied by manufacturers.

V_F, I_F, V_R, I_R: These specifications are presented as follows:

a. Maximum forward voltage (V_F), usually 1.0 V, at some forward current (I_F). For critical applications, both maximum and minimum forward voltage limits are given at various I_F levels. An ambient temperature of 25°C is normally specified.

b. Maximum reverse current (I_R) at some reverse voltage (V_R). Normally, this test is specified for performance at 25°C and some elevated (generally 150°C) temperature. Rules of thumb for predicting reverse current changes with temperature are "I_R doubles for each 12°C increase in temperature" (for large changes in temperature) and "I_R increases about 7% for each 1°C in temperature" (for small changes in temperature).

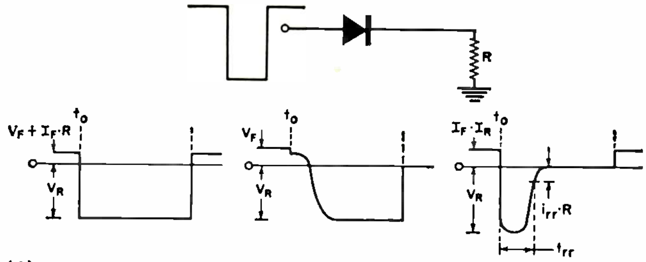
V_{BR}, I_{BR}: Generally speaking, the breakdown voltage (V_{BR}) is much lower for switching diodes than for rectifiers. It is one of the parameters that must be sacrificed in order to obtain faster switching times. The breakdown voltage is normally quite sharp so that voltage transients in excess of the breakdown voltage can result in very high reverse currents (I_{BR}), if current is not limited by external circuitry. Reverse transients are probably the greatest single cause of device failures in switching diodes and rectifier applications.

Specifications usually include a minimum reverse breakdown (V_{BR}) at some reverse current (I_{BR}), such as 5 μA or 100 μA. The test is customarily performed only at room temperature. (V_{BR} is only slightly temperature dependent; it increases approximately 0.1% per °C increase in temperature).

t_{rr}: Fig. 1 illustrates the reverse transient behavior of a switching diode. The time period from the instant of switching until the reverse current through the diode has diminished to some acceptably low value. i_{rr}, is the reverse recovery time, t_{rr}. Some generalizations about reverse transient behavior may be made. Reverse recovery time increases for increasing I_F, R_L, T_A (ambient temperature), and decreasing i_{rr}; it decreases for increasing I_R.

The most often used circuit for measuring t_{rr} is shown

Fig. 1. Switching diode reverse transient characteristics.



(A) INPUT VOLTAGE WAVEFORM (B) VOLTAGE ACROSS DIODE (C) VOLTAGE ACROSS R

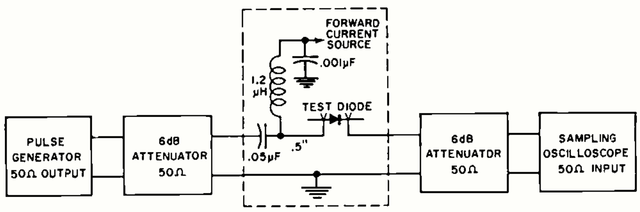


Fig. 2. Test circuit used to measure reverse recovery time.

in Fig. 2. Considerable care must be exercised in the construction of the circuit otherwise damped oscillations ("ringing") will occur in the region of i_{rr}, making the measurement of t_{rr}, with any degree of accuracy, impossible.

Formal standardization on the measurement of this parameter for very fast diodes has not been established because of the difficulty in defining an adequate procedure for evaluating the test circuit (test fixture primarily). However, the Electronic Industries Association is working in this direction.

C: Capacitance of a semiconductor diode decreases with reverse voltage, as shown in Fig. 3. In many applications, the diode is required to block spurious signals when reverse biased. Small signals, although insufficient in amplitude to reverse the state of the diode, can be coupled directly by the diode's capacitance to the next stage, giving a false indication of a change in state.

Because forward capacitance of diodes is not usually important, capacitance specifications normally list a reverse or zero bias condition for measurement. Zero bias is the most commonly used condition and the measuring frequency and T_A are usually 1 MHz and 25°C, respectively.

V_p, t_{fr}: Forward transient behavior of switching diodes is of concern only when the diode (*e.g.* driving magnetic cores) is subjected to high (100 mA and up) forward current pulses of extremely fast rise times. Fig. 4 shows the typical transient behavior of a switching diode subjected to a high-amplitude, fast-rise-time, forward-current pulse. The peak forward voltage, V_p, is due to the initially high ohmic drop of the bulk silicon. After current flows for an appreciable period, the conductivity of the silicon increases due to the increased carrier densities. As this occurs, the voltage, V_p, decreases and eventually a steady-state value, V_F, is reached. The time required for the forward voltage to recover to an acceptably low value ($1.1 \times V_F$, usually) is called the forward recovery time, t_{fr}.

The variables affecting forward transient behavior are:

1. As reverse bias increases, V_p and t_{fr} increase. However, the variation is quite small so that zero bias is usually called for. A slight forward bias, on the other hand, sharply reduces V_p and t_{fr}.
2. As the rise time decreases, V_p increases and t_{fr} decreases.
3. As I_F increases, both V_p and t_{fr} increase.
4. As R_L increases, V_p and t_{fr} decrease. Resistance R_L is not, however, a critical variable except that large value resistors are often inductive and thus reduce the rise time of the current pulse.
5. As T_A increases, V_p and t_{fr} decrease.

Special Switching Diodes

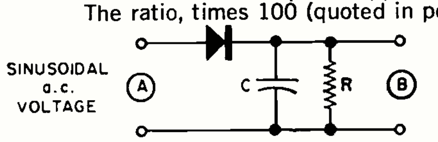
Various "special" switching diodes (such as the *p-n-p-n*, hot-carrier, tunnel, and charge-storage diodes) are finding greater application. These will be briefly treated in this section. Elsewhere in this issue the reader will find detailed accounts of these diodes.

"P-n-p-n" Diodes: The *p-n-p-n*, or four-layer, diode has a characteristic as shown in Fig. 5. These diodes may be biased near breakover, then triggered by a low-voltage, short-duration pulse to a low-impedance state. The devices are ideally suited for applications wherein it is desirable to switch reasonably large currents or voltages with small signals. Generally, *p-n-p-n* switches do not appear suitable for logic gating diode applications since they must be reset after firing.

Hot-Carrier Diode: The hot-carrier, or hot-electron, diode has characteristics very similar to, but are actually faster than, conventional switching diodes. It is faster because it does not store minority carriers—an unescapable characteristic of conventional diodes. Generally speaking,

Table 1. The important parameters and symbols that are employed for switching diodes.

PARAMETER	SYMBOL	DESCRIPTION
Forward voltage	V_F	Forward voltage across a diode—anode positive, cathode negative.
Forward current	I_F	Forward electron current through a diode—from cathode to anode.
Reverse voltage	V_R	Reverse voltage across a diode—cathode positive, anode negative.
Reverse current* (reverse leakage)	I_R	Reverse electron current through a diode—from anode to cathode.
Reverse breakdown voltage	*V_{BR}, B_{VR}, B_V, PIV	The value of reverse voltage across a diode at which breakdown occurs.
Reverse breakdown current	*I_{BR}, I_R	The value of reverse current in the breakdown region.
Reverse recovery time	t_{rr}	The time required for the reverse current or voltage to recover to a specified value after instantaneous switching from a forward current (or voltage) condition to a reverse current (or voltage) condition.
Capacitance	C	Capacitance of a diode under either forward or reversed biased condition.
Peak forward voltage	V_P	The maximum transient forward voltage appearing across a diode after instantaneous switching from a reverse voltage condition to a forward current condition.
Forward recovery time	t_{fr}	The time required for the forward voltage to recover to a specified value after instantaneous switching from a reverse voltage to a forward current condition.
Temp. coef. of forward volt.	TC	The change in forward voltage resulting from a specified change in temperature.
Forward dynamic impedance	*R_d, R_f, Z_f	The ratio of the incremental change in voltage occurring with an incremental change in current under stated conditions of d.c. forward current (or voltage) and stated incremental change in current. (Normally specified at some d.c. current level, $I_{d.c.}$ with a superimposed a.c. current, $I_{a.c.}$; $I_{a.c.}$ is normally equal to 0.1 $I_{d.c.}$.)
Series resistance	R_s	Series resistance of bulk semiconductor material and internal attaching parts, exclusive of junction impedance.
Stored charge	Q_s	The charge stored in a semiconductor diode under a forward voltage or current biased condition.
Thermal res. (junction to ambient)	θ_{J-A}	The ratio of the temperature rise of the junction of a diode above ambient to the d.c. power applied to the device.
Rectification efficiency	R.E.	The ratio, times 100 (quoted in percent), of the d.c. voltage at point B to the peak a.c. voltage at point A in the circuit. Conditions of frequency f, resistance R, and capacitance C, must be stated. (RC»1/f).



*Preferred Usage.

the reverse characteristics are poorer than that of conventional diodes. The forward-voltage characteristics are better (lower forward drop) at lower currents (less than 20 mA) but poorer at higher currents.

Hot-carrier diodes cannot withstand large current surges without damage and are more susceptible to contamination during manufacture. The selection of a hot-carrier diode over conventional switching diodes would normally be made when either extremely fast switching or a low forward-voltage drop is required. When these needs are not critical, considerations of reliability, cost, and other electrical characteristics would normally dictate the selection of the conventional diode.

Tunnel Diodes: These devices can be switched very rapidly through the negative resistance region. The tunnel diode's characteristic is such that it is not easily compared to conventional diodes. Its range of operation is very restrictive in that the voltage, and current range encompassing the negative resistance region, is limited to a few tenths of a volt and a few milliamperes, respectively.

Charge-Storage Diode: Charge-storage diodes have the same general characteristics as conventional switching diodes and rectifiers. The distinguishing feature of this type of device is that its reverse recovery time is designed to be long. The recovery waveform is very similar to that of Fig. 1C, except that corners are more nearly square.

The device remains in the reverse conducting state for a comparatively long time, then recovers sharply. This characteristic has resulted in its often being referred to as a "snap-off" diode. Its t_{rr} is dependent on the amplitude and duration of the forward current applied prior to switching. This particular characteristic is normally controlled and this enables the user to deliberately incorporate known delays in switching.

Germanium vs Silicon

Typically, the reverse current of germanium devices is roughly 1000 times that of silicon and even more sensitive to temperature. Thus, germanium diodes can rarely be operated at even moderately elevated temperatures (90°C) else thermal runaway occurs due to the added heating effects resulting from the combination of a reverse voltage and the resulting large reverse currents. Most silicon devices are operational to 150°C with no danger of thermal runaway occurring. Germanium diodes, however, have one very important characteristic advantage over silicon; the forward voltage at low forward currents is much less than for silicon. The forward voltage at a forward current of 1.0 mA is typically 0.3 V for germanium and 0.6 V for silicon. At much higher currents, however, the difference is not so pronounced. Capacitance is about the same and the t_{rr} of silicon is generally better than for germanium, principally because more effort has been expended on improving the performance of silicon in recent years.

Because of temperature limitations, germanium usage has been dropping rapidly, and silicon has been on the upswing. Although the average selling price of germanium is still slightly lower than silicon, germanium now constitutes only approximately 10 to 15% of the total diode market (including rectifiers).

Mechanical Considerations

Fig. 6 shows the three packages which have emerged as high-volume sellers. The relative merits of the three packages are:

1. Package A, the DO-7, is most commonly used for switching diodes and is available from the largest number of manufacturers. It is time proven in reliability and performance.

2. Package B is smaller than A and equally rugged mechanically. It is available in very large quantities but only from a few manufacturers. Projected cost of manufacture of this device are less than those of package A. Projected costs of package B as compared with C lead to disagreements as to which can ultimately become the most economical.

3. Package C is the smallest package available in any quantity and is economical to manufacture. Compared with the A and B packages, package C has less mechanical strength and a somewhat limited operating temperature range.

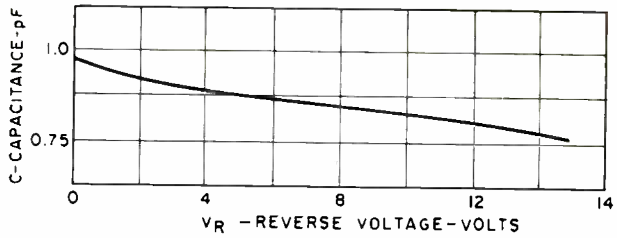


Fig. 3. Typical 1N3600 capacitance versus reverse voltage.

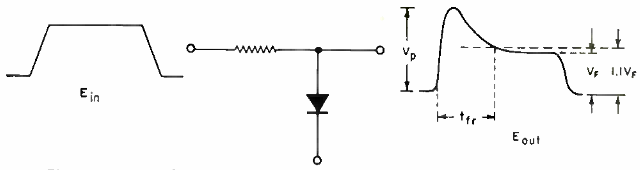


Fig. 4. Switching diode forward transient characteristics.

Mounting: Most switching diodes are mounted conventionally to printed-circuit boards and are operated at low power levels where heatsinking is unnecessary. For devices operating at average power levels of over 25% of rated power, mounting can become an extremely important consideration. Axial lead devices are normally rated with infinite heat sinks attached to the leads, ⅜" from the end of the body. This is unrealistic but has been considered a usable figure. The user can measure the temperature rise at the ⅜" point resulting from his less-than-perfect mounting and adjust the rating accordingly.

General guidelines for mounting axial lead devices operating at elevated power levels are:

1. Provide as good a heat sink and as close to the body as possible. Heat flow is predominantly from the cathode lead for most designs—it is about 90% for package A.

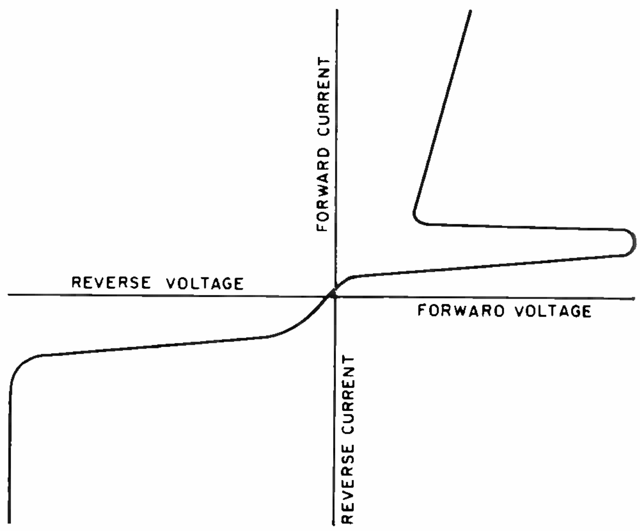
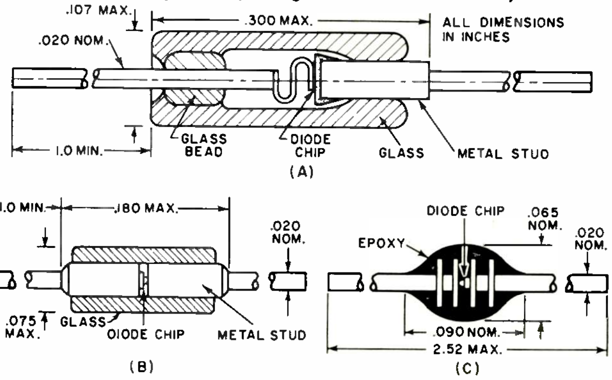


Fig. 5. Typical four-layer diode characteristics are shown.

Fig. 6. Switching-diode packages that are most widely used.



2. Provide forced draft air flow if possible. Although most heat flow is *via* conduction through the leads, this condition can be reversed if the thermal resistance of the mounting is high and a good forced draft is provided.

Selecting the Right Diode

Selection should begin with switching time considerations. One should first determine whether forward recovery time ("turn-on" time) or reverse recovery time ("turn-off" time) is the most critical. Manufacturers' data sheets for switching diodes do not generally include forward recovery time specifications. This does not imply that they are poor. It is extremely difficult to specify a set of conditions from which performance can be predicted for all combinations of rise time, current drive, loop resistance, etc. Relative performance can be anticipated, however, by considering three other parameters: reverse recovery time, capacitance, and forward voltage. In general,

1. The faster the reverse recovery time, the faster the forward recovery time.
2. The higher the capacitance, the faster the forward recovery time.
3. The lower the forward voltage, the faster the forward recovery time.

Gating circuits with large fan-in can exhibit considerable propagation delay if the capacitance of the diodes is large. Consider a simple four-input gate with 5 pF of capacitance per gate. If initially all gates are "off" (reverse biased), then one gate is switched "on" with a current drive of 1.0 mA, 15 nsec are required to change the voltage on the other three gates by 1.0 V. This proceeds from:

$t=[(n-1)CV]/I_F=[(4-1)(5\text{ pF})\cdot(1.0\text{ V})]/10^{-3}\text{A}=$ 15 nsec. where I_F=gate drive current, t=time, n=total number of diode gates, C=diode capacitance, and V= voltage change across diode gates in time, t. Obviously, capacitance can be an important consideration.

With respect to reliability, breakdown voltage and forward voltage are of principal concern. For example, the breakdown voltage of the device should be high enough so that reverse voltage transients never exceed it. Even though a device may be rated at, say, 400 mW, it should not be inferred that it can be operated at that level in breakdown. Switching diodes, unlike voltage regulator diodes, are not designed for uniform breakdown. More often than not, breakdown current is concentrated in a small area resulting in very high localized heating.

Forward voltage should be given more than just circuit considerations if the application is for short-duty-cycle, high-current operation. Power should be minimized in that failure rates in semiconductors are very strongly dependent on junction temperature. The lower the forward voltage, the lower the power for a given current drive, and hence the lower the junction temperature.

The Future

Certain trends are evident that are likely to continue. Discrete switching diodes are being replaced in greater numbers by integrated circuits in computer applications. However, the higher power handling capability and superior electrical parameters of discrete components will enable them to endure for some time to come. A decrease in the number of switching diodes sold is not likely for a year or two because of general market growth. Ultimately, however, the large volume applications must yield to integrated circuits that are yet to be offered.

Within the next two years, a rapid switch from package A to package B can be expected for reasons of economy. Average selling prices during the next two years will probably drop to half that of current prices due to manufacturing efficiencies. No significant breakthroughs in performance are expected for the conventional switching diode. Emphasis will be on cost reduction to expand the consumer and industrial markets. Newer types of "special" switching devices such as light-activated switches, charge-storage diodes, multilayer diodes, etc. will probably emerge in abundance. ▲

P-I-N DIODES

THE *p-i-n* (Positive Intrinsic Negative) diode is better described as a variable resistor than as a conventional diode. Its normal use is at a sufficiently high frequency so that it does not rectify the applied signal and does not generate harmonics. The resistance of the *p-i-n* diode is controlled by a d.c. or a low-frequency bias or modulating signal. The high-frequency signal being controlled sees a constant resistance independent of polarity, although limited by reverse breakdown voltage. This characteristic of the *p-i-n* diode depends upon the minority carrier lifetime being much longer than the period of the controlled signal.

The dynamic resistance of the *p-i-n* can be larger than 10,000 ohms because of the existence of an exceptionally wide high-resistivity layer next to the junction. Because of this layer, the reverse breakdown voltage of the *p-i-n* diode can be as high as several hundred volts. Correspondingly, capacitance per unit of junction area will be very low, yet conductivity during forward conduction can be high because the conductivity of this layer will be increased by the presence of stored charge (conductivity modulation).

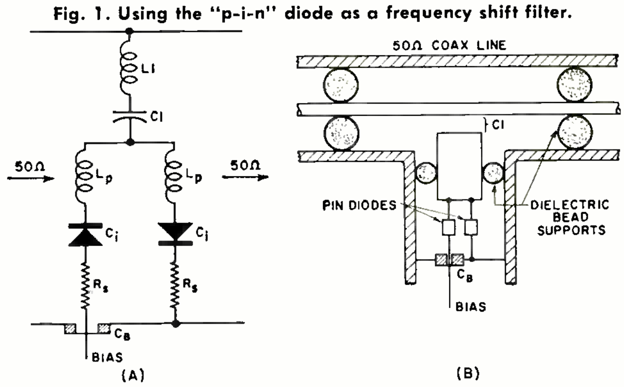
There are two general areas of application for the *p-i-n* diode: it may be used as a microwave switch to be operated by abrupt changes in bias; or it may be used as a variable resistance microwave amplitude modulator. In either case, the impedance of the diode is controlled by the external bias, and it approximates a linear passive impedance to the applied microwave signal. These diodes are also finding use in digital phase shifters and may soon find application as flexible, low-loss control elements and variable resistances. The ability of these diodes to switch the frequency response of microwave filters without degrading "Q" opens up many new system design possibilities.

In the *p-i-n* diode frequency-shift bandstop filter shown in Fig. 1, it is assumed that a broadband mixer and a 1-GHz local oscillator are used in a receiver connected to the coaxial line. The i.f. is 30 MHz and it is desired to make a switchable stop filter reject either 970 or 1030 MHz. In this circuit, *hpa* 3001 *p-i-n* diodes are used. The diodes are represented in Fig. 1A by L_p, C_i, and R_s. Inductor L1 is a loop, shown in Fig. 1B, while C1 is the capacitance between this loop and the center conductor of the coaxial cable. Capacitor C_B is a bypass for the bias lead. The network is resonant at 970 MHz.

The two diodes are in series for the bias but in parallel for the signal (r.f.). Switching the diodes from forward to reverse bias changes the total capacitance just enough to shift the network resonant frequency from 970 to 1030 MHz. The insertion loss at the frequency of operation is about 34 dB, while at the other frequency, insertion loss is 0.01 decibel.

Because the conductance of the *p-i-n* diode can be altered with a change in the applied bias, a great variety of attenuation and switching networks becomes possible. ▲

Fig. 1. Using the "p-i-n" diode as a frequency shift filter.



Our author joined Motorola in the Solid State Systems Division where he held the position of Senior Engineer concerned with study of parametric amplification. He was also with the B-58 Navigation System as group leader for developing automatic microwave instrumentation. In 1963 he transferred to the Semiconductor Products Division in his present capacity. Prior to joining Motorola, Dr. Schaffner was with Stewart-Warner Electronics where he developed modulator and the L-band microwave portions of three subminiature beacons and, as project leader, developed i.f. amplifiers and L- and S-band microwave beacons. Dr. Schaffner received his PhD (EE) from Northwestern University in 1956. He is a member of IEEE, Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

Varactor Diodes

By GERALD SCHAFFNER

Group Leader, Varactor Circuit Research, Motorola Inc.

Selecting variable-capacitance diodes for the following: tuning, harmonic generation, switching and limiting, pulse shaping, parametric amplification, and phase shifting.

NEW industry-wide varactor diode developments have extended the advantages of solid-state performance and reliability to new applications and to frequencies in the microwave region. Varactors provide solid-state tuning that is faster and more reliable than mechanical tuning; r.f. power available at higher power levels and higher frequencies than with transistors and with greater efficiency and reliability than tubes can offer; faster switching than with tubes or mechanical relays; and lower noise amplification than with either tubes or transistors. The versatile varactor also offers such functions as limiting, pulse shaping, and phase shifting.

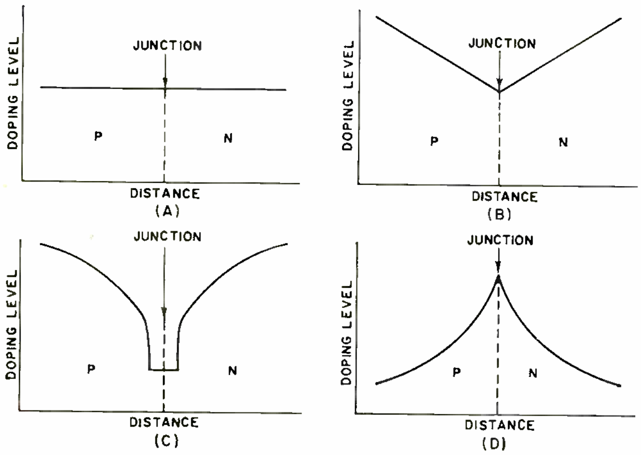
The varactor or variable-capacitance diode differs from conventional diodes in that the prime objective is to have the back-biased junction purely capacitive. There is usually relatively little concern for the forward characteristics. This unusual attitude exists because varactor operation utilizes the voltage-variable depletion capacitance of a *p-n* junction. The capacitance of a junction can be described by:

$$C_j = C_0/(1 - V/\phi)^k \quad \ldots\ldots\ldots\ldots (1)$$

where: C_j is the junction capacitance, C_0 is the zero-bias capacitance, V is the applied voltage, ϕ is the contact potential, and k is the law of capacitance which depends on the construction of the diode as illustrated by the impurity profile diagram (Fig. 1).

For abrupt junctions, k has the value of ½. If the doping level decreases linearly through the active region of the junction up to the depletion layer, k becomes ⅓, and the device is *linearly graded*. When the doping is heavy throughout the semiconductor, except when it decreases abruptly for a narrow region around the junction, k becomes as low as 1/30. Such a device is called a *step-recovery* or *snap-off* diode. Extending the width of this lightly doped region leads to a *p-i-n* diode. Finally, if the doping level increases toward the depletion layer, one obtains a hyper abrupt or retrograded junction and k as high as 2 or 3 is possible.

Fig. 1. Impurity profiles. (A) Abrupt junction. (B) Linearly graded. (C) Step-recovery or "p-i-n". (D) Hyper abrupt.



Function	Desired Attributes	Diode Structure
Tuning	Large capacitance swing, high f_c, high BV_R, low I_R	Silicon abrupt or hyper-abrupt junction
Harmonic Generation	High f_c, high BV_R, low ϕ_{jc}	Silicon or gallium-arsenide abrupt or graded junctions and silicon step-recovery junctions
Switching & Limiting	Low R_f, with forward bias, low C_j, high BV_R, low ϕ_{jc}, fast recovery from conducting to non-conducting condition	Silicon p-i-n or Schottky-barrier for very fast low-level switching
Pulse Shaping (a) Sharpening risetime	Capable of storing large amount of charge in forward direction, long minority carrier lifetime, short transition time (time of recovery to zero current after return of minority carriers)	Silicon step-recovery diodes
(b) Clipping overshoot	Very short minority carrier lifetime, low R_f, low C_j	Silicon or GaAs Schottky-barrier diodes
Parametric Amplification	High cut-off frequency, high f_c, high β	Silicon or GaAs abrupt diodes
Phase Shifter	For analog shifter same as for tuning For digital shifter same as for switching	

Table 1. Listing of varactor functions with desired device attributes along with the most commonly used diode structures.

The relatively small capacitance variation with voltage of the step-recovery and *p-i-n* diodes represent somewhat of a departure from conventional varactors. In these diodes, the capacitance variation is concentrated at one point near zero volts bias. Since step-recovery and *p-i-n* diodes still do utilize the change in capacitance or reactance, they are legitimately classified as varactors.

Varactors can also be classified by the semiconductor used, *i.e.*, silicon, germanium, and gallium-arsenide. When formed with a semiconductor-metal junction, varactors are called *hot-electron, hot-carrier,* or *Schottky-barrier* diodes.

Present practice, however, is to stress the function in classification. Varactors are used for tuning, harmonic generation, switching and limiting of r.f. power, shaping of pulses, parametric amplification, and phase shifting (see Table 1).

Because varactor technology is still advancing rapidly—especially with regard to reliability and stability—in general only the varactors introduced within the past two or three years should be considered when designing new devices. Because the best varactors have only recently been introduced, some do not have a JEDEC registration or a MIL designation. Consequently, in listing typical available varactors, as is done in Table 2, some company numbers must be referenced along with the registered numbers.

There is little standardization of varactor tests except for the conventional diode measurements of BV_R, I_R, etc.

Of all the parameters, perhaps f_c (or "Q") is the most important to measure. For lower frequency varactors, various bridges such as the *Boonton* 33A are convenient and accurate. However, if the varactor equivalent parallel resistance exceeds 100,000 ohms, microwave measurement methods should be used. Quality factor can be derived from R_S and previously measured capacitance.

There have been few MIL-Specs for varactors. These specifications are written according to MIL-S-19500 ("Semiconductor Devices, General Specifications for") with the tests made in accordance with MIL-STD-750.

There are basically two materials used for varactors: silicon and gallium arsenide; germanium, the other major semiconductor material, is not used because of its excessive leakage current.

Table 3 is a comparison of devices made from gallium-arsenide and silicon in various configurations. Basically, gallium-arsenide varactors have considerably higher "Q's" than their silicon counterparts. However, the latter have superior thermal and mechanical properties. In addition, it is more difficult to passivate a gallium-arsenide surface than a silicon one, and minority carrier lifetime is shorter in gallium-arsenide than in silicon. Finally, gallium-arsenide varactors cost more than silicon varactors.

Because of these limitations, gallium-arsenide diodes are usually used only for low-noise parametric amplifiers and millimeter-region harmonic generators. For about 75 percent of all varactor applications, the silicon epitaxial configuration is used.

No matter what the application, the user should always try to get varactors that are hermetically sealed and whose junctions are passivated. Welded ceramic packages are preferred to those which are merely soldered.

Tuning Applications

Tuning requirements usually include tuning range, "Q", leakage current, temperature stability, and perhaps limits on distortion when large signals are impressed.

The user should first select the minimum useful voltage which gives the desired temperature stability and distortion. Temperature stability, for example, can change from 300 p.p.m. (parts per million) at −4 volts to 50 p.p.m. at BV_R.

Once the minimum voltage is determined, the maximum voltage can be calculated from tuning range considerations.

$$f_{max} = 1/[L(C_{ckt}+C_c+C_{min})]^{1/2}$$
$$f_{min} = 1/[L(C_{ckt}+C_c+C_{max})]$$

where C_{max} and C_{min} correspond to junction capacitances at minimum and maximum voltages, respectively. The capacitances or voltages can be obtained from Equation (1).

Fig. 2 is a family of curves for percentage tuning range in terms of C_{min}/C_{max} (or V_{min} and V_{max} if an abrupt junction is assumed). From these equations or curves, the junction capacitances can be determined.

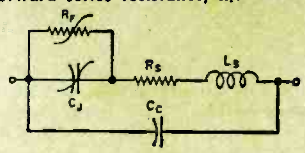
After V_{max} and C_j are determined, the manufacturer's catalogues should be consulted to see if the desired "Q" is available. It should be remembered that "Q" goes down as BV_R goes up. The same consideration holds for I_R. However, in many cases the manufacturer may supply better devices than the minimum indicated in his catalogue.

Harmonic-Generator Application

Varactors for harmonic generators are selected on the basis of power and efficiency, linearity, temperature sta-

DEVICE PARAMETERS

Forward series resistance, R_f: Over most of the usable frequency range this



BV_R = DIODE VOLTAGE GIVING REVERSE LEAKAGE CURRENT I_R

$f_C(V) = \dfrac{1}{2\pi\, C_J(V)\, R_S}$ DIODE CUT-OFF FREQ.

ϕ_{JC}=THERMAL RESISTANCE °C/W

resistance follows the d.c. resistance closely and can be measured with an audio-frequency bridge or curve tracer. This parameter is especially important in switching circuits.

Junction capacitance, C_j is the voltage-dependent capacitance of the depletion region which follows Eq. (1). Junction is usually determined from a capacitance bridge measurement after subtracting the case capacitance, C_c.

Reverse series resistance, R_S, which is in series with C_j, is a result of contact resistance plus the path resistance through the semiconductor to the depletion layer edges. Resistance R_S is somewhat voltage-dependent since depletion layer width varies with voltage.

The combination of R_S and C_j determines a most important diode parameter, **cut-off frequency.** $f_c=1/\pi R_S C_j$). Since both C_j and R_S are voltage-dependent, f_c is as well, being highest at BV_R, and the lowest near 0 volts.

Basically, f_c is a measure of junction capacitance quality factor ("Q") with f_c being merely "Q" times the measurement frequency. Measurement of "Q," f_c, or R_S can be accomplished on an r.f. bridge or in various microwave impedance-measuring circuits.

Case capacitance, C_c is primarily due to the relatively high dielectric constant of the ceramic or glass housing. Case capacitance is a particularly undesirable parasitic in switching applications because it lowers the impedance when device is reverse-biased. This capacitance is also undesirable in tuning applications as it reduces the tuning range.

Lead inductance, L_S arises from the leads from the semiconductor contacts to the package contacts. Lead inductance can be determined by measuring the diode self-resonance frequency and a previously determined junction capacitance.

Lead inductance has an especially undesirable effect on high-frequency operation of tuning diodes because it makes the effective capacitance larger and "Q" smaller. In harmonic generators and parametric amplifiers, lead inductances make broad-banding more difficult, acting as an additional energy storage element. In switching, the effect of L_S is to increase forward insertion loss.

Efficiency, η is the conversion efficiency of harmonic generators: $\eta = P_{out}/P_{in}$.

Table 2. Examples of some readily available varactor diodes for four important applications.

COMPANY	VARACTOR		CHARACTERISTICS		
1. Tuning—estimated unit cost $2 to $40					
Crystalonics	VA-203	$C(-4\ V)=47$ pF	$BV_R=150$ V	$f_c(-4\ V)=5$ GHz	$C_2/C_{150}=6.2$
Fujitsu	15535	$C(-0.1\ V)=65$ pF	$BV_R=25$ V	$f_c(-8\ V)=0.5$ GHz	$C_{0.1}/C_{15}=65$
Motorola	MV1864B	$C(-4\ V)=6.8$ pF	$BV_R=60$ V	$f_c(-4\ V)=30$ GHz	$C_4/C_{60}=3.1$
Philco	V4093	$C(-8\ V)=500$ pF	$BV_R=115$ V	$f_c(-8\ V)=2$ GHz	$C_4/C_{100}=4.1$
TRW	PG347	$C(-4\ V)=47$ pF	$BV_R=50$ V	$f_c(-4\ V)=15$ GHz	$C_2/C_{50}=4.3$
Varian	VAT-IIE	$C(-4\ V)=2.2$ pF	$BV_R=120$ V	$f_c(-4\ V)=20$ GHz	$C_0/C_{120}=8.1$
2. Harmonic Generation—estimated unit cost $28 to $150					
Hewlett-Packard	hpa-0241	$f_{in}=100$ MHz	$f_{out}=2$ GHz $P_{in}=1$ W, $\eta=25\%$		
Microwave Associates	MA4765	$f_{in}=4$ GHz	$f_{out}=12$ GHz $P_{in}=1$ W, $\eta=30\%$		
Motorola	1N5155	$f_{in}=2$ GHz	$f_{out}=6$ GHz $P_{in}=5$ W, $\eta=40\%$		
Sylvania	D5047C	$f_{in}=9.6$ GHz	$f_{out}=28.6$ GHz $P_{in}=.41$ W, $\eta=55\%$		
Varian	VAB-802	$f_{in}=500$ MHz	$f_{out}=1.5$ GHz $P_{in}=14$ W, $\eta=55\%$		
3. Switching and Limiting—estimated unit cost $10 to $50					
Microstate	MS-6009	$C(-50\ V)=0.9$ pF	$BV_R=1400$ V $R_s=1.7\Omega$		
Microwave Associates	MA4497	$C(-50\ V)=0.4$ pF	$BV_R=200$ V $R_S=1.5\Omega$ $P_d=7.5$ W		
Motorola	MV1892	$C(-50\ V)=2.5$ pF	$BV_R=700$ V $R_s=0.62\Omega$ $P_d=20$ W		
Sylvania	D-5025A	$C(-50\ V)=1$ pF	$BV_R=1000$ V $R_s=2\Omega$ $P_d=1.5$ W		
Varian	VSD-508BE	$C(-50\ V)=1.9$ pF	$BV_R=500$ V $R_s=0.7\Omega$ $P_d=5$ W		
4. Parametric Amplification—estimated unit cost $50 to $400					
Micro Optics	MO-101LS	$C(0\ V)=0.2-0.39$ pF	$BV_R=5.5$ V	$f_c(0\ V)=300$ GHz	
Microstate	MS4017	$C(0\ V)=0.2-0.5$ pF	$BV_R=4$ V	$f_c(-6\ V)-320$ GHz	
Microwave Associates	MA4039	$C(0\ V)=0.3=0.5$ pF	$BV_R=3$ V	$f_c=120$ GHz	
Texas Instruments	TIXV07	$C(0\ V)-0.3-0.6$ pF	$BV_R=6$ V	$f_c(-2\ V)=500$ GHz	

bility, and impedance or capacitance. From a set of manufacturer's curves, such as those shown in Fig. 3, the varactor performance at most power levels and frequencies can be predicted. Further, many manufacturers will test their products with respect to power at the customer's specified frequencies, if so desired.

Although published power data should be the principal selection criterion rather than specifying abrupt, linear-graded, or step-recovery junctions, some generalizations can be made about these varactor types. As far as efficiency is concerned, all are about the same with the step-recovery junction having an edge with respect to power. If linearity (constant efficiency with changing power input) is a concern, the step-recovery diode should be used as its average capacitance value changes less with power variations than other types. Of course, for large step multiplications without idlers, only step-recovery diodes should be used.

Gallium-arsenide varactors are not recommended for harmonic generation unless the frequency is too high for silicon or the power level is low and efficiency is the overriding consideration.

Where tuning range or bandwidth requirements are severe, careful attention must be paid to diode impedance. Filter techniques can be used for wideband design, using estimated or measured varactor impedance. Impedances can also be obtained by removing the varactor from an optimized narrow-band circuit and substituting a probe connected to impedance measuring equipment. Finally,

Table 3. Relative characteristics of varactor materials.

Material	Type	ADVANTAGES	DISADVANTAGES
GALLIUM-ARSENIDE	Diffused Epitaxial	High f_c for a given BV_R	Poor thermal resistance
		Excellent stability with temperature changes	Short minority carrier lifetime
		Very low noise and highly efficient, especially when cooled	Only low BV_R available (60 volts is maximum)
			Relatively expensive
	Point Contact	Very high f_c	Poor device uniformity
		Very low capacitance (0.1 pF)	Very low burnout rating
		Gives low noise figure in parametric amplifier	Low BV_R
			Expensive
	Schottky Barrier	Very high f_c (500 GHz)	Higher C_j than with point contact (0.3 pF)
		Higher burnout than point contact	Low BV_R (6 V)
		Gives low noise figure in parametric amplifier	Expensive at present
SILICON	Diffused	Very high BV_R	Low f_c
		Low thermal resistance	Poor control of diode capacitance
		Low cost	Without glass passivation, poor temp. stability
	Epitaxial Diffused	High f_c (200 GHz)	BV_R not as high as with diffused (150 V)
		With glass passivation, excellent temp. stability	Minimum capacitance only 0.4 pF
		Uniform characteristics	
		Retrograded junctions possible	
		Low thermal resistance	
		Low cost—high yield	
	Epitaxial Alloy	Capacitance law $=0.5$ pF	Low BV_R (110 V)
		Reasonably high f_c $(-4V)=150$ GHz	High capacitance
			Poorer uniformity than with diffused epitaxial
			Higher cost than diffused epitaxial
	Diffused Mesa	Very low capacitance devices possible (0.1 pF)	Poorer uniformity than epitaxial
		Higher BV_R possible than in epitaxial (200 V)	Without glass passivation, poor temp. characteristic
		Low cost	Lower f_c than with epitaxial devices

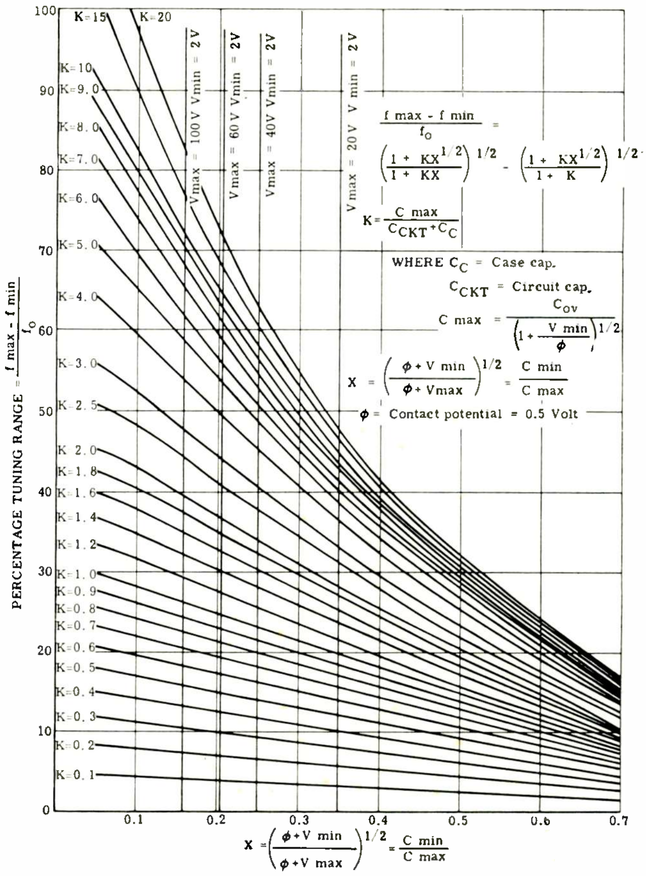


Fig. 2. Percentage resonant circuit tuning range.

when either wide tuning range or bandwidth is needed, the varactor self-resonant frequency:

$$f_{sr} = 1/[2\pi(L_s C_j)^{1/2}]$$

should be as high as possible, consistent with power needs.

Parametric Amplification

The parametric amplifier designer is primarily concerned with varactor "Q" or cut-off frequency and capacitance variation. The highest cut-off frequency and capacitance swing should be selected consistent with varactor cost. It is in this area that gallium-arsenide varactors are especially attractive.

When a wide bandwidth is required, it is helpful to have diode self-resonance at the idler frequency. This results in the lowest possible amount of energy storage in the idler circuit.

Other factors to be considered for parametric amplifier varactors are uniformity of product and temperature stability since the amplifier is often mounted on an antenna away from a completely sheltered housing. Both of these requirements tend to favor silicon-epitaxial devices.

Switching Applications

The switch or limiter designer is primarily concerned with diode capacitance, forward resistance, power dissipation, voltage breakdown, and inductance. The capacitance, C_j, and forward resistance, R_f, determine the ratio of isolation (I) to insertion loss (L).

$$I/L = 1/(\omega C_j R_f)$$

Power handling in the reverse direction is:

$$P_{max} = (BV_R)^2/8Z_o$$

where Z_o is the transmission line characteristic impedance. When a diode is operated at optimum impedance $Z_o = (BV_R)\sqrt{R_f/8P_{max}}$, it will reach the thermal limiting and breakdown at the same power level. Hence,

$$P_{max,\,opt} = (BV_R)\sqrt{P_{max,\,diss}/8R_f}$$

For most applications, the reactance of the lead inductance

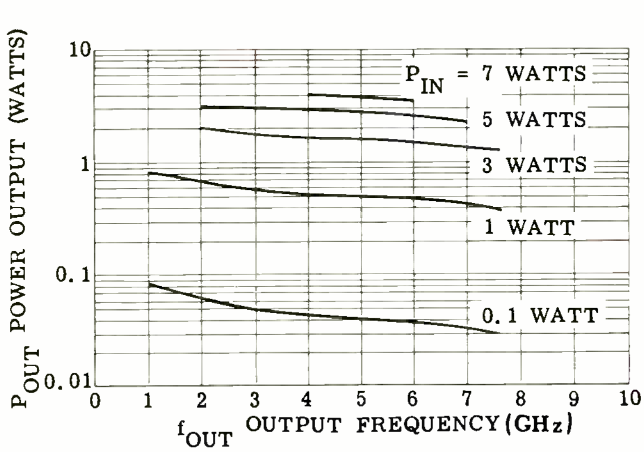


Fig. 3. Characteristics of 1N5155 varactor used as a tripler.

should be less than R_f. Where this is not possible, other modes of operation may have to be considered in which the conducting condition is with reverse bias, with the junction capacitance resonating the lead inductance of the diode.

Although some conventional, low-frequency diodes can be used for microwave switching, they generally have not been optimized for lowest package parasitics and the lowest series resistance consistent with junction capacitance. For best high-frequency switching performance, varactors such as *p-i-n* diodes should be used.

Phase Shifting

Varactor phase shifters operate by altering the velocity of propagation (v_p) of a transmission line or filter. The velocity of propagation is defined by $v_p = 1/\sqrt{LC}$ where L and C are the inductance and capacitance per unit length of the transmission line. In operation, varactors are placed periodically across the line so that a change in the applied bias changes C and therefore v_p. As a result, phase shift is controlled by the bias level.

Essentially the same considerations necessary for tuning applications apply to varactors used in phase shifters.

Pulse Shaping

Various types of varactors can be used to sharpen pulse rise times and clip overshoots. For example, a forward-biased step-recovery diode placed across a pulse generator in the reverse direction will short-circuit the generator until the pulse current removes all the charge stored by the forward bias. At the instant of charge depletion, the varactor impedance and the voltage across the varactor rise steeply. The resulting risetime is equal to the varactor transition time which can be made as low as 0.1 nonosecond.

Overshoot clipping is accomplished by varactors such as Schottky-barrier diodes that have low minority carrier lifetime and so store an almost negligible charge. For overshoot clipping, it is desirable that the diode impedance change almost instantaneously from low to high when the applied voltage changes from forward to reverse biasing. In Schottky-barrier diodes, the time for this change can be as short as 0.1 nanosecond.

Future Developments

Within the next few years, tuning diodes will exhibit a fair increase in f_c, a considerable increase in tuning ratio, and an appreciable lowering of price as high-volume applications increase in number. A doubling of f_c is possible for a given BV_R; however, manufacturing tolerances will probably limit this increase to 50 percent. Tuning ratio will increase by use of retrograded junctions, with diodes having $k=2$ or 3 becoming available. Finally, as use of electronic tuning spreads into high-volume commercial and military applications, the price of varactors will drop while reliability will increase.

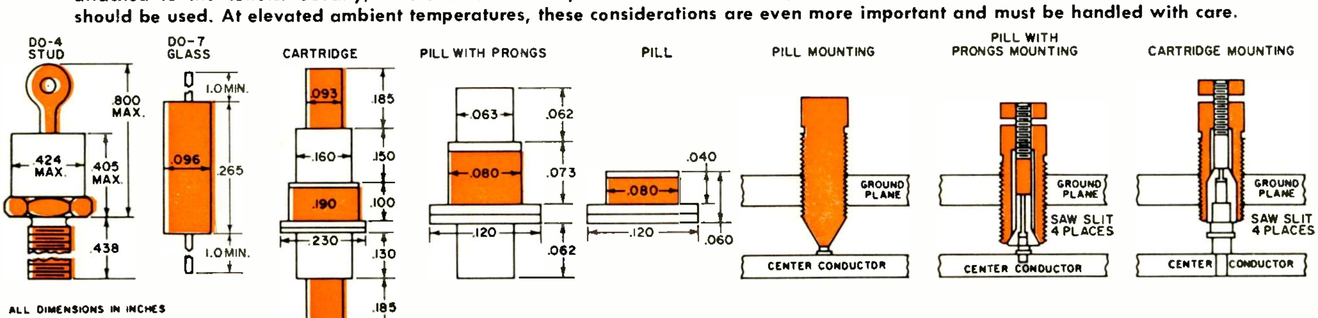
Progress in varactors for harmonic generation, will see power output increased by 3 dB at a given frequency, especially in the millimeter wave region; reliability will be substantially improved, and MIL-approved varactors will be available. However, the price for harmonic generator varactors will not drop significantly since there is little prospect of developing a high-volume demand for such units. With regard to power, it appears that varactors will always exceed conventional transistors by factors of 3 to 10 because varactors can make use of charge storage effects in the forward voltage region.

For parametric amplification, the most significant progress will be in lowering of millimeter frequency noise figures. In addition, bandwidth capabilities will be increased by development of low-parasitic packages. Other features will remain nearly the same, including price, since high-volume applications are not indicated.

Switches and limiters will see power and frequency boosts of 2 to 3 times and the availability of high-reliability MIL-Spec devices, along with a considerable reduction in price. High-volume applications, such as phased arrays and solid-state microwave communications systems, will trigger the price reduction.

Perhaps the most important developments will be the emergence of new varactor-like devices such as Gunn-effect devices, Read diodes, and silicon-avalanche diodes. The prime attraction in these devices is the direct conversion of d.c. to microwave energy. With such components, the practical solid-state klystron will be a reality—at least for local-oscillator applications. ▲

Table 4. Varactor package characteristics, along with suggested mountings for ceramic packages. Besides the ability to withstand shock and vibration, the most important mounting consideration is to provide an adequate heat sink. Holding collets (mountings) for the ceramic packages are made out of brass and grip tightly to the pedestal side of the varactor package. Contact is made to the top-cap side when the collet is screwed into its mount. Where additional heat sinking is needed, fins can be attached to the collets. Usually, where varactor dissipation exceeds 5 watts, an external heat sink of fins or a metal block should be used. At elevated ambient temperatures, these considerations are even more important and must be handled with care.



Package	Size	Relative Cost of Package	Typical Lead Inductance	Typical Case Capacitance	Ruggedness	Type of Circuit Most Likely Used	Mounting	Thermal Properties
DO-4 Stud	Large	High	4 nH	0.5 pF	Limited	Lumped	Very easy	Excellent
DO-7 Glass	Small	Low	5 nH	0.2 pF	Strong	Lumped, Stripline	Very easy	Poor
Cartridge	Large	High	1.5 nH	0.5 pF	Strong	Coaxial, Waveguide	Easy	Excellent
Pill with Prong	Small	High	0.5 nH	0.3 pF	Strong	Coaxial, Waveguide	Fairly easy	Good
Pill	Small	High	0.5 nH	0.3 pF	Strong	Stripline, Waveguide	Difficult	Fair

The author received his B.S. (E.E.) from Northeastern University in 1949 and his M.S. (E.E.) from the University of New Hampshire in 1950. He joined Sylvania in 1950 at the Engineering Test Laboratory in Boston where he worked on the evolution and development of microwave diode test equipment. He transferred to the Semiconductor Applications Group in 1952 and, in 1954, became a member of the Microwave Diode Development Group. He was made Section Head of Microwave Diode Development and Production in 1956 and is presently Manager of the Microwave Diode Dept. He is a Senior Member of IEEE, a Reg. Prof. Engr. (Mass.), and chairman of EIA's U.H.F. and Microwave Diode Committee.

Mixer and Detector Diodes

By EUGENE J. FELDMAN
Manager, Microwave Diodes, Sylvania Electric Products

Recent and significant developments have occurred mainly in the u.h.f. and microwave regions where smaller junction capacitances and lower noise figures are very important.

APPLICATIONS of mixer and detector diodes can be separated into two frequency areas—below u.h.f. and above. For selected frequencies below u.h.f., various point-contact germanium diodes (such as 1N34A's) and selected low-capacitance computer diodes are used for detecting and mixing applications. While both areas are important, it is primarily in the u.h.f. region (450-900 MHz) and above where more recent and significant developments have occurred.

Unlike lower frequency "signal" diodes, u.h.f. mixer diodes have smaller junction capacitance and are characterized by a noise-figure measurement. Production units are of the point-contact (silicon and germanium) design; silicon devices (1N82A types) are currently in highest production. Newer potential u.h.f. mixer diodes are Schottky-barrier designs made of silicon. Such diodes are presently under evaluation by television u.h.f. tuner manufacturers.

U.h.f. frequency detection or demodulation is normally performed with a point-contact type detector diode. This diode is also of small junction capacitance and would be characterized for rectification efficiency at a given frequency. Rectification efficiency is defined as the ratio (in percent) of d.c. output voltage to peak a.c. input voltage. A figure greater than 65 percent is typical.

Structures Employed

Above the u.h.f. band, there are thousands of diodes typed for use in microwave frequency applications from about 1000 MHz to 100 GHz. Point-contact types predominate and, in time, will be followed and replaced in many applications by Schottky-barrier devices and back diodes. All three diode types are used for mixing and detecting. Fig. 1 shows the construction and *V-I* characteristics of point-contact, Schottky-barrier, and back diodes. Each has a metal semiconductor rectifying "barrier," the first created by a metal whisker wire pressure contact, the second formed by an evaporated metal contact, and the last by an alloyed junction.

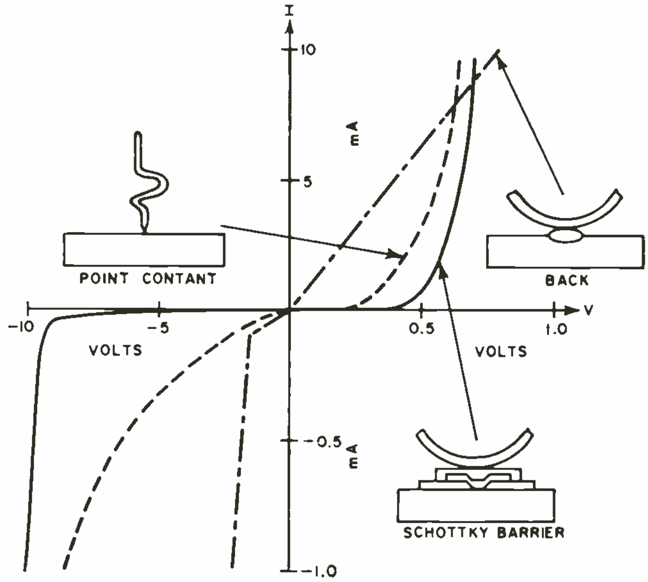
At these high frequencies package parasitics, such as capacitance and inductance, can play an important role in the diode circuit operation. It is necessary for these parasitics to be low, and the actual package shape is designed to be part of the transmission line—waveguide, coaxial line, or stripline.

Point-contact structures are the oldest; the earliest (1N21) of which dates back to 1942 for S-band applications. Metal-semiconductor rectification has been reported as early as 1907, using carborundum as the semiconductor material. Modern-day diodes almost universally employ tungsten as the wire material (for hardness and spring action), sharply pointed with a pressure contact against silicon. There also are phosphor-bronze and titanium wires used with germanium devices.

Instead of the barrier being formed by a metal wire pressure contact, the Schottky-barrier diode has its barrier formed by a metal interface which has been evaporated or sputtered on the semiconductor surface. Such a device has a more theoretically perfect or ideal metal-semiconductor interface and is hence referred to as the truer Schottky-barrier. This diode, like the point-contact, is a majority carrier device unlike *p-n* junction diodes. When forward-biased, the majority carriers are injected into the metal from the semiconductor and, because practically no minority carriers flow, the higher frequency use is not restricted and the diode should have less rectification noise. There are no registered (EIA) Schottky-barrier types at this writing.

While the tunnel diode with its negative resistance advantage is familiar to most designers, the back-diode version is of some importance in mixing and detecting microwave frequencies. This device, which is fabricated from an alloyed metal with semiconductor, is a tunnel diode whose forward biased negative resistance region is minimized. It is then used in the back direction. In other words, the normal tunnel diode reverse characteristic is used as the forward, having as its advantage the sharp current rise from

Fig. 1. Point-contact, Schottky-barrier, back diode curves.



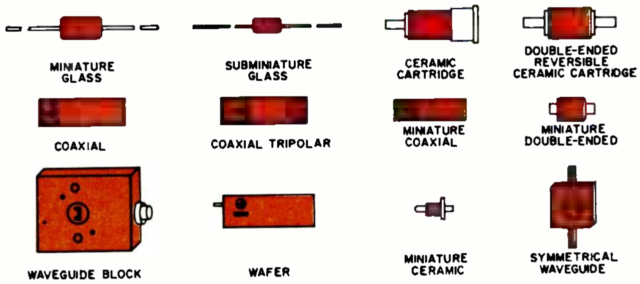


Fig. 2. Various mechanical configurations for microwave diodes.

BAND	TEST FREQ. (MHz)	PACKAGE	MAJOR SERIES
U.H.F.	450-890	Glass	1N82
L	1000	Ceramic	1N25
S	3060	Ceramic	1N21
X	9375	Ceramic	1N23
K_u	16,000	Coaxial	1N78
K	23,984	Coaxial	1N26
K_a	34,860	Min. Coax.	1N53
W	69,750	Waveguide	1N2792

Table 1. Mixer diode types and the major frequency bands.

BAND	TEST FREQ. (MHz)	MAJOR SERIES	PACKAGE
V.H.F./U.H.F.	100	1N830	Glass
L-X	1000	1N358	Tripolar
S	3060	1N32	Ceramic
X	9375	1N1611	Coaxial
K_u-K	10k-21k	1N2926	Coaxial
K_a	26k-40k	1N446	Min. Coax.

Table 2. Detector diode types and major frequency bands.

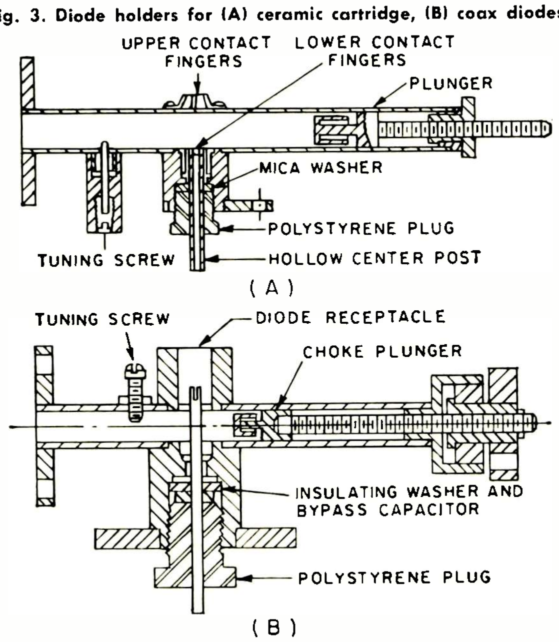
FREQUENCY (MHz)	TYPE
1000	1N25
3000	1N3655
9375	1N3747
16,000	Non-EIA

Table 3. Commonly used high burnout mixer diode types.

SHOCK	1500 G, 0.5 ms
VIBRATION	15 G, 100 to 2000 Hz
ACCELERATION	20,000 G
TEMPERATURE CYCLING	−65°C to +150°C
MOISTURE RESISTANCE	90-98% relative humidity Cycled 25° to 65°C (10 days)

Table 4. Typical levels of environmental performance are shown.

Fig. 3. Diode holders for (A) ceramic cartridge, (B) coax diodes.



extremely low voltage levels at the origin. Because of the extremely low resistivity of the semiconductor (which is generally germanium) material that is employed, the $1/f$ noise is low when the diode is used as a mixer and, because of the sharp current rise at the origin, it makes a good low-level video detector.

Frequency Bands

The frequency spectrum is classified into major bands and usually a certain diode family is specified. Table 1 shows the major frequency bands (and test frequencies) for mixer diodes used in the u.h.f. range and above.

Table 2 gives a breakdown of the important detector diodes, including operating frequency and package types. The package configurations that were illustrated in Fig. 2 also apply to detector diodes as well.

Materials and Packages

The major material in use today for mixer diodes is silicon. This is true for point-contact types, of which there are now hundreds of types, as well as the new Schottky-barrier devices for S- and X-bands. Silicon devices have also provided the lowest noise figures across the microwave frequency spectrum.

Detector diodes have been fabricated only from silicon, at least for commercial devices. Until recently back diodes fabricated from germanium as alloyed junctions show some distinct advantages for low-level detection. Tangential signal sensitivity is just slightly poorer at the higher microwave frequencies than the best silicon devices but they have a low video resistance (below 1000 ohms) for good pulsed signal fidelity.

Gallium-arsenide is just being introduced into commercial devices and is used primarily in millimeter-wave experimental mixers. Some major development is being done with gallium-arsenide Schottky-barrier diodes for mixing above the X-band.

Most silicon devices are rated to 150°C but many can be operated or stored up to 250°C, provided there is no package processing limitation to temperature. The germanium devices are generally limited to 100°C for operation or storage.

A fairly complete grouping of packages is shown in Fig. 2. Materials used for the packages are generally brass and nickel, with ceramics and glass used for insulators.

The only package design that can be characterized by impedance is the coaxial structure. Both the standard and smaller counterparts have a geometric impedance of 65 ohms. The diode junction impedance is designed to match this 65-ohm transmission line so that there will be little, if any, reflection and the signal power can be converted to useful i.f. or detected power. The measurement of v.s.w.r. is a measure of how well the junction "matches" the transmission-line impedance. Typical mounting structures for the diode packages are shown in Fig. 3.

Selecting Mixer Diodes

Noise Figure versus Cost: For normal application of mixer diodes, local oscillator power availability is 1-2 mW, signal power desired is on the order of −104 dBm, and the i.f. is 30 to 60 MHz. Diodes can be selected for the frequency range from 1 GHz through 35 GHz and 69 GHz from manufacturers' data sheets. The manufacturer specifies noise figure and, from the formula $S=K{\cdot}B{\cdot}NF$, where S is sensitivity in −dBm, K is a constant, B is receiver bandwidth, and NF is the noise figure, the designer can determine the required noise figure.

For most diodes, one will find a varied noise figure availability by suffix letter and cost decreasing as noise figure increases. As an example, at X-band the 1N23 series has enjoyed the most use. Listed in the manufacturer's literature are the 1N23, 1N23A, 1N23B, 1N23C, 1N23D, 1N23E, 1N23F, and 1N23G. The 1N23, A and B, are now relatively obsolete, but the 1N23C with a maximum noise figure of 9.5 dB sells for about $1.00; while the 1N23F with a maximum noise figure of 7.0 dB sells for about $7.00 from distributors. Table 5 summarizes the major differences between the 1N23C and 1N23F specifications.

	NF (Max.) dB	L_c (Max.) dB	NR_o (Max.)	Z_{IF} (Ω) Min.	Z_{IF} (Ω) Max.	V.S.W.R. (Max.)	Burnout Ergs
1N23C	(9.5)*	6.0	2.0	325	475	1.5	1.0
1N23F	7.0	—	—	335	465	1.3	2.0

*Unspecified, but comparative figure.

Table 5. Comparison between 1N23C and 1N23F specifications.

TYPE	FREQ. COVERAGE (MHz)	TEST FREQ. (MHz)
1N21F	400-4000	3060
1N831A	400-4000	3060
1N1132	3000-12,400*	Same
1N23F	4000-9500	9375
1N832A	4000-12,400	9375
1N4605	12,400-18,000*	Same
1N78F	15,000-17,000	16,000
1N26B	20,000-24,000	23,984
1N53B	24,000-36,000	34,860

*Untuned

Table 6. Popular mixer diode types and test frequencies.

Frequency Coverage: Where only one test frequency is specified, the diode is probably a fairly narrow-band device. Broadband devices usually are specified with controlled r.f. impedance (in terms of v.s.w.r. in a given holder) across a certain frequency band. Good examples of such types are the 1N1132 that can operate from 3 GHz to 12.4 GHz and the 1N4605 which is operable from 12.4 to 18 GHz. Optimum performance can be obtained when the diode is used in a carefully matched holder at or near the center band. High-frequency diodes generally can be utilized in lower frequency circuits with little degradation, if matched well into the circuit.

Table 6 indicates frequency capabilities of popular types, along with test frequencies.

Package Choice: For a strip transmission circuit, the miniature glass pigtailed 1N831 and 1N832 (for S- and X-bands respectively) generally suffice for series mounting (there are also even smaller glass types available). These miniature types offer substantial frequency bandwidths of operation; at least an octave band, and up to two octaves.

When coaxial line is the choice (below X-band) of circuitry, the standard double-ended cartridge types of 1N21 and 1N23 series, as well as the miniature types, are available. For waveguide, the field is again wide open with the addition of the coaxial diode. Although a waveguide-to-coaxial line transition must be designed for this diode, bandwidth is excellent and a large variety of types is available, especially for applications above X-band frequencies. The coaxial diode does not have the inherent large bandwidth capability of the miniature devices, but has an advantage in a specified r.f. impedance design of 65 ohms. For such units, the designer can make up a holder without ever measuring groups of diodes; he simply designs to match a "dummy" 65-ohm load.

Matched Pairs: Mixer diodes are supplied as matched pairs, either as two forward polarity or one each forward and reverse polarity. A matched pair is used to suppress local oscillator noise and to isolate the antenna terminal from the local oscillator terminal.

The EIA has adopted the following matching criteria: Conversion loss—within 0.3 dB of each other; i.f. impedance—within 25 ohms of each other; and v.s.w.r. maximum—1.6. The v.s.w.r. requirement is for the isolation problem. Generally speaking, premium noise figure diodes up to X-band can be matched randomly by the user. This is true because of the uniformity achieved by manufacturers in producing these types. Such types do not have a v.s.w.r. greater than 1.3 as single units.

Schottky or Back Mixer Diodes: At this writing commercially available Schottky-barrier and back diodes are being sold for mixer use up to X-band. The prime advantage of the back diode is its very low low-frequency noise, probably the lowest of any diode. This makes it an ideal Doppler diode. Because of fabrication problems, its frequency response is limited. Other disadvantages of the back diode are lower operating dynamic range, lower temperature capability, and lower breakdown voltage. Burnout resistance, as compared to point-contacts, is unknown at this time.

DEVICE PARAMETERS

For EIA or military specified type numbers, manufacturers must adhere to electrical and mechanical standardization. For "house number" diodes, measurements and test procedures may vary slightly among manufacturers in certain respects, but they almost always follow a basic method with test holder, power input, and load impedances specified.

Mixer Diodes

Noise Figure (NF_O): Noise figure is defined as the ratio of the r.m.s. output noise power of the receiver to that of a hypothetical receiver of the same gain and bandwidth, whose input noise power is equal to the thermal agitation noise power developed across its input impedance. As standard practice, the mixer diode is impedance-matched to both the signal and image frequencies.

The measurement of noise figure of the mixer diode is dependent upon the diode/holder impedance condition for both the r.f. input case and i.f. output case. Any power loss by reflections is included in the measurements. The holders themselves, for the major frequency bands, are individually specified on drawings available from the Armed Services Electro Standards Agency.

The noise figure can be compared to the receiver sensitivity. The sensitivity is the minimum power that can be detected by the receiver. It is generally defined as **minimum detectable signal** or as **tangential signal sensitivity.** The latter is 4 dB worse than the former. The direct relationship between noise figure **(NF)** and minimum detectable signal **(S_i)** is: $S_i = K\Delta f\ NF$, where **K** is a constant and Δf is receiver bandwidth.

Conversion Loss (L_c): This is the diode loss in converting the r.f. power to the i.f. power. This measurement is made in a fixed-tuned holder and any reflection losses are included. Typical losses are 4 to 6 dB.

Noise Ratio (NR_O): Noise ratio is the ratio of the noise power developed by the diode to the thermal noise of an equivalent resistor at a given temperature. The measured noise includes thermal, rectification (barrier), and fluctuation noise. The latter diode noise increases as an inverse function of the i.f. and is very important for Doppler type radar equipment.

I.F. Impedance ($Z_{I.F.}$): The i.f. impedance of a mixer diode is the impedance of the diode including its holder as seen from the output terminals. Typical values are 100 to 600 ohms.

R.F. Impedance (v.s.w.r.): This parameter is the impedance looking into the r.f. terminals of the mixer at the local-oscillator frequency and power level. It is almost always measured in terms of v.s.w.r. in the transmission line. It is a function of both holder and diode impedance combination at the given frequency and power level. Newest specifications limit this v.s.w.r. to 1.3.

Detector Diodes

Video Resistance (R_V): The operating level of the detector is from hundredths of a microwatt to a nanowatt. The low-level impedance of the diode or "video resistance" is the reciprocal of the slope of the current-voltage characteristic at the operating point. The **RC** time constant formed by this value plus the holder, cable, and input capacitance, may cause poor pulse response if it is too high.

Current Sensitivity (β): Sometimes called out in individual specification, this parameter is the current developed through a short-circuit load for an input power of 5 μW or less.

Figure of Merit (FM): This parameter is originally developed from the signal-to-noise equation. It is given by $M = \beta R / (\sqrt{R + R_a})$ where β is the current sensitivity, **R** is the video resistance, and R_a is the equivalent noise resistance of the video amplifier input.

Tangential Signal Sensitivity (TSS): This parameter is the amount of signal power, below a one milliwatt reference level, required to produce an output pulse whose amplitude is sufficient to raise the noise fluctuation by an amount equal to the average noise level. Tangential signal sensitivity is approximately 4 dB above the minimum detectable signal (MDS) on an "A" scope presentation.

Burnout and Environment

Burnout refers to any changes in diode characteristics caused by stray power at the diode terminals. This power may be in the form of narrow spike energy leakage from protective circuits in front of the diodes (such as TR tubes). The spike time is on the order of a few nanoseconds which is below the thermal relaxation time of most diodes, hence, the energy content rather than power is important. Most mixer diodes are 100 percent subjected to at least one spike of a given energy rating to serve as a type of screening. See Table 3.

Other than microwave frequency burnout, diodes can be damaged by excessive d.c. voltage or current. Some mixer diodes are rated for reverse breakdown voltage and forward current maxima.

In general, the same considerations apply to detector diodes. However, the most sensitive detector diodes are less rugged than mixer diodes in a mechanical environment. Typical levels of environmental performance are given in Table 4.

Military vs "Commercial" Specs

Because over 90 percent of microwave mixer diodes are used in military systems, there is essentially no difference between military and so-called commercial specifications. At this writing there are only 15 JAN types specified, less than 100 EIA registered types, and thousands of "house number" types. About the only difference between the JAN type specification and the commercial one is in sampling plans for environmental testing. For the most part these are also identical.

There are special high-reliability specifications for non-JAN diodes which are far more complex, especially for environmental performance. Specs with various screening procedures are available, particularly for diodes used in missiles and satellites.

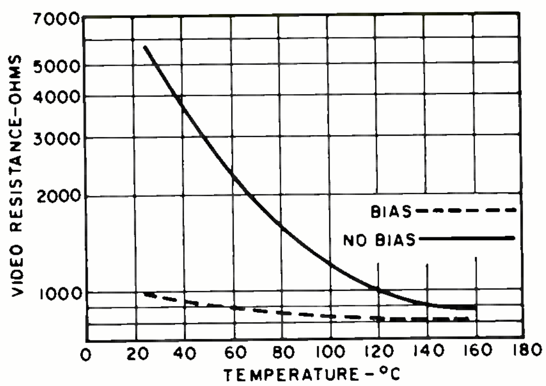


Fig. 4. High-temperature characteristics of 1N630 diodes.

Schottky-barrier diodes are made with significantly higher breakdown (15 volts) voltage than point-contacts (5 to 6 volts). This provides an increased dynamic range with less distortion. The rectification noise is lower than point-contacts with unity noise ratios and, hence, potentially lower over-all noise figure. Table 7 compares the two new diode types with the point-contact.

Selecting Detector Diodes

Of prime importance to the microwave circuit designer is either sensitivity in terms of tangential signal or actual voltage output across a load resistance.

The outstanding advantage of the back diode for video detection (below X-band at present) is its low r.f. impedance as well as its low i.f. impedance, hence a small *RC* time constant is achieved for good pulse fidelity. Output voltage is low—less than 0.1 volt. These diodes should operate into low-impedance transistorized amplifiers for best results. Most commercial devices should not be operated above 100°C.

The Schottky-barrier devices can operate efficiently as detectors if sufficient bias current is used. For low video bandwidth systems, their inherently lower flicker noise is advantageous. Point-contact types, of course, are used universally and probably will be the best choice at frequencies above the X-band for some time to come.

The impedance of a diode increases as the temperature is lowered and at values below 0°C pulse fidelity may be seriously impaired. High temperatures have little detrimental effect. To counteract the effect of low temperatures, a small forward bias current may be employed. Such a bias will lower the video impedance and lessen the effect of temperature variations upon the diode, as shown in Fig. 4. The back diode, because it is fabricated from very low resistivity semiconductor material, has a low video impedance advantage.

Cost Differences: Diodes with the highest sensitivity, of course, are highest in cost. The tangential signal sensitivity (rather than noise figure) will be graded by suffix letter. The sensitivity improves as the alphabet suffix letter advances.

Packaging: Both mixers and detectors utilize the same type of packaging. The tripolar diode package has an output terminal for i.f. frequency, while the detector utilizes this terminal for the detected signal. The "built-in" capacitor makes the holder r.f. choke and capacitor unnecessary, greatly simplifying holder design in general, but very much so for broadband requirements. The 1N358 diode, for example, covers a specified frequency range from 1 GHz to 12.4 GHz, but has been found to have satisfactory performance (in terms of TSS) from 500 MHz to 20 GHz. Degradation from specification is only 1 to 2 dB.

The Future

We can look forward to mixer diodes with noise figures below 4.5 dB up to frequencies of about 4 GHz for both point-contact types and Schottky-barrier diodes. At X-band, below 5 dB should be attainable, with 7.5 dB up to K_a-band. Temperature capabilities for many types should reach 250°C which is well above system requirements for several years to come.

In the new diode category, watch for the introduction of gallium-arsenide mixer diodes on a commercial basis for the higher microwave frequencies, including millimeter wavelengths. Eventually, we will see a completely integrated microwave "front-end" which would be a solid-state diode local oscillator, mixer diode balanced pair, d.c. load circuit, and microminiature i.f. amplifier.

Improvements in low-level video detectors will probably be along the lines of carefully controlled back diodes with resultant tangential signal sensitivities on the order of −65 dBm for narrow pulse widths. This value should be attainable at least to X-band and for 10 MHz video bandwidth. We should also expect such devices to be operable to 150°C.

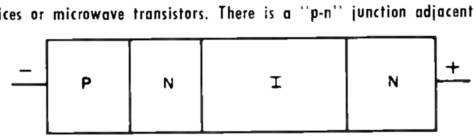
Basic technology advancements, along with new fabrication procedures and techniques, presages a new era of reliability. Elaborate screening procedures for such programs, going beyond the built-in quality, assure the ultimate in a truly reliable product. ▲

Table 7. Characteristics of Schottky-barrier and back diodes are compared with point-contact types.

TYPE	BV	BURNOUT	NF	1/f NOISE	REPRODUCIBILITY	DYNAMIC RANGE	GENERAL RELIABILITY	OPERATIONAL TEMP.
Point-Contact	Low	Fair	Excellent	Poor	Fair	Low	Good	Excellent
Schottky-Barrier	Higher	Potentially better	Potentially better	Lower	Potentially better	Higher	Potentially better	Potentially higher
Back	Lower	Unknown	N.A.	Lowest	Equal	Lower	Equal or better	Lower

MICROWAVE READ-TYPE AND OTHER OSCILLATOR DIODES

THE diagram shows the proposed Read diode which can generate microwave c.w. power far in excess of tunnel-diode oscillators and at higher frequencies than Gunn devices or microwave transistors. There is a "p-n" junction adjacent to a very



low conductivity or "intrinsic" "i" region, which is itself adjacent to another "n" region. When a voltage is applied in the "negative" direction and is increased beyond the small leakage current region, the carrier velocity increases and ionization takes place causing a cumulative or avalanche effect. The reverse current increases very sharply and must be limited by a series resistor in this breakdown voltage region. As the carriers "transit," they drift through the intrinsic region. The current-voltage phase relationship results in negative resistance for the proper transit time. The frequency of oscillation caused by the negative resistance is determined by the transit and avalanche times. The true Read structure is extremely difficult to fabricate.

The more conventional "p-n" junction diode exhibits a negative resistance in avalanche breakdown. The frequency of oscillation is determined by the transit time of carriers through the depletion layer of the space charge region. Such "p-n" junction oscillations (pulsed and c.w.) have been observed from 1 GHz to 50 GHz in silicon and gallium-arsenide diodes. Silicon diodes have been reported to develop c.w. output power of 13 mW at 10.5 GHz and gallium-arsenide devices of 25 mW c.w. at 17 GHz. The d.c. input power-to-output microwave power efficiencies run to 5 percent, which is superior to klystron tube-power supply combinations. The frequency of "p-n" junction oscillators can be controlled both electronically and mechanically.

Measurements of power output can be made with the diode mounted in a simple X-band waveguide detector mount and tuned by means of short circuit plunger and slide screw tuner. Care must be taken, however, to isolate the different frequencies of oscillation. This can be done by suitable filtering and power substitution methods.

One application of these new devices is expected to be as a high-frequency local oscillator, since only a few milliwatts of power are required. Noise sideband measurements show substantially more noise than a conventional reflex klystron, but this situation should improve as more knowledge is gained. It is also expected that with properly balanced mixer diode pairs, noise should be virtually eliminated.

Television pictures have been sent over a microwave beam that had as its power generator a gallium-arsenide microwave oscillating diode.

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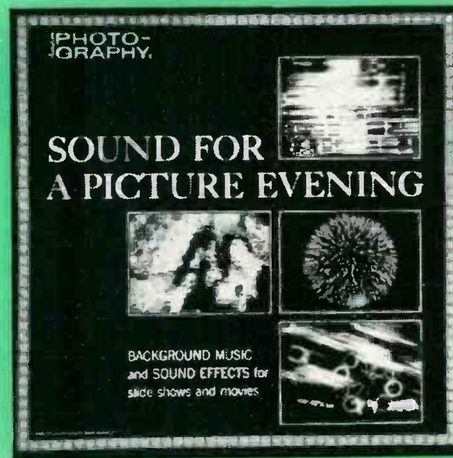

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JOHN FRYE

In the past twenty years, the kit business has grown into a major industry with very bright prospects for the future.

ELECTRONIC KITS

BARNEY dropped his alignment tool under the service bench and smothered a huge yawn as he stooped to pick it up. "If sound from this set I'm working on is keeping you awake, I can turn down the volume," Mac, his boss, suggested sarcastically. "You were, maybe, spooning under the June moon too late last night?"

"Nope, I was home assembling my new 'Heathkit' SB-100 transceiver. When I get started on one of those darned kits, I can't seem to quit. It was one-thirty this morning when I finally yanked the pencil iron and swept up the clipped resistor leads."

"I know," Mac agreed. "An unfinished kit is harder to let alone than a bowl of salted peanuts. You ought to be pretty good at putting amateur kits together."

"If practice makes perfect I should be. I put together the Mohawk receiver, the SB-10 SSB exciter, and the DX-100 as well as the Apache and Marauder transmitters before tackling this SB-100 SSB transceiver. It's fascinating to observe how ham kits—or all kits, for that matter—and assembly manuals have improved since I started 'kitting.'"

"How do you mean?"

"Take manuals, for instance. The DX-100 manual had 68 pages that told you how to put the kit together and tune the transmitter, but that was about all. The SB-100 manual has 149 pages and is far more than a profusely illustrated assembly guide. For example, it has *six pages* of preliminary checks and resistance measurements to be made on the completed transceiver before power is ever applied to it. The function of every circuit is explained. Operating instructions for every set of conditions are given. Finally, there is a complete trouble-shooting section. In short, it is a theory, assembly, operating, and service manual all rolled into one."

Early History

"I was acquainted with the man who started the *Heath Company* in the electronic kit business," Mac offered.

"After the war I bought my first 'Heathkit,' a scope, and put it together. I had some trouble getting the spot as small and round as I desired because of stray magnetic fields, and I cured this by putting a war-surplus Mumetal shield over the cathode-ray tube. I wrote *Heath* about this and started a correspondence between Howard Anthony, the president, and myself. When he invited me up to Benton Harbor to see his plant, I accepted and had a most enjoyable visit with him.

"Originally the *Heath Company* actually marketed an airplane—the famous *Heath* 'Parasol'—in kit form. The founder, Edward Bayward Heath, was killed in a test flight in 1931. Howard Anthony purchased the company in 1935.

During the war they were engaged in building some electronic gear for the government but could not buy the test equipment they needed because of insufficient priority; so they simply started building their own test instruments. Howard told me this proved to be so interesting that after the war he designed a 5-inch scope kit around a surplus scope transformer he had in quantity and took a small ad in RADIO NEWS, now called ELECTRONICS WORLD. The response was most gratifying, and the *Heath Company* was off and running in a new direction.

Howard Anthony was killed in an airplane accident in 1954. *Daystrom* bought the company and then sold it to *Schlumberger Limited* in 1962.

"The first 'Heathkits' were service instruments—scopes, v.t.v.m.'s, v.o.m.'s, etc.—designed to be assembled by experienced technicians who needed little more than a diagram and a picture or two in the way of instructions. This continued to be true when *Heath* came out with kits for radio amateurs. Most hams at that time were experienced in construction because a large percentage of their stations were 'home-brew.'

New Trends

"But gradually two divergent trends have developed in electronic kits: 'kitted' devices are becoming more and more complicated and sophisticated; yet people buying them know less and less about electronics. Musicians are building electronic organs; housewives are assembling hi-fi amplifiers; high-school boys are building laboratory-type scopes; 'plug-in appliance' hams are tackling complicated SSB equipment; and Sunday sailors are building marine telephone, direction-finding, and depth-sounding equipment for their boats.

"This provides a real challenge to kit engineers and persons preparing the manuals. Designing a complicated instrument so that it can be easily assembled by a person who knows nothing about mechanics or electronics and must be told how to make a decent soldered connection before he starts is no snap."

"Use of printed circuits and pre-assembled and aligned critical components has helped," Barney suggested. "For example, in the SB-100, the linear master oscillator that controls the frequency in both the transmitting and receiving modes comes pre-assembled and sealed. The same goes for the crystal filter. Practically all wiring is on printed-circuit boards, and that means distributed capacitances so important in high-frequency work, are carefully controlled and independent of the builder's wiring."

"Pre-assembled and aligned units raise the cost considerably," Mac pointed out, "but through their use any kind of electronic device can be offered in kit form—everything from color-TV sets and videotape recorders to TV cameras and electronic computers."

"My friend Jerry, who is an EE student at Purdue, recently did a term paper on the kit business, and he let me read some of the background information he collected," Barney said. "It was most interesting. The *Eico Electronic Instrument Company* is another big name and pioneer in the electronic kit industry, and this company started when Harry R. Ashley, the founder and president, quit his radio servicing and insurance selling back in 1945 and brought out a v.t.v.m. in kit form. Since that time 3,000,000 *Eico* kits have been sold. Unlike *Heath*, who sells kits directly from the factory, from seven domestic Electronic Centers, or from several foreign branch plants, *Eico* markets its 250 products through independent electronic distributors—some 2500 of them. *Eico* kits cover a wide range of service instruments, hi-fi equipment, amateur and CB equipment, and industrial electronic equipment."

"You don't need to tell me about *Eico* equipment," Mac interrupted. "I've always admired the good shielding and excellent tracking adjustments on their Model 324 r.f. signal generator. How about 'Knight-Kits'? Did Jerry have any dope on those?"

"You bet. 'Knight-Kits,' of course, are a product of *Allied Radio Corporation* of Chicago. You might say 'Knight' is a real patriarch in the electronic kit business. *Allied* first offered electronic kits in the 1920's, although they were not called 'Knight-Kits' then. Early *Allied* catalogues offered a choice of a 3-tube Cockaday kit, a 5-tube Neutrodyne kit, or a 5-tube radio-frequency kit. All were broadcast receivers using 201-A tubes and batteries. The 'Knight-Kit' name was first used in the early 1930's, and one of the first kits offered was the '2-Tube DX-er Shortwave Radio Kit' with these prices: All Parts with Wiring Diagram, \$5.15; 4 Plug-in Coils, \$1.58; Tube and Battery Kit, \$2.80; Brandes Phone, \$1.65."

"Stop! I can't stand the nostalgia!" Mac interrupted.

"I have a 'Knight' s.w.r. meter," Barney said, "and my experience with it underscores an important point. Fair results can be obtained from almost any kit with minimum effort, but quite often outstanding performance can be obtained through careful assembly and precise calibration. I took great pains putting that s.w.r. meter together and then spent a half-day calibrating it; but I was finally able to make it read right along with a directional wattmeter costing six times as much on five different bands. Anyway, 'Knight' offers about 100 kits that include everything from a crystal receiver to a laboratory scope. 'Knight' also has service instruments, ham and Citizens Band equipment, hi-fi units, and even an exposure meter in kit form.

"The *Conar Instruments Company* of Washington, D. C. is a comparative latecomer to the kit business, since it first offered kits in 1962; yet it is not new in the electronics field. You see, *Conar* is an expansion of the *National Radio Institute*'s student supply division that functioned primarily to supply test equipment to *NRI* students and graduates. In fact, the name 'Conar' is rather torturously derived from the first letters of 'COmpany, NAtional Radio.' *Conar* was thus able to enter the market with a complete series of radio-TV test-equipment kits of proven design developed by *NRI's* technical staff. Presently, *Conar* offers about twenty different kits with more in the developmental stage. Some are rather unusual and exotic, such as their Model 800 closed-circuit TV camera kit that can be used with any TV set as a monitor and their metal locator kit that should go big with treasure hunters."

"There are many more electronic kits on the market these days," Mac said. "The success of these large companies has caused many concerns to bring out one or more of their products in kit form. Some do well; others do not. After all, I suspect there are a lot of headaches in the kit business. Do the large kit manufacturers seem to agree on many points?"

"Yes. All agree that when an instrument is offered in both kit and wired form, the kit far outsells the assembled unit. They agree aesthetic considerations are increasingly important in kit design. Not only must the completed unit work well, but it must also have an attractive appearance. The old, overgrown, boxy look is 'out'; the new, compact, stylishly-shaped-and-colored look is 'in.' All kit manufacturers stress the importance of giving prompt and helpful assistance to a purchaser who has trouble with a kit. All maintain service facilities for straightening out the difficulty if it cannot be handled through correspondence. All agree engineering a kit is much more difficult than engineering an instrument for assembly by skilled workers in a factory where progress is constantly being inspected. Finally, all were unanimous in foreseeing a bright future for the kit business."

"I can't argue with that last," Mac said. "Good incomes, increased leisure, and increasing interest in electronics all point toward a healthy growth of the kit business. Americans are natural-born do-it-yourselfers, anyway; and kits are to electronic design what numbered painting is to art. In neither case is there true creativity, but there is still room for a lot of personal satisfaction and pride in the finished products."

"It seems to me," Barney said slowly, "that kits have performed at least two major services for the electronics field. In the first place, they brought down the prices of formerly expensive laboratory instruments, such as the v.t.v.m., scope, sweep generator, and 'Q' meter, to where every service technician could afford them and learn to use them. Secondly, they have aroused an interest in electronics in many people working in unrelated fields. Photographers, musicians, and boat owners have assembled simple electronic instruments for use in their own hobbies and have ended up with electronics as a second hobby."

"That's right," Mac agreed. "And that probably helps explain why weak little 'kits' have grown into roaring tigers in only two short decades." ▲

Insulated Gate Transistor

(Continued from page 36)

The IGT may be used for extremely sensitive ammeters and for high-impedance electronic voltmeters. Fig. 4 shows an electronic ammeter with a full-scale sensitivity of 1 picoampere (10^{-12} ampere). The current drawn at the input produces a voltage drop across the biasing resistor which, in turn, shifts the operating point of the left IGT. This is differentially compared to a second IGT matched to the first. The resulting current unbalance is then monitored on an ordinary sensitive 0-10 d.c. microammeter. The input biasing resistor determines the full-scale sensitivity. The values shown produce a range of meter sensitivities from 0-1 picoampere to 0-1 μA.

IGT voltmeters work in the same manner as vacuum-tube voltmeters except they need not be connected to the nearest a.c. socket and will easily measure voltage differences well above or below ground. This combines the accuracy and non-loading of a v.t.v.m. with the convenience of a conventional v.o.m. Fancier circuitry allows peak-reading voltmeters, averaging voltmeters, and true r.m.s. voltmeters, all of which are considerably less complicated than conventional designs.

Switches and Choppers

Fig. 5A shows an IGT r.f. switch, useful from d.c. to several megacycles. It can handle up to a volt of peak-to-peak signal. Since there is no offset voltage, there is no distortion of the controlled signal, and the control and the signal remain completely isolated.

An effective method of d.c. amplification is to chop up a d.c. signal into a series of pulses whose amplitude is proportional to the d.c. voltage. These pulses are very easy to amplify in an ordinary a.c. amplifier with no gain stability or drift problems. A rectifier and filter at the output then recovers the d.c. signal, amplified many times. The difficulty is that the chopping switch is far from perfect. Mechanical devices have limited speeds, contact noise, dwell time, and bounce; semiconductor junction devices have offset voltage; tubes are uinpolar and have a poor "on" resistance. The IGT has none of these disadvantages and is well suited for chopper applications. Fig. 5B is typical—a series-shunt chopper that alternately connects the output to ground or the input signal.

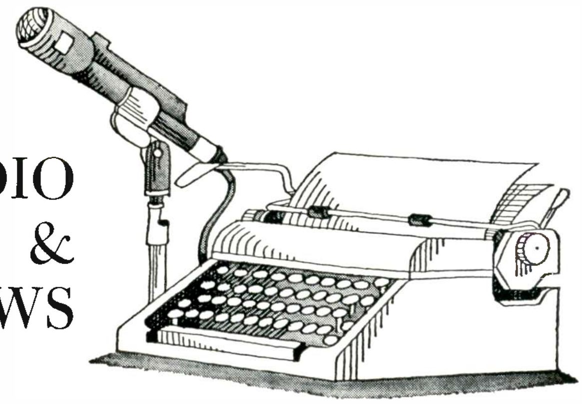
Many conventional circuits can benefit from conversion to IGT's. For instance, Fig. 5C shows an IGT voltage amplifier with a voltage gain of 2500, a 22-megohm input impedance, and a 5-Hz to 60-kHz frequency response. Note the absence of any large capacitors, particularly emitter bypass electrolytics, and the simple biasing. This sort of circuit lends itself readily to integration.

The high input impedance comes in handy in monostable and astable multivibrators where significantly smaller values of capacitance can be used to obtain the same delay times. When used as level detectors, voltage comparators, or Schmitt triggers, there is no loading of the input signal. Another area for the IGT is the sine-wave oscillator. Very pure waveforms may be easily obtained using an IGT and a phase-shift network in a Wien-bridge configuration.

For two final applications, consider Figs. 5D and 5E. If we apply a constant voltage to an IGT gate, a constant current results. The IGT can then be used as a constant-current source in exactly the same way a zener diode is used as a voltage source. This is useful for current regulation, circuit protection, and for generating linear ramp waveforms. On the other hand, if an IGT is biased in the normal manner with no input signal, it behaves like a constant-resistance device which, for low-level signals, is electrically variable. The uses for automatic gain control, electronic multiplication, modulation, and demodulation, are obvious.

A more subtle application lies within integrated circuits. It makes no difference in cost how many transistors go on a certain substrate, for they are simply more holes in the various masks. Thus, it pays to use IGT's instead of load resistors in integrated circuits. Not only are they smaller than conventional deposited resistors, but they eliminate the extra steps necessary to fabricate conventional resistors. ▲

Editor's Note: As pointed out in this article, because of the extremely high input impedance inherent in the IGT, permanent damage to the component can result in the event of a careless moment of mishandling. To remove the possibility of such damage, the General Instruments Corp. *is manufacturing a line of IGT's having a built-in zener diode between the gate and the substrate. This zener protects the gate from any accidental voltage damage, however, it reduces the input impedance of the IGT to the order of 10^{10} ohms.*



RADIO & TV NEWS

IT has been twelve years since the FCC authorized use of the NTSC color-TV system in the U.S. While we have been manufacturing a few million color sets, brought their prices down, and improved our engineering practice to the point where color is now a proven system, the Europeans are still searching for a color system.

The International Radio Consultative Committee (CCIR), the OIRT (East European broadcasting authority), and the European Broadcasting Union (EBU) have been trying for quite a while to come up with a system that will satisfy all countries. It is hoped that by the time this appears in print, the June meeting in Stockholm, Sweden, will have come up with an answer.

In the running at this moment are the French SECAM, the German PAL, the American NTSC, and some minor sub-systems such as the British ART. The only country not heard from is the Soviet Union. For the past few months, Soviet engineers have been talking up a merger of color systems, so that everyone will be satisfied. At the time of this writing, it appears that this expedient system—called NIR by the Soviets, SECAM-4 by the French, SEQUAM by others, and "From Russia With Love" by still others, will be the eventual winner.

Space-Age Lights

For many years, whenever a light source was required to illuminate a panel indicator or to indicate when a circuit was in operation, an incandescent lamp was used. In addition, neon or other gas-filled lamps are also employed for this purpose.

Now, visible light from a solid semiconductor diode is being used as a signal light or panel indicator. Developed and marketed by *Monsanto Co.*, these space-age indicator lamps emit a nearly monochromatic red light, and under typical use conditions operating at 1.6 volts, surface brightness exceeds 50 footlamberts with a current flow of 50 mA. The light becomes brighter with an increase in current flow. Because the device is actually a diode, light emission occurs only when the current flow is in a forward direction.

Expected lifetime of the light diode is more than 10,000 hours, and "on-off" time is 8 to 10 nanoseconds.

Color-TV Boom Continues

Although, at present, only Japan and the U.S. are active in color-TV, word now comes from England that color-TV is planned for that country in 1967.

Although a final decision has yet to be made as to which color system will be used, British manufacturers are anticipating sales of 250,000 color sets per year by 1970. The anticipated price for a 25-inch unit is about $700.

According to *BBC* spokesmen, certain u.h.f. stations will begin by offering 4 hours of colorcasting a week, increasing to 10 hours a week within one year.

Meanwhile, in the U.S., color-TV sales reported for 1965 jumped to 2,746,618 units, a rise of 101% over 1964 sales.

Monochrome TV sales totaled 8,027,981 units in 1965, a rise of 4.5% over 1964, with sales in December slipping 5.6% from the same month the previous year.

Sales of home radios during 1965 went up 23.3%, while FM radio sales went up 53.9% over 1964.

Electronic Inspector

One of the major irritations in almost any factory occurs when a wrong carton accidentally gets into a production line.

Now, *Parke-Davis & Co.* has come up with a carton verifier, called "Vericode," that automatically reads special code bars printed on the flaps of cartons as they pass down the line.

A pair of photoelectric optical scanners read the code lines printed in regular ink (only 1/64 inch wide and ½ inch long) and pass the converted electrical information to a control unit. Using integrated circuits for size reduction, the control unit is "aware" of the proper code for that particular production run. If the scanners send back an improper code, the control unit sets off an alarm and stops the production line.

The scanners can read almost any contrasting color combination. The six-bar code can handle 248 different products, while a 12-bar code can cope with 65,000 different products. ▲

EW Lab Tested

(*Continued from page 22*)

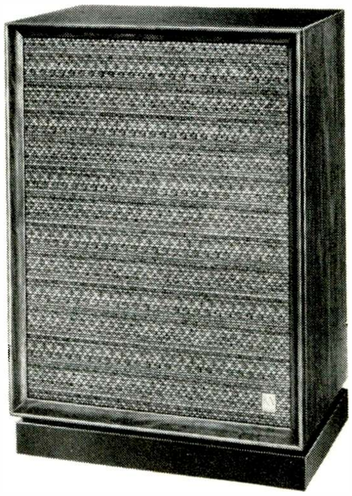
Low frequencies are handled by a 15″ high-compliance woofer with a 1⅞-pound ceramic magnet. Its 1½″ voice coil is stated to have a maximum excursion of 1⅛″. The free-air cone resonance of the woofer is 16 Hz.

Middle and high frequencies, from 2000 to 10,000 Hz, are radiated by a horn-loaded compression driver, with a 1″ voice coil and a 2½-ounce ceramic magnet. A small dome radiator takes over above 10,000 Hz. The built-in crossover network has level controls for the middle- and high-frequency speakers. The system impedance is 8 ohms. It is rated to handle up to 50 watts of program material, but is efficient enough for use with 10-watt high-fidelity power amplifiers.

We tested the speaker system in both floor and shelf locations. In the latter case, six positions were used. The composite frequency response curves obtained from these data were very similar and, after correcting for the known frequency response of our test room, showed a strong and relatively uniform response from approximately 20 to 15,000 Hz.

From 100 to 1500 Hz, the response was within ±3 dB. The midrange and tweeter level controls were set to their mid-positions for these measurements, resulting in a "shelf" above 2000 Hz. Increasing the control settings can give a very uniform response all the way up to 15,000 Hz, since the frequency response from 2000 to 15,000 Hz is within ±2.5 dB.

Tone-burst tests at various frequencies revealed generally good transient response. Near the crossover to the midrange speaker, at 2.1 kHz, there was sustained ringing after each burst, but this occurred only in a narrow band of



frequencies. The low-frequency distortion was very low down to 50 Hz, rising to 14% at 20 Hz. It was largely a cone flutter, or buzzing sound, rather than simple harmonic distortion. It was not heard when reproducing program material at listenable levels, but could be heard with sine-wave test signals below 40 Hz even at relatively low loudness levels.

In listening tests, the "Knight" KN-2380 had a full-bodied, warm character. We found the sound to be most pleasing with both speaker level controls set about three-quarters of the way to their maxima. The sound from the three speakers was well unified and the bass was powerful without being overbearing or boomy. The system has a "big" sound in keeping with its size. With patience, it should be possible to tailor its response to meet the needs of any home listening environment or individual preference. We doubt that many people will wish to mount it on a shelf, due to its sheer bulk and weight (which is about 45 pounds).

The "Knight" KN-2380 sells for $149.95, including the floor-mounting base. This is well below the price of other speaker systems of comparable size. It deserves serious consideration by anyone who wishes a large speaker system but has a limited budget. ▲

DIRECT TV BY SATELLITE

ALTHOUGH most of the technology is available, a program aimed at developing a satellite system to beam television directly into homes could still cost around $150 million. This is an investment too big for one private company or a consortium of companies to absorb and, therefore, will have to be funded by the Federal Government (NASA) if, indeed, such a system is desired by the TV-owning U.S. taxpayer. (See "Home TV Via Satellite" in our May, 1966 issue.)

These observations were contained in a recent paper by Dr. Richard C. Booton and Fred H. Kaufman of *TRW Systems.*

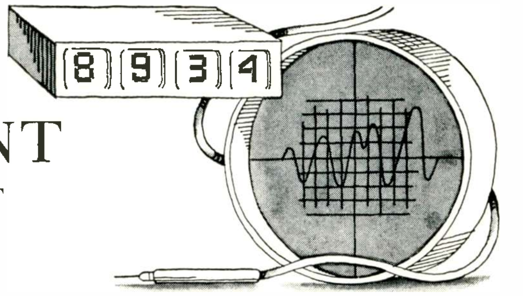
Booton and Kaufman also outlined some of the design characteristics of a satellite that might be used as a television signal relay. Because of the enormous ultra-high-frequency power that would have to be beamed toward earth, the spacecraft itself would be quite large. For instance, a 16.5-kilowatt transmitter would need internal power that could be supplied by a pair of solar-cell-mounted panels 8 feet high and each about 260 feet long. The antenna on the spacecraft, parabolic in shape, might be 12 to 16 feet in diameter. The body of the spacecraft might be about 11 feet high with a heat radiator at its base some 20 feet in diameter. Total weight would be around 7500 pounds and would require a Saturn 1B/Centaur booster to launch it into a synchronous orbit. The configuration suggested could handle at least one and perhaps up to three channels, including necessary redundancy and switching circuits for providing constant and reliable service to the user.

Underlying the start of the program which has the development of a direct TV satellite as its main objective is the acceptance of the average TV set owner and his willingness to increase his investment in order to receive satellite signals. According to Booton and Kaufman, the design they are suggesting would require the installation of a new antenna and some form of preamplification. The cost of these modification kits could range to up to as much as $100. To a segment of the U.S. population not now being served by local TV or CATV, this could be considered a comparatively small investment. But, to those in multiple-channel areas, there may be some question as to its relative value. And to those with a choice of only one or two channels, it is a toss-up. In any event, direct TV by satellite, for some time to come will augment rather than replace existing TV systems. ▲

WANTED:

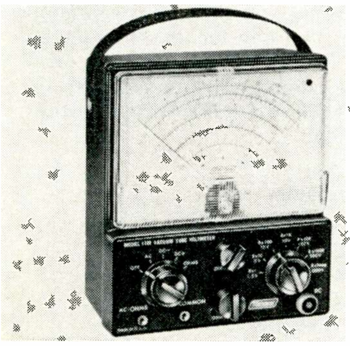
half a million

TEST EQUIPMENT
PRODUCT REPORT



Mercury Model 1700 Vacuum-Tube Voltmeter

For copy of manufacturer's brochure, circle No. 22 on Reader Service Card.



WITH all the specialized test equipment that is available today for servicing color-TV receivers and FM-stereo sets, one is apt to forget that there is still a definite need for the workhorse instruments on the service bench—the v.o.m. and the v.t.v.m. Nevertheless, these basic instruments are far more widely used than the more esoteric and special-purpose generators and bridges.

A new v.t.v.m. that has recently come to our attention is the *Mercury* Model 1700. This unit has all the usual voltage and resistance ranges at accuracies of within 2% on d.c. and 5% on a.c. measurements. There are seven voltage ranges, up to 1500 volts (or 4000 volts peak-to-peak a.c.), and seven resistance ranges. Input impedance is 11 megohms on d.c. and 1.4 megohms on a.c. A decibel scale is also provided along with a zero-center scale marker.

The instrument uses a large, six-inch meter with easy-to-read scales so that it is convenient to use in the shop or on service calls. The meter is housed in a portable, high-impact case with a convenient carrying handle.

The circuitry is conventional with a 12AU7 twin triode serving as meter bridge, a 6AL5 full-wave a.c. rectifier, and a silicon diode as power rectifier. One-percent precision resistors are used as the multipliers and in the d.c. probe. Components are mounted on a printed-circuit board for solidity and trouble-free performance.

The meter is available through parts distributors at a price of $39.95. ▲

"Knight-Kit" KG-685 Color-Bar Generator

For copy of manufacturer's brochure, circle No. 23 on Reader Service Card.

WITH the continuing color-TV boom, new test equipment for color sets is coming out almost as rapidly as the sets themselves. The most important piece of this equipment is the color-bar generator. Early generators were large, bulky, and used vacuum tubes throughout, but we are now beginning to see a "second generation" which is characterized by small size, low-silhouette designs that are portable enough to be carried into the set owner's home. These generators are sometimes battery-powered and they invariably use transistors, including unijunction types, for the many counting circuits that are required.

The new "Knight-Kit" Model KG-685 is the latest example of such a "second-generation" instrument that we have seen. It produces the usual keyed rainbow of ten color bars, plus vertical lines, horizontal lines, crosshatch, and dot patterns. Incidentally, the horizontal lines are only a single raster line in thickness for maximum definition and the dots are very small in size for accurate convergence adjustments. In addition, there is a special gray-scale pattern to permit adjusting the black-and-white tracking of the color set. This consists of eight bars ranging from white through six shades of gray to black. An additional pattern, which is really no pattern at all, makes a total of seven. With the pattern-selector switch in this position, sync is provided and the color set is adjusted for best color purity with a uniformly colored raster.

Three crystal oscillators are used: the master oscillator is at 189 kHz, the color oscillator is at 3.56 MHz, and the sound subcarrier oscillator is at 4.5 MHz. Output from the generator is adjustable for channels 3, 4, or 5 so that the unit can be set for a channel that is unoccupied by a local TV station. Composite video output is also available at plus to minus 2 volts (p-p), and a separate sync signal output is supplied for TV receivers that use separate picture and sync detectors.

Some extra features included are: gun-interruption switches for the three separate guns of the color picture tube, a chrome-plated metal mirror to let the technician see the tube screen while making back-of-set adjustments, and a low-voltage service light which obviates the need for a flashlight to see into the dark recesses of the TV set. Incidentally, the generator can be placed right on top of the color set without affecting the picture. This is because the instrument's power transformer has very low flux leakage and the entire unit is well shielded.

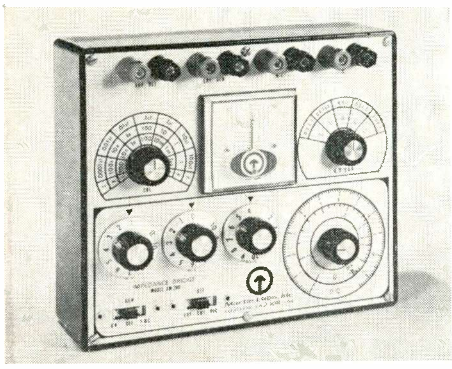
A final good word should be said about the 32-page operator's manual supplied with the generator. Not only does the manual tell how to use the generator, but it also contains a large useful section on the color tube and all the adjustments required to get the best color and black-and-white picture. Purity and convergence adjustments (with colored illustrations) are covered in detail, along with gray-scale tracking and color sync and demodulator checks.

The "Knight-Kit" KG-685, which consumes only about 10 watts from the 117-volt a.c. power line, is available in kit form from *Allied Radio*. It is priced at $89.95. ▲

Martin Labs AM 200 Impedance Bridge

For copy of manufacturer's brochure, circle No. 163 on Reader Service Card.

THIS portable, battery-operated impedance bridge can be used to quickly measure resistance, capacitance, inductance, "Q" of a coil, and D (dissipation factor) of a capacitor. Its accuracy is within one percent. The instrument was designed mainly as a low-cost, laboratory-type unit. In addition to a high-quality Mylar capacitor reference, it uses precision metal-film resistors throughout



in order to maintain long-term accuracy.

An easily changed 9-volt battery is the power source, allowing complete portability for production testing or for use in engineering and school laboratories.

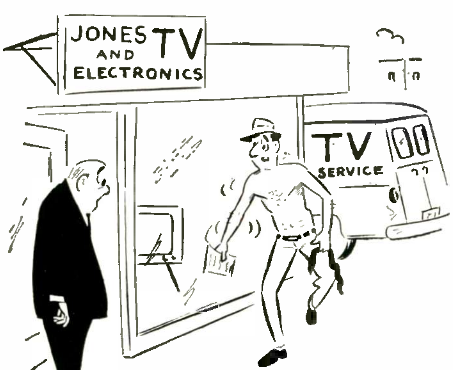
Older bridges employed buzzers as their signal sources. This instrument uses a highly stable 1000-Hz silicon transistor oscillator. An oscilloscope, v.t.v.m., or headphones may be used as external detectors for impedance measurements.

For resistance measurements, the sensitive 25-0-25 microampere d'Arsonval meter built into the instrument serves as null detector. This meter is protected by a shunt resistor which can be removed with the "Detector" switch as the null is approached. A flick of the switch allows full detector sensitivity.

The reading resolution of the instrument is to three significant figures direct and to four significant figures using interpolation. The readout knobs are placed in-line to allow for easy viewing and convenient readings.

Resistance measurements range from 0.015 ohm to 1.11 megohms; inductance measurements from 10 microhenrys to 1100 henrys; and capacitance ranges from 7 picofarads to 1100 microfarads. "Q" is measured in two ranges, 0 to 11.5 and 0 to 1000. The two ranges for D are 0 to 0.115 and 0 to 1.00.

The AM 200 is housed in a black, high-impact Bakelite molded case and, as an option, a metal carrying case with cover and handle can be supplied. The bridge is quite compact, measuring only about 8½" by 7½" by 3". It is priced at $139.50. ▲



"I've got to watch my bidding on these big jobs until I learn a little more about them.

SAW-TOOTH TESTING OF AUDIO AMPLIFIERS

By E.N. MONACCHIO and A.L. PLEVY

In many ways, a saw-tooth waveform is superior to either sine- or square-wave testing of audio amplifiers. A discussion of these advantages and the circuit for a saw-tooth generator are covered.

THE saw-tooth waveform, one of the most widely used analog waveshapes, can be effectively employed as a test signal for video or audio amplifiers. Using the saw-tooth waveshape for these test purposes provides many features which, if used in the proper manner, offer several advantages in contrast with the square-wave or sine-wave methods of testing amplifier response.

There are certain basic criteria that determine an amplifier's response and these have to be checked out in order to assure proper amplifier performance. They include frequency response, saturation points, treble or bass response, over-all distortion, transient response, and power gain without distortion.

These parameters can be readily determined by sine-wave testing. However, this technique presents certain disadvantages in that the frequency of the test oscillator has to be continuously adjusted to cover the frequencies of interest. Another disadvantage is that the test oscillator must be capable of furnishing a constant-level output voltage over this frequency band to assure that the proper 1-dB or 3-dB points are noted.

To eliminate some of the difficulty associated with sine-wave tests, square-wave testing techniques are often used. A square wave makes use of the fact that a complex wave, such as a square wave or a saw-tooth, can be represented as a combination of different frequency sine waves, which when added together produce the square or saw-tooth waveform. This concept is called the Fourier analysis of a waveshape. However, suffice it to say that such complex waves can be represented by a plurality of harmonically related sine waves of various amplitudes. Hence, to properly amplify the complex wave, the amplifier must be capable of passing a sufficient number of these harmonic components without distortion.

The saw-tooth is preferable to the square wave in that the saw-tooth contains *all* harmonics rather than just the odd ones and the amplitudes of these frequencies are related according to $1/n$ where n is the nth harmonic of the fundamental frequency. Therefore, to properly recreate a 1-kHz saw-tooth, the amplifier must have a bandwidth of at least 10 kHz because the saw-tooth requires the harmonics at 2, 3, 4, 5, 6, 7, 8, 9, and 10 kHz. The amplitude of the 10th harmonic is approximately 10% of the fundamental's amplitude. Therefore, if the amplifier properly amplifies 90% of the over-all energy, an undistorted saw-tooth will be present at the amplifier output. In contrast, if a square wave is used, the amplitudes of the harmonics also varies as $1/n$, but there is only energy at the odd harmonics, such as the ninth, eleventh, etc. Hence the amplifier response does not have to be as wide to amplify an undistorted square wave.

Assume that a relatively undistorted saw-tooth (Fig. 1A) is to be used in conjunction with the proper amplifier load and an oscilloscope (preferably one that responds down to d.c.) to test the response of an amplifier. If the amplifier has a poor high-frequency response, it will not pass all the high-

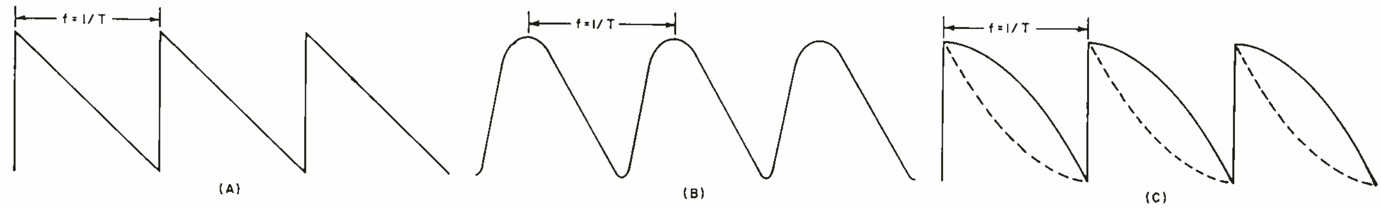


Fig. 1. (A) Ideal linear saw-tooth where the frequency is the reciprocal of time. (B) Loss of high frequencies. (C) Excessive low-frequency response can result in a bowing out of the saw-tooth, while a loss in the lows can result in a concavity.

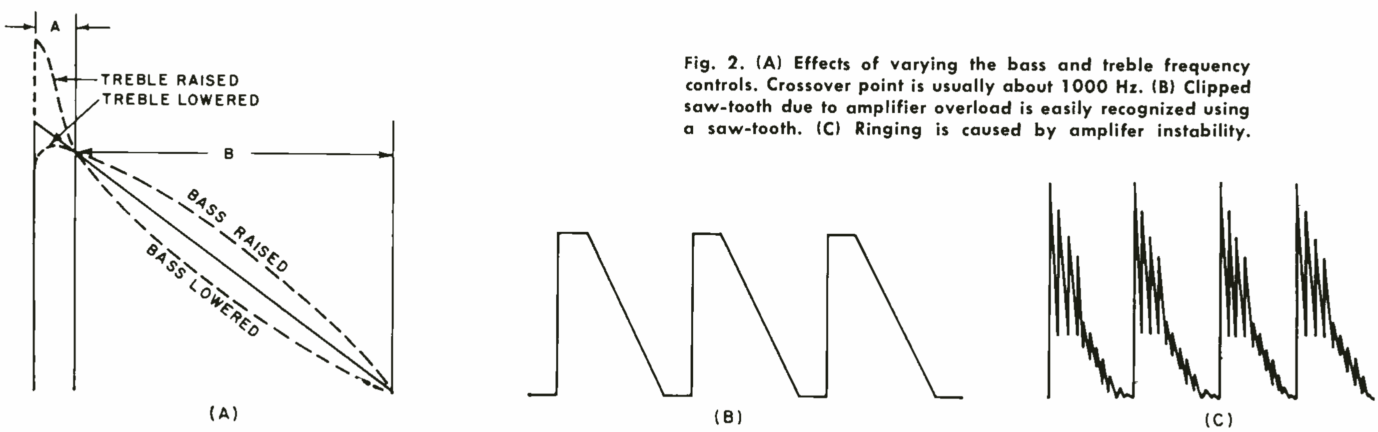


Fig. 2. (A) Effects of varying the bass and treble frequency controls. Crossover point is usually about 1000 Hz. (B) Clipped saw-tooth due to amplifier overload is easily recognized using a saw-tooth. (C) Ringing is caused by amplifer instability.

Total battery current drain: 2.5 mA at all frequencies				
Transistor voltage readings to ground using a v.t.v.m.:	*Q1*	*Q2*	*Q3*	*Q4*
emitter	+3.9	+6.8	+0.64	+6.6
base	+4.2	+5.2	+0.78	+6.8
collector	+6.8	+9	+5.2	+9
Nominal output impedance: 2000 ohms				
		1 kHz	*10 kHz*	*20 kHz*
Freq. vernier (R2) control range:		.2 to 1.56	1.82 to 12.5	4 to 25
Maximum output level:		5 mV to 3 V	8 mV to 3.8 V	8 mV to 4.4 V

Table 1. Test specifications for the saw-tooth oscillator.

frequency energy-contributing harmonics and the saw-tooth will appear at the amplifier output as shown in Fig. 1B. This waveshape is beginning to take on a sinusoidal appearance, and the straight, clean lines of the saw-tooth fast rise time are gone, indicating that the high-frequency response of the amplifier is limited. Of course, the amplifier might be one designed for a 100-kHz bandwidth and hence the 1-kHz saw-tooth would pass through undisturbed. If this is the case, then a 10-kHz saw-tooth may be used, or even a higher frequency saw-tooth, depending on the bandwidth dictated by the manufacturer.

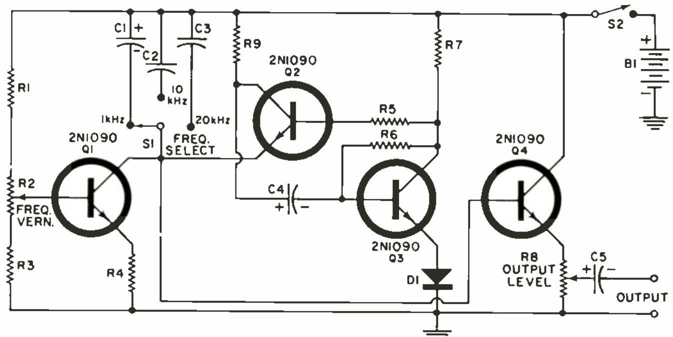
If the low-frequency response of the amplifier is poor, the saw-tooth may take on the appearance of the waveform shown in Fig. 1C. Proper setting of the amplifier bass and treble controls should cause reproduction of the saw-tooth depicted in Fig. 1A.

The bass-control setting of an amplifier usually affects the gain in the region from 500 to 1000 Hz, while the treble control usually affects the gain from 1000 Hz and above. These are merely representative ranges and in any given amplifier they may overlap. Fig. 2A shows a saw-tooth and the composite effects of varying the bass and treble controls. The solid line represents the ideal saw-tooth. The portion of the saw-tooth denoted as the "A" region is that affected by the treble control. The portion of the saw-tooth in the "B" region is that affected by the bass control.

If the treble control is raised, the amplified saw-tooth overshoots during the saw-tooth's fast transition. This overshoot is shown in Fig. 2A as the dashed line labeled "treble raised." If the treble is lowered, the clean, sharp top of the saw-tooth will not be properly amplified and will appear rounded as shown. If the bass control is raised, the saw-tooth "bows" out as shown in section "B" and becomes concave for a lowering of the bass response. Hence, to obtain a properly amplified saw-tooth, both the bass and treble controls must be adjusted until the amplifier reproduces the clean saw-tooth shown in Fig. 1A. When such a saw-tooth waveform is obtained, the control settings at this point are called the "flat settings" of bass and treble.

The utility of the saw-tooth for testing is obvious, as a 1-kHz saw-tooth will check bass down to 100 Hz and treble to 10 kHz. It is a simple matter to check overload of an amplifier with a saw-tooth as the extremities flatten when the amplifier is driven from cut-off to saturation as shown in Fig. 2B. To drive an amplifier to saturation with a square wave accomplishes very little, however, as the top and bottom of the square wave are already flattened. A saw-tooth of a certain peak-to-peak rating has an equivalent sine-wave rating. For example, a saw-tooth of 20 volts peak-to-peak would represent a sine wave of 7.07 volts r.m.s. If a peak-to-peak saw-tooth of 20 volts is the largest amplitude the amplifier passes without clipping as shown in Fig. 2B, the equivalent sine wave is then 7.07 volts r.m.s. and the power output capability of the amplifier would be $(7.07^2/R)$ where R is the terminating or load resistor.

Maximum power rating can be approximated by noting the



R1—56,000 ohm, ¼ W res. ±5%
R2—100,000 ohm pot
R3,R4,R5—10,000 ohm, ¼ W res. ±5%
R6—200,000 ohm, ¼ W res. ±5%
R7—2700 ohm, ¼ W res. ±5%
R8—10,000 ohm pot
R9—150 ohm, ¼ W res. ±5%
C1—0.1 µF, 35 V tantalum capacitor
C2—0.01 µF, 150 V mica capacitor
C3—4700 pF, 150 V mica capacitor
C4—1 µF, 35 V tantalum capacitor
C5—100 µF, 35 V tantalum capacitor
D1—1N91
S1—S.p. 3-pos. switch
S2—S.p.s.t. switch
B1—9 V battery
Q1,Q2,Q3,Q4—2N1090

Fig. 3. Schematic and parts list for the saw-tooth generator.

peak-to-peak value of the undistorted output of the amplifier, using a calibrated scope or peak-to-peak voltmeter; dividing this value by 2.83 to obtain the equivalent r.m.s. sine-wave value; and calling it E. The power capability of the amplifier is then given by E^2/R where R is the terminating or load resistor.

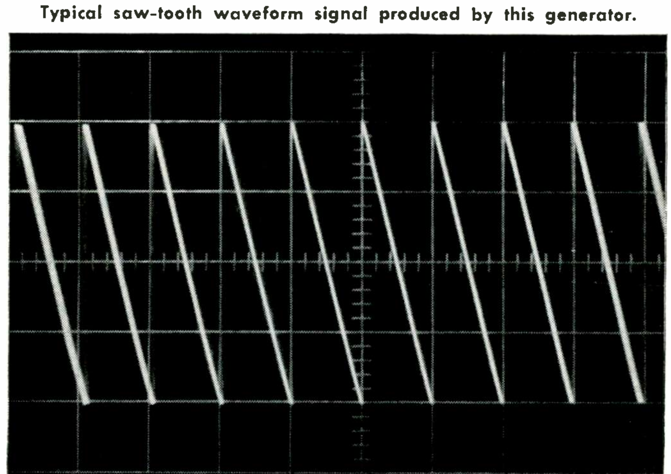
The saw-tooth also possesses a steep leading edge which may cause unstable amplifiers to "ring" when they are trying to amplify this rapid wavefront. This phenomenon is due to poor transient response of the amplifier caused by instabilities in design. Fig. 2C shows a typical response due to ringing. Usually the manufacturer has taken care of ringing by appropriate bypass networks in the feedback path. Such instabilities are cured by connecting relatively small capacitances to ground at various signal points within the amplifier.

An amplifier might have more gain at some harmonic other than the fundamental; therefore, its frequency *vs* amplitude response curve would have peaks and valleys and would not be the typical flat response of a good amplifier. If the response is poor, the bass and treble controls may be used to compensate to a clean saw-tooth. The amplifier may generate harmonics due to non-linearity of the transistor or tube characteristics, and such distortion may not be easily remedied.

Saw-Tooth Generator

A saw-tooth oscillator is not an ordinary piece of test equipment which is readily found among the audiophile's inventory. The practical test oscillator to be described produces a saw-tooth which covers the frequency range from 200 Hz to 25 kHz with a linear output over this range and which is amply stable for amplifier testing. Circuit is shown in Fig. 3.

Typical saw-tooth waveform signal produced by this generator.



Operation of the circuit is as follows. Assume that switch S1 is in the 1-kHz position and that the voltage at the collector of *Q*1 and the emitter of *Q*2 is essentially the battery voltage. *Q*3 is biased in its active region and the voltage at its collector is the battery voltage minus the voltage drop across *R*7 (due to collector current); hence, *Q*2 draws no current, as its base, coupled to *Q*3 collector through *R*5, is at a lower potential than its emitter.

As timing capacitor *C*1 starts to charge through *Q*1 and emitter resistor *R*4, the voltage at the collector of *Q*1 starts to reduce due to collector current through *Q*1 and *R*4. As this voltage decreases, the emitter of *Q*2 also goes less positive, and as this potential approaches the base potential, *Q*2 starts to conduct and places a low-Z discharge path across *C*1 through *Q*2 and *R*9.

As the collector voltage of *Q*2 drops, the negative-going transition is coupled *via* *C*4 to the base of *Q*3. This causes *Q*3 to cut off, making its collector voltage rise rapidly. This rapid rise in voltage, in turn, is coupled to the base of *Q*2, causing it to conduct even more and lowering the discharge path resistance for *C*1. This rapid feedback technique allows *C*1 to discharge very rapidly to obtain the fast flyback for the saw-tooth.

Variable resistor *R*2 controls the collector-to-emitter resistance of *Q*1 and hence the charging time of *C*1, or frequency of operation. *Q*1 also functions as a constant-current source for charging the timing capacitor. A typical waveform is shown in the photograph.

The changes in frequency obtainable by varying *R*2 are shown in Table 1. The circuit shown will operate with *p-n-p* transistors if the battery polarity, diode *D*1, and the polarized capacitors are reversed. The circuit shown should be capable of higher or lower frequency operation by the addition of suitable capacitors in place of, or in addition to, *C*1, *C*2, or *C*3. Actually, a saw-tooth having a duration of seconds can be obtained by making *C*1 a 25-μF capacitor.

To test the performance of the oscillator, check the wiring of each stage before inserting the transistors. With this done, connect a v.t.v.m. to the base of *Q*1 and vary *R*2 until +4.2 volts are measured at this point. Then measure the voltage drop at the emitter, base, and collector of each stage to see if they comply closely with the Table 1 values.

The 2N1090's shown in Fig. 3 are switching transistors and have a minimum *beta* of 30, but the maximum value might be much higher. If this is the case, the collector of *Q*3 might be at a lower voltage value than indicated, which will cause a concave saw-tooth. To remedy this, either interchange *Q*3 with a lower *beta* transistor or parallel *R*7 until the proper level is obtained. ▲

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The demand for licensed men is enormous. Ten years ago there were about 100,000 licensed communications stations, including those for police and fire departments, airlines, the merchant marine, pipelines, telephone companies, taxicabs, railroads, trucking firms, delivery services, and so on.

Today there are over a million such stations on the air, and the number is growing constantly. And according to Federal law, no one is permitted to operate or service such equipment without a Commercial FCC License or without being under the direct supervision of a licensed operator.

This has resulted in a gold mine of new business for licensed service technicians. A typical mobile radio service contract pays an average of about $100 a month. It's possible for one trained technician to maintain eight to ten such mobile systems. Some men cover as many as fifteen systems, each with perhaps a dozen units.

Coming Impact of UHF

This demand for licensed operators and service technicians will be boosted again in the next 5 years by the mushrooming of UHF television. To the 500 or so VHF television stations now in operation, several times that many UHF stations may be added by the licensing of UHF channels and the sale of 10 million all-channel sets per year.

Opportunities in Plants

And there are other exciting opportunities in aerospace industries, electronics manufacturers, telephone companies, and plants operated by electronic automation. Inside industrial plants like these, it's the licensed technician who is always considered first for promotion and in-plant training programs. The reason is simple. Passing the Federal government's FCC exam and getting your license is widely accepted proof that you know the fundamentals of electronics.

So why doesn't everybody who "tinkers" with electronic components get an FCC License and start cleaning up?

The answer: it's not that simple. The government's licensing exam is tough. In fact, an average of two out of every three men who take the FCC exam fail.

There is one way, however, of being pretty certain that you will pass the FCC exam. And that is to take one of the FCC home study courses offered by the Cleveland Institute of Electronics.

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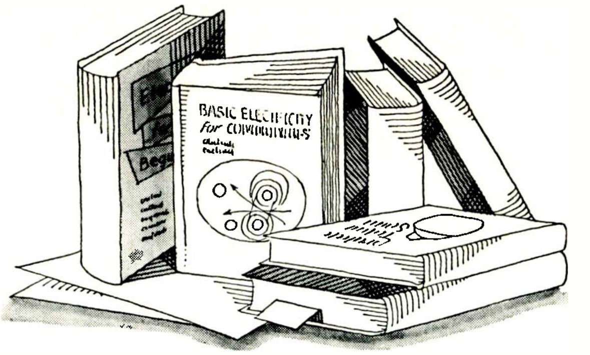
BOOK REVIEWS



"COMMUNICATIONS ELECTRONICS CIRCUITS" by J. J. DeFrance. Published by *Holt, Rinehart and Winston, Inc.*, New York, N.Y. 537 pages. Price $9.50.

This volume deals solely with circuits used in electronics communications and is addressed to the engineering/technician student. In order to provide the widest coverage of the field which includes aircraft and vessel navigational systems; depth, range, and altitude finders; missile guidance; detection and tracking of moving targets; anticollision devices; and telemetry systems as well as the transmission and reception of radio waves, the author has considered both vacuum-tube and transistorized equipment.

Before tackling this volume, the student should have a good working knowledge of a.c. and d.c. fundamentals, vacuum-tube and transistor characteristics, basic electronic circuitry, and a background in algebra, vector algebra, basic trig, and calculus. This book is used as a textbook at New York City Community College and is laid out and presented in a form suitable for classroom instruction.

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"SEMICONDUCTOR CIRCUITS HANDBOOK" compiled and published by *Techpress, Inc.*, Brownsburg, Indiana 46112. 127 pages. Price $1.95. Soft cover.

This is a second volume in this publisher's series of schematics for use in building a variety of hobby and experimental circuits using semiconductor devices. The material is divided into four main sections: power supplies and regulators, power converters, logic circuits, and non-linear circuits. Each schematic is printed with correct parts values and there is a brief technical discussion of the circuit's application, variations, and possible parts substitutions.

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"ELIMINATING ENGINE INTERFERENCE" by John D. Lenk. Published by *Howard W. Sams & Co., Inc.*, Indianapolis. 110 pages. Price $1.95. Soft cover.

This book is addressed to those who own, operate, or maintain communications equipment whether radio amateurs, users of CB equipment, or operators of marine radio gear.

The author explains how the electrical system of an engine creates interference and tells how to isolate the specific components that are the noise source. He also shows what can be done to reduce noise at the source and outlines suppression and shielding methods to keep interference from reaching the radio equipment. Commercial noise suppression and shielding kits are discussed, along with installation instructions. Adding squelch and noise-limiting circuitry to existing equipment is also discussed in some detail.

The book is well illustrated with photographs, line drawings, schematics, graphs, and charts and is sufficiently detailed to permit its use by the non-technical as well as the professional.

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"INTRODUCTION TO LASER PHYSICS" by Bela A. Lengyel. Published by *John Wiley & Sons, Inc.*, New York. 300 pages. Price $8.95.

The reader of this book will require a moderate background in atomic physics and electronics and easy familiarity with mathematics. The author who was a member of the *Hughes Research Laboratories* staff when the first laser was built there has written an earlier book entitled "Lasers." This present volume is an outgrowth and expansion of the earlier book and reflects the present state of the art.

The text is divided into eight chapters covering the background material on radiation and atomic physics, a general description and theory of lasers, solid-state lasers, fluid-state lasers, gas lasers, variation of laser oscillations in space and time, nonlinear phenomena, and laser applications. In addition, there is a historical introduction, a brief note on laser literature and bibliography, and an appendix.

Those with the requisite background will find this volume useful and enlightening.

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"CATV SYSTEM ENGINEERING" by William A. Rheinfelder. Published by *TAB Books*, Thurmont, Maryland 21788. 206 pages. Price $9.95. Soft cover.

Subtitled, "How to Plan and Design Modern Cable TV Plants," this volume is addressed specifically to the technicians who have been maintaining CATV systems principally by the "cut-and-try" method and to those who plan to enter this fast-growing field.

The text is divided into ten chapters covering CATV system concepts (including performance standards of such systems), head-end design, CATV amplifier characteristics, optimum system spacing, the practical aspects of spacing, level diagrams for system design, matching and reflections, amplifier controls, automatic CATV, and testing CATV amplifiers. Six appendices cover the calculation of cumulative noise and overload, mathematical derivation of optimum spacing, typical equipment specifications, CATV data and charts, literature and references, and a glossary of CATV terms. The text is illustrated with graphs, tables, and line drawings.

° ° °

"FUNDAMENTALS OF TRANSISTORS" by *RCA Service Company*. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 223 pages. Price $10.00.

This is a programmed text designed as a self-instruction manual for technicians, experimenters, and others interested in transistors and transistor circuitry.

The text is divided into 68 individual "sets," each of which is a comprehensive presentation of a specific idea or aspect of semiconductor devices and each forming a link in the sequence. Progressing from simple concepts, through junction theory and transistor behavior, the text leads to a thorough understanding of amplifier behavior and its many applications.

The text is amplified by the use of hundreds of illustrations and a set of reference panels at the end of the book. Since the book has been designed specifically for the do-it-yourself student, the explanations and illustrative material are clear and copious.

° ° °

"RADAR . . . PRINCIPLES AND PRACTICES" by F. Jonathan Mivec. Published by *Techpress, Inc.*, Brownsburg, Indiana. 256 pages. Price $4.95. Soft cover.

This volume has been prepared for the technician who wishes to include radar maintenance and servicing among his specialties. It is the author's contention that reluctance to tackle such equipment is generally caused by the lack of truly basic texts dealing with radar circuits and their operation.

In this volume the author has spelled all this out in simple terminology. There are nine chapters covering an introduction to radar, timing, amplifiers and oscillators, modulation and detection, r.f. lines, waveguides and resonant circuits, radar-frequency oscillators, radar antennas, and synchros and servomechanisms.

On the minus side, the text is set in extremely small type and the reproduction is a bit smeary. ▲

Multiplex Demodulator

(Continued from page 33)

matically from monophonic to stereophonic operation according to whether stations are being received with mono or stereo modulation. Off-station, there is enough noise output from the FM detector to give the 19-kHz pilot circuit the same amount of signal as the pilot signal normally broadcast from the FM station. However, under these conditions, the stereo indicator would light off-station and the multiplex circuit would be switched to stereo. This is a common failing of most automatic multiplex circuits.

Further refinements were made to prevent the circuit from switching to stereo unless the minimum signal-to-noise ratio exists.

For this fully automatic switching, the detector output is connected to a high-pass filter which passes noise above 75 kHz since an FM detector can produce signals of 150 kHz and higher when the tuner is tuned off-station. The amount of high-frequency noise reaching the noise amplifier can be adjusted by shunting the output of this filter with the 50,000-ohm threshold control. The output of the noise amplifier is rectified in a peak-to-peak two-diode detector which produces a reverse bias to the first 19-kHz amplifier. Thus, the 19-kHz amplifier cannot operate unless the noise at the output of the FM detector has decreased to such a value that it will not cause further reverse bias of this 19-kHz amplifier.

The sensitivity of this switching circuit is adjusted so that it does not switch the multiplex demodulator circuit over to stereo unless the amount of the amplified pilot signal is well in excess of that required for good synchronization of the 38-kHz oscillator. This, in effect, removes noise modulation of this oscillation and permits listening to stereo program material with an improved signal-to-noise ratio.

The switching circuit is also designed to require a higher signal-to-noise ratio for switching to stereo than for switching back to mono, preventing the multiplex section from continually switching as a marginal stereo signal fades in and out.

Fig. 3 shows the complete automatic multiplex circuit. The circuits of Figs. 1 and 2 are portions of this circuit. It may also be of interest that there is only a single-pole, single-throw switch required to make this circuit perform as either an automatic mono-stereo circuit or to operate in mono only. Here, operating bias for the 19-kHz amplifier is removed completely. This patented circuit has been proved to be extremely reliable and is now used in all current *H. H. Scott* tuners. ▲

Time & Time Measurements

(Continued from page 29)

whose stability and accuracy must be known if the accuracy of their measurement is to be known.

We need not know frequency to 9 or more significant figures for all purposes, of course. So frequency and time-interval measuring equipment of lower cost with entire satisfaction may sometimes be referred to the power line. Its long-term average accuracy is high since it is corrected frequently by the power companies, so it is very useful for driving clocks. Its accuracy during any given 1-second or 10-second measurement, however, may safely be taken in most situations as only ±0.1% or so (1 part in 10^3).

Well-cut modern quartz crystals of moderate cost will demonstrate stability of a few parts in 10^6 per week, even in uncompensated environments. As we have seen, this does not mean that measurements referred to them are *accurate* to a few parts in a million, unless they have recently been calibrated to a known standard. Better modern quartz-crystal time bases, in well-designed proportionally controlled ovens, exhibit stability of a few parts in 10^9 or 10^{10} per day. These are found in the more precise electronic counters, those with 8 displayed digits and the ability, with plug-ins or other accessories, to count frequencies well into the microwave region.

More and more often it is necessary to measure time intervals or very high frequencies with something like 8-place accuracy. To do so, one must have a time base of this high order of stability, and one must calibrate it often against a standard whose accuracy is even more closely known. That is why many laboratories maintain a "house standard," which may be one carefully monitored time base in a fine electronic counter, a separate and still more stable central oscillator in the parts-in-10^{11} category, or else by the use of an atomic-based oscillator.

Comparison with the U.S. Frequency Standard (USFS) may be made almost anywhere in the United States with the precision of a few parts in 10^{10} by v.l.f. phase-comparison methods. The USFS itself may be taken for all practical purposes to be absolutely accurate. Its reception, however, is subject to some error. Reception of the 60-kHz (kilocycle) broadcasts of the National Bureau of Standards' WWVB from Boulder, Colorado has proved vastly better, for frequency-comparison purposes, than the NBS h.f. broadcasts because propagation at low frequencies is much less subject to ionospheric disturbances. To establish time of day, however, the h.f. broadcasts are most useful. Comparison to so many significant figures requires considerable time, a matter of perhaps hours. It may be accomplished automatically by use of a modern phase-tracking v.h.f. receiver and along with an associated recorder.

Keeping very accurate time of day is accomplished, at the highest level, by driving a specialized clock mechanism with a frequency standard of precisely known accuracy, such as a precisely monitored quartz oscillator or an atomic-based standard. These clocks are designed to be fail-safe; *i.e.*, they stop or show an automatic indication if they miss a single beat of the driving frequency. They also generate precisely timed electrical "tick" signals of a standard kind in order that other equipment may be accurately synchronized with them.

A typical, highly accurate electronic counter, with a time-base stability of better than 3 parts in 10^9 per day. Time intervals are measured by using external signals to gate the counter's internal time-base, a high-frequency oscillator. Counting circuits total oscillations during the measured interval; the electronic arithmetic circuits then scale the reading to the time units.

Conclusion

Nothing like adequate attention has been given here to the intricacies of timekeeping at the national standards level. The accomplishments of the National Bureau of Standards which keeps the U.S. Frequency Standard and of the U.S. Naval Observatory which keeps the official U.S. time of day have not begun to be described. Some of the means they use have been indicated, however, and means of approximating their performance have been described in the literature.

The direction of today's efforts toward further progress is, of course, toward still higher levels of stability and accuracy in the instruments. The hydrogen maser, which was not touched upon, appears capable, in a controlled laboratory environment, of defining time accurately to parts in 10^{13}, and its limits may not have been reached. Somewhere in the region of parts of 10^{13} or 10^{14}, we must begin to take relativistic effects into account. Here and beyond, science may begin to test and perhaps even to make use of such advanced thinking as the Unified Field Theory. Here, it is thought, lie the secrets of gravity, among other mysteries. The science of time may well be taken, then, as one of man's most worthwhile endeavors. ▲

NEW DIGITAL READOUT SYSTEM

By C. W. MARTEL / Raytheon Co. Component Div.

"Datastrobe" display uses strobe light and an optical projection system for in-line, non-segmented numbers.

DIGITAL readouts have become very popular for use in a variety of measuring equipment. Voltmeters, current meters, frequency meters, resistance and impedance measuring apparatus, and many other items used in electronics laboratories and maintenance installations are now available with digital readout instead of meters and/or dials. Commonly, the electronic types of digital readout have used numerical indicator tubes or incandescent lamps, with their associated control circuitry using additional electron tubes.

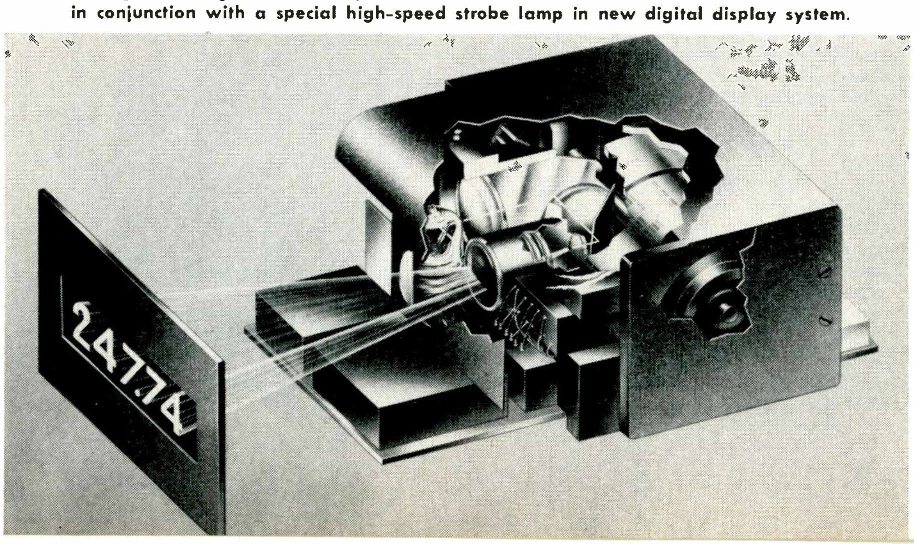
Now a new digital readout, called the "Datastrobe" subsystem, has been developed and placed on the market by *Raytheon*. It provides a completely different method for producing the white-on-black digits and includes the necessary circuitry to operate from a low-level, true 4-bit BCD code that does not require complementary input. Greater reliability, adaptability to user's individual needs, and lower cost often result when compared with existing digital readout systems.

The Datastrobe character generator uses a high-speed xenon strobe flashtube, the light output of which is directed through a rotating-drum character mask and suitable optical elements to a viewing screen (see cutaway photo). The rotation of the drum and the flashing of the strobe are controlled and synchronized so that the correct digits are displayed. The drum contains up to 6 rows of digits from 1 through 0, for a 6-digit display. Rows are in different segments of the drum's circumference, so only one digit of one row is in the optical path when the flashtube fires. The speed of rotation is such that each digit flashes at a fast enough rate to present the viewer with a steady, bright display. Only 22 milliseconds are required to change from one 6-digit display to another. The rotating drum also includes a section which, in conjunction with the magnetic pickup head and associated circuitry, controls synchronization of the flash lamp with the drum position to illuminate the correct digit at the proper time. Thus a synchronous motor is not required.

The display unit contains all necessary circuitry, using solid-state components throughout. Six columns of low-level 4-bit BCD information from the user's output is serialized by the unit's gating logic, actuated by signals from its column-gating generator. As each column comes to the proper position, the corresponding 4 bits are supplied to the single decoder-comparator circuit and, when the desired number on the drum is in the viewing area, a trigger pulse fires the flashtube. Persistence of vision and the fast scanning rate results in a high-contrast, flickerless 6-digit number on the screen.

The single flashtube used for a 6-digit display replaces either 66 incandescent lamps or 6 numerical display tubes having 60 cathodes, as used in other systems. It has no filament to burn out, so the failure mode is a gradual diminishing of intensity—not a catastrophic burnout. The time-shared logic circuits require less than one-half the number of components typically needed for other display systems. Also, there are no relays, slide plates, or intermittent-motion mechanisms, no decoders, no inverters, no amplifiers, nor set pulse-signals. The simplicity of the electronic circuitry is repeated in the optical portion, which can be supplied to meet a variety of space requirements and to provide wide variation in the size and style of the viewing screen display. ▲

A single rotating drum with up to six columns of characters inscribed on it is used in conjunction with a special high-speed strobe lamp in new digital display system.



NEW PRODUCTS & LITERATURE

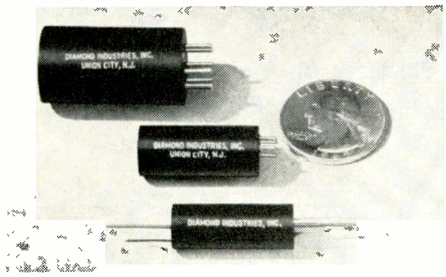
Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • HAM • COMMUNICATIONS

ENCAPSULATED REED RELAYS

A standard line of reed relays, in miniature and subminiatures sizes, is now in production. The stock models are available from 0.25 to 0.5 ampere at a maximum of 300 volts in form A or C. Coils from 150 to 2500 ohms can be supplied, with or without magnetic or electrostatic shielding.

Model DRM-138 is 0.437" x 1" high and has four pins for PC boards; the Model DRM-139



is 0.375" x 1⅛" with four axial leads; and the Model DRM-140, which is 0.750" x 1¼" high, has standard 7-pin layout for 7-pin miniature tube socket or PC board. Specially designed units are also available. Diamond Industries

Circle No. 126 on Reader Service Card

RESISTOR STANDARDS

A new line of resistor standards, virtually independent of ambient temperature effects and variations, is now being offered. Guaranteed accurate to within ±10 parts per million over a temperature range from −30°C to +60°C, the actual resistance change in a laboratory with less than a 5°C temperature variation will be almost impossible to discern, according to the manufacturer. Single resistors, matched pairs, or accurate ratio resistors are available.

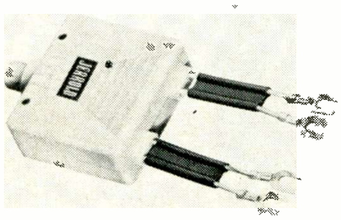
The combination of accuracy and independence from temperature has been achieved by assembling the standard precision resistor (or set of resistors) into a proportionally controlled oven to form the new Type N2032 standards. The housing for the entire assembly is 2⁵⁄₁₆" x 4⁵⁄₁₆" x 4½" including posts. Power requirements are 6 watts at 6.3 V a.c. The precision resistors and heater are mounted in a hermetically sealed, removable cylinder. The oven is controlled by a thermistor which regulates the wattage dissipation, scheduling the heat input as a function of ambient temperature.

Complete details and dimensional drawings are available on request. Nytronics

Circle No. 127 on Reader Service Card

SIGNAL SPLITTERS

Currently available are two new signal splitters which will handle the output of an 82-channel antenna (twin-lead or coax). The Model 1460 B twin-lead splitter/mixer splits a single twin-lead into two separate outputs, feeding the



u.h.f. and v.h.f. signals to their respective antenna inputs on the receiver. The unit can also be used as a mixer to combine the output of separate u.h.f. and v.h.f. antennas into a single downlead.

The second unit is designed for coaxial installations. Designated Model T-380, this matching transformer/splitter matches 75-ohm coax to 300-ohm TV sets. This unit then splits the signals, providing separate u.h.f. and v.h.f. twin-lead inputs to the set. Jerrold

Circle No. 1 on Reader Service Card

MATCHING TRANSFORMERS

A new line of high-performance indoor and outdoor matching transformers which permit the conversion of 300-ohm twin-lead antenna systems to 75-ohm shielded coax operation is now on the market.

The Model 7512-AB matching transformer kit includes both indoor and outdoor matching transformer baluns, weatherboot, mounting hardware, and complete instructions for a quick, easy installation. Individual indoor and outdoor balun transformers are also available.

The components are designed for u.h.f., v.h.f., and FM signals and will pass a.c. or d.c. current. The company claims low signal loss at all frequencies, flat frequency response, and low standing-wave ratio. Finney

Circle No. 2 on Reader Service Card

FUEL VAPOR DETECTOR

The MI-25 fuel vapor detector features a built-in 2500-Hz audio alarm, a meter which indicates "Safe-Dangerous-Explosive," and relay circuits to activate additional warnings or switch "off" the ignition system. The audio alarm sounds when atmospheres are "Dangerous."

Although the all-transistor circuitry can be expected to perform perfectly, a "fail-safe" pro-

vision has been incorporated so that any component failure will give a warning of "Dangerous" or "Explosive" vapors.

The indicator unit is marine styled in aluminum and stainless steel with a black and white enamel finish. All necessary interconnecting cables and complete, detailed instructions for owner installation are included. The kit is designed to operate on all craft with 12-volt electrical systems (positive or negative ground). Heath

Circle No. 3 on Reader Service Card

STRIP-TYPE GROMMETING

A U-shaped, strip-type grommeting material, extruded from natural polyethylene, can be cut to size to provide a tough, smooth surface around the edge of practically any size or shape of hole.

The new grommet strip is available in five sizes, to fit any thickness material from 20 gauge to ¼" plate. Just one size will fit any shape or size hole in the specific gauge material for which it is designed. This has the advantage of reducing and simplifying inventory and stock records. The strip is packaged in 75-foot lengths in a specially designed box for simplified "snip-n-fit" application. Electrovert.

Circle No. 128 on Reader Service Card

TRANSISTORIZED INVERTER

A new solid-state power inverter, the "Gemini" Model 50-128 has just been put on the market. It changes the regular storage battery current of a car or boat to 117 volts of filtered a.c. Capacity of this inverter is 450 to 500 watts.

The unit is housed in a heavy-gauge copper-clad case with carrying handle. Typical items the

unit will operate include amplifiers, radios, portable TV sets, lights, can openers, electric shavers, electric drills, and soldering irons. Terado

Circle No. 4 on Reader Service Card

U.H.F. TV ANTENNA SYSTEM

A new u.h.f. TV antenna distribution system is built around a new solid-state u.h.f. distribution amplifier (Model A-222) and solid-state line extenders which will drive an unlimited number of u.h.f. sets. In addition to use in apartment buildings, motels, schools, etc., the system can be used for demonstrating u.h.f. sets in dealer showrooms and display floors.

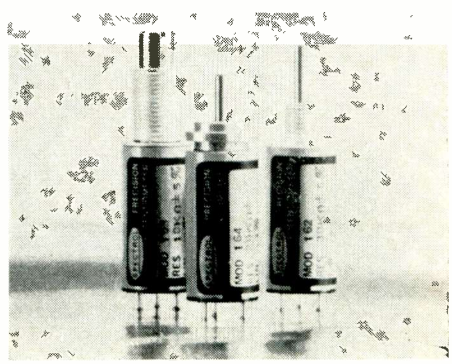
In addition to the amplifier, the company is offering all necessary components to handle any size system: u.h.f. line splitters, tap-offs, matching transformers, line extenders, preamplifiers, and antennas. Winegard

Circle No. 5 on Reader Service Card

TEN-TURN PRECISION POTS

A new line of 10-turn, ½-inch-diameter precision potentiometers for industrial use is now on the market in a resistance range from 100 to 105,000 ohms (±5% max.) and with a standard linearity of 0.30%. Power rating is 2 watts at 40°C and operating temperature range is −55°C to +125°C. Resolution is from 0.101 to 0.015%.

The use of molded thermosetting materials, precious metal contacts, and gold-plated rear



terminals provide the designer with high-reliability pots in a small, convenient configuration. Spectrol

Circle No. 129 on Reader Service Card

PANEL-MOUNT SQUARE POTS

All wirewound and non-wirewound square adjustment pots currently in the company's line are now available in panel-mount styles. These include the ½" square Models 3250 (wirewound), 3251 (non-wirewound), and 3255 (wirewound, industrial), as well as the ⅜" square Models 3280 (wirewound) and 3281 (non-wirewound). According to the company, no performance degradation is required for panel mounts. Sealed bushings also make them well suited to potting applications. Bourns Trimpot

Circle No. 130 on Reader Service Card

HI-FI—AUDIO PRODUCTS

MUSICAL INSTRUMENT AMPLIFIERS

Two new all-transistor musical instrument amplifiers are now available as the "Baronet 808" and the "Baronet 810." The two units are similar, but the 810 offers tremolo as an additional feature. Both units have 5-watt solid-state amplifiers and full-fidelity 9" oval speakers housed in a scuffproof Royalite case measuring 10" high x 14" wide x 5" deep.

Complete information on either or both of these new "Ampli-Vox" units is available on request. Perma-Power

Circle No. 6 on Reader Service Card

STUDIO RECORDER/REPRODUCER

The new "Maestro" tape recorder/reproducer is a professional, studio-type instrument which features a unique tape transport system which is said to be the most precise and quick-acting in the industry and an all-solid-state electronics rack.

Utilizing two capstan drives to carry the tape

instead of the conventional single capstan, the unit has a starting time measured at less than 0.01 second and a stopping time equal to ½ inch of tape at 7½ ips running speed. This quick reaction permits ultra-precise programming and editing, actually enabling the user to "split" a recorded eighth note.

The standard model is available with 7½ and 3¾ ips tape speeds and accommodates 10½ inch tape reels for ¼" tape. It has a capacity of 2400 feet of 1.5-mil tape and 7200 feet of "Triple-Play" tape. The recorder may also be ordered with 15-7½ ips; 3¾-1⅞ ips; or 1⅞-15/16 ips tape speeds. Full specifications on the "Maestro" will be supplied by the manufacturer. Tape-Athon

Circle No. 131 on Reader Service Card

8-TRACK CARTRIDGE PLAYER

A hi-fi stereo tape player that gives up to 80 minutes of music or sound from an eight-track cartridge is being marketed as the "8 Stereo." The player is designed for use in the car, home, or in boats.

Knob controls include dual volume, dual balance for left and right speakers, dual balance for front and rear speakers, and dual tone. The amplifier delivers 24 watts of power. The player turns on automatically as the cartridge is slipped in then plays continuously as desired and automatically turns off as the cartridge is removed.

Battery drain is prevented if the driver forgets to remove the cartridge since power to the player is cut off when the ignition switch is turned off. The unit can be used with either 6- or 12-volt battery systems. The tape player is compact and lightweight. It uses 14 transistors in the solid-state amplifier and preamp to help reduce size to 8" wide x 7" deep x 2½" in front, tapering to 2¼" in the rear. Weight is 7 pounds. Soundex

Circle No. 7 on Reader Service Card

"BUILT-IN" TAPE RECORDER

The new Model 2406 tape recorder which is designed to fit into the company's built-in wall

cabinet and fold into the wall when not in use, has just been put on the market.

Newly designed transistorized preamplifiers have enabled the company to reduce the price substantially over early models. In addition, the new unit features automatic cut-off at the end of the reel, three speeds, numerical counter to show location on the tape, easy push-button operation, vu meters for accurate setting of recording levels, and a pause-and-pause-lock lever to hold and save tape during periods when the system isn't being used for recording. The system plays back and records both 4-track stereo and mono tapes. NuTone

Circle No. 8 on Reader Service Card

TRANSISTOR ORGAN IN KIT FORM

A kit version of the Thomas "Color-Glo" transistor "Artiste" ART-1 organ is now being offered to those with little or no musical training since the "Color-Glo" feature makes it possible to play complete songs with melody, harmony, and bass after only a few minutes of practice.

Lighted white keys on the upper keyboard indicate the next note to be played matching the letters on the keys and the letters on the music. This feature can be turned off once the user has mastered the keyboard and the reading of standard scores.

Additional features include 10 organ voices; variable repeat percussion to add banjo, mandolin, balalaika effects; 13-note heel and toe bass pedals; two overhanging 37-note keyboards; 12" speaker; 50-watt EIA peak music power amplifier; two levels of vibrato intensity; manual balance control; variable expression pedal; variable bass pedal volume; all in a handcrafted, handrubbed walnut cabinet.

Total kit construction time is about 50 hours and no special skills, tools, or knowledge are required. Heath

Circle No. 9 on Reader Service Card

AIR-SUSPENSION SPEAKER SYSTEMS

Two new air-suspension speaker systems, the same as offered in the company's complete music systems, are now being marketed as separate components. The deluxe HK-40 has a 10" woofer and a 3½" tweeter and is virtually flat from 30 to 18,000 Hz. The system measures 23" high x 13½" wide x 10½" deep. The bookshelf HK-30 has an 8" woofer and 3" tweeter. It measures 17" high x 11¼" wide x 8" deep and has a virtually flat frequency response from 40 to 18,000 Hz.

Both speakers employ high-compliance woofers with one-pound magnet structures which move through an unusually long excursion to activate large volumes of air. The tweeters are isolated in their own critically designed acoustical chamber that provides a volume approximately six times that of the ordinary closed-back tweeter. Both have continuously variable high-frequency controls for adjustments to room environment and personal tastes. The systems are offered in oiled-walnut cabinets with changeable snap-out grille cloths, furniture protection pads, and 24 feet of plug-in speaker leads. Harman-Kardon

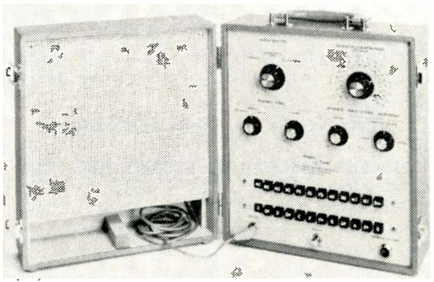
Circle No. 10 on Reader Service Card

ELECTRONIC TUNER-METRONOME

An electronic tuner-metronome, which differs from other tuning devices in its ability to sound any interval from a minor second to an octave at the touch of a button, is being marketed as the "Magna-Tuner."

The unit has 156 different fixed tones and 144 intervals, all selected by push-button. It is possible to sound the complete chromatic scales over a three-octave range, if desired, or two tones simultaneously for a study of intervals and harmony. The second tone of the interval is adjustable in pitch so just or tempered intervals can be selected at will.

The instrument is housed in a vinyl-covered carrying case which measures 7½" x 11" x 12½" and weighs 15 pounds. The unit is transistorized and operates on batteries. The metronome feature may be used alone or simultaneously with any of the single tones. A special output provides for



external switches so that tone and metronome signals can be remotely controlled with foot or hand switches. Electronic Research Products

Circle No. 11 on Reader Service Card

TRANSISTORIZED AUDIO PREAMPS

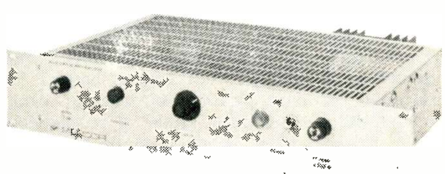
Two new high-gain audio preamps, designed for internal d.c. power operation, are being introduced as "Mix-Amps." These miniature transistorized devices provide uniform gain across the audio-frequency range and are particularly suited for increasing output of low-level microphones and reducing high-frequency-response loss in long microphone cable runs. They may also be used for impedance matching and fixed gain applications and, particularly, for boosting low-level outputs of attenuating networks and pads.

Models 503 and 504 have uniform response (± 1 dB) across the audio-frequency spectrum from 20 to 20,000 Hz. An impedance switch allows selection of "low" impedance output (2000 ohms) with 25 dB gain and a "hi" impedance output (35,000 ohms) with 6 dB gain. Complete specifications on these units will be supplied by the manufacturer on request. Switchcraft

Circle No. 12 on Reader Service Card

50-WATT MONITOR AMPLIFIER

A new 50-watt solid-state monitor amplifier featuring all-silicon semiconductors is now available as the Model AB-47. The unit is designed for a wide range of professional applications and may be used as a driver for disc cutting heads while an optional integral output autotransformer provides a 70-volt line for sound distribu-



tion and reinforcement systems. It can also be used to drive ultrasonic transducers or motors.

The class-B output circuitry of the amplifier is supplied from a self-contained power supply. If the output of the amplifier is short-circuited during operation, the dissipation limiting circuit is activated immediately. Under any condition, the amplifier will not sustain damage even if deliberately shorted.

Featured are bandwidth of 20 to 15,000 Hz, sensitivity of 70 mV to produce rated output, full power out for 4, 8, and 16 ohm outputs, high-impedance input, simple rugged construction, and easy servicing. Melcor

Circle No. 132 on Reader Service Card

30-WATT STEREO AMPLIFIER

A 30-watt stereo amplifier, the LA-224B, features a full range of stereo control facilities including these front-panel controls: 3-position input selector, 4-position mode switch, bass and treble controls for each channel, concentric volume/balance control, pilot light, rumble filter switch, phase reverse switch, speaker/headphone selector switch and power "on-off" switch, and headphone jack.

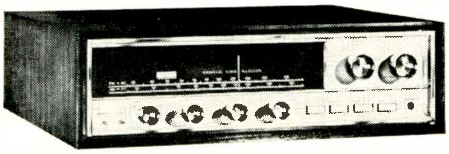
Frequency response is 25 to 25,000 Hz ±1.5 dB. Power output is 15 watts per channel, 30 watts mono. The rear panel has a speaker impedance switch permitting connection to either 8 or 16 ohm speakers.

The unit measures 14⅛" wide x 5$\frac{1}{16}$" high x 10½" deep. It has a gold anodized, extruded aluminum front panel. The amplifier is designed to operate from 105-125 volts, 50-60 Hz a.c. Lafayette

Circle No. 13 on Reader Service Card

ALL-SILICON AM-FM STEREO RECEIVER

The Model S-7800 AM-FM stereo receiver is an all-silicon-transistor unit rated at 130 watts music power at 4 ohms and 100 watts at 8 ohms with only 0.3% total harmonic distortion. IM distortion below 10 watts is 0.1%. The S-7800 combines low-noise AM circuitry with FM circuitry rated at 1.6 μV (IHF) and interchannel



hush. A specially designed dual automatic gain control system maintains proper selectivity under the strongest signal conditions.

The receiver also features noise-gated FM stereo/mono switching, instant indicator-light identification of FM stereo programming, a professional-type zero-center FM tuning meter, front-panel stereo headphone jack, and rocker switches for tape monitor, noise filter, and main and remote speaker switching.

Power bandwidth is 12 to 35,000 Hz at 1% distortion. The receiver uses 43 silicon transistors and 16 silicon diodes and rectifiers. Chassis size is 16½" x 14" x 4½". Sherwood

Circle No. 14 on Reader Service Card

CB-HAM-COMMUNICATIONS

PORTABLE TWO-WAY RADIO

The "Cambridge" portable two-way radio features a self-contained battery supply and provides communications in the 25 to 174 MHz range. It is compatible with any two-way FM system.

The all-transistor receiver permits the unit to be switched on for long periods of time without discharging the battery. The transmitter section has no need for a "standby" position. The transistors and quick-heating tubes permit immediate operation, plus longer battery life through reduction in standby current drain.

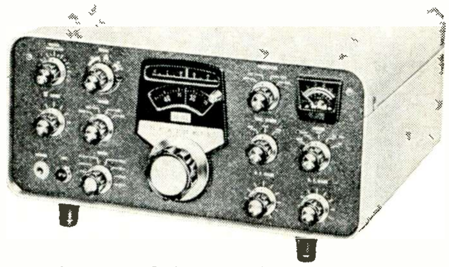
The unit comes with either a rechargeable 9-Ah battery or a nickel-cadmium battery of 6-Ah capacity. The former provides up to 60 hours operation on receive and up to 18 hours in a nominal ratio of tansmit-to-receive time.

The radio is being offered in either AM or FM versions, single or two-channel simplex. The full specifications on this unit will be forwarded on request. Aircraft Radio

Circle No. 15 on Reader Service Card

80-10 METER SSB TRANSCEIVER

A new 80-10 meter SSB transceiver, the SB-100, features a number of innovations said to be unique in amateur radio equipment. The new unit features five-band coverage with simple bandswitching and tune-up, alternate "remote" power supplies for fixed or mobile



operation, a "Switch-Board" coil and band-switch assembly, and a new automatic level control circuit for wide variation in speech level.

The crystal filter features a six-pole lattice filter (six individual crystals) to produce a 2:1 shape factor for sharper receiver tuning and greater sideband suppression. The filter passband is symmetrical for identical characteristics on both upper and lower sideband signals and for optimum SSB reception.

Transmitter power is 180 watts p.e.p. which is an ideal level for driving the majority of today's high-power linear amplifiers. Special features and circuitry have been incorporated, making the kit easy to construct and tune. Heath

Circle No. 16 on Reader Service Card

STANDARD FREQUENCY RECEIVER

A new standard frequency receiver, specifically designed to make full use of the tones and ticks as broadcast by stations WWV and WWVH, is now being marketed as the Model SR-7-F.

The new instrument contains a dual filtered output bridged across the existing audio output. The outputs, conveniently placed on the front panel, permit the selection of any two tones (1200, 1000, 600, 440 Hz) simultaneously. This is especially valuable where accurate starting or stopping of other equipment is desired, since the timing of the start and conclusion of the tones and ticks is held very accurately by the NBS. These filtered outputs are on BNC connectors.

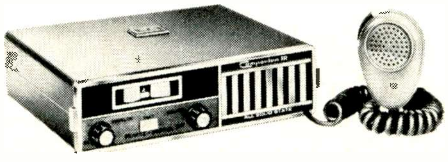
The receiver is a crystal-controlled front-end unit covering the 2.5, 5, 10, 15, 20, and 25 MHz bands with double conversion, a 2-MHz first i.f. and 175-kHz second i.f. The unit has an illuminated carrier level 'S' meter, speaker with "on-off" switch, unfiltered output, filter switches, and filtered outputs on the front panel. It measures 3½" high x 19" wide x 8½" deep. Specific Products

Circle No. 133 on Reader Service Card

SOLID-STATE CB UNIT

The "Companion III" is an all-solid-state, six-channel plus p.a. CB radio which measures only 2¼" high x 8½" wide x 6⅜" deep. It weighs 3 pounds.

This new unit features "Touch-Tap" tuning for instant channel selection—push the button



and the channel changes automatically. Other features include a chrome-plated die-cast front panel, front-panel speaker which permits dashboard mounting, a p.a. system jack, electronic switching, receive and transmit indicator light, push-pull audio amplifier, LC filter for sharp selectivity, squelch and automatic noise limiting circuitry, 100% modulation-automatic limiting, two r.f. stages in the receiver, and a corrosion-proof aluminum chassis. It comes complete with channel-9 crystals installed for immediate use on the H.E.L.P. monitored channel. Pearce-Simpson

Circle No. 17 on Reader Service Card

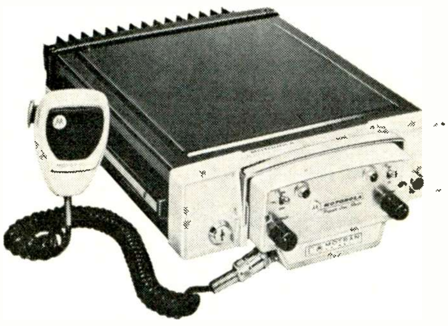
150-174 MHz TWO-WAY RADIO

A new all-solid-state two-way radio which operates in the 150-174 MHz FM service is being marketed as the "Motran."

The unit's receiver has been redesigned to permit off-channel frequency interference to be increased from 65 to 80 dB. The improved selectivity is especially important in areas heavily congested with radio transmitters. The new receiver can pick up usable signals as weak as 0.35 μV while an optional r.f. preamplifier improves this sensitivity to 0.175 μV.

Stability of the radio is ±5 parts per million and with optional high-stability "channel elements," it can be improved to ±2 ppm. Both receiver and transmitter stability are guaranteed over a temperature range of −35°C to +70°C.

The new unit operates and transmits the full 30 watts r.f. power output instantly over the



expanded temperature range. The elimination of the power supply in the radio makes this possible, permitting cooler operation and longer lasting circuitry. Battery drain is only 8.7 A for 30 watts r.f. power. Full technical details are included in Bulletins TIC 3133 and TIC 3134 which will be forwarded upon request. Motorola Communications

Circle No. 134 on Reader Service Card

MANUFACTURERS' LITERATURE

COMPONENTS CATALOGUE

A new 1966 catalogue of electromechanical components and equipment has been published. The 68-page, fully illustrated booklet, listing products of all major manufacturers, features gyros, a.c. and d.c. motors, pressure transducers, test equipment, trimmer potentiometers, and a special 20-page section on relays. American Relays

Circle No. 135 on Reader Service Card

AUTOMATED FILING

Complete information on the new "Videofile" document storage and retrieval system is offered in a new 12-page illustrated booklet (No. D001). Featured in the brochure is a detailed flow chart of document filing and retrieving, as well as an explanation of the concept of recording document images on magnetic tape.

In addition, a typical application of the system involving the industrial credit files of a large commercial bank is outlined. Ampex

Circle No. 136 on Reader Service Card

ELECTRONIC COMPONENTS

A new 92-page 1966 catalogue containing design data for a broad range of electronic components is now available. Specifications and illustrations are given for insulated terminals, encapsulation cups, weldab'e terminals, terminal boards, instrument-panel hardware and tooling, and retainers.

In addition, the company has issued a new 4-page illustrated brochure on its new "Orcon" lighted push-button switch. USECO Div., Litton Industries

Circle No. 137 on Reader Service Card

R.F. CONNECTORS

A new 28-page, fully illustrated catalogue (RF-2) which simplifies the selection and specification of r.f. connectors and coaxial cable is now available.

Thirty connector types are listed, along with various accessories and cable-matching information. Coaxial-cable data is presented in easy-to-read tabular form with cross-references to matching types of r.f. connectors. All cables that do not meet the latest version of MIL-C-17 are given in orange type.

Also included are tables of attenuation ratings and a page of mounting specifications. Amphenol Distributor Div.

Circle No. 138 on Reader Service Card

ALKALINE BATTERIES

Complete technical information on the "VO" series of rechargeable, encapsulated alkaline batteries is supplied in a new 4-page illustrated bulletin, No. VO-113a.

Using sintered-plate nickel-cadmium cells, the batteries are sealed to prevent loss of electrolyte, require no maintenance, and are capable of withstanding severe environmental conditions. Gulton

Circle No. 139 on Reader Service Card

AUDIO CONNECTORS

A new 8-page catalogue (No. C-503) covering a complete line of quality miniature audio connectors has been released. Over 90 plugs and receptacles are described, including straight cord and right-angle cord plugs and control and switching receptacles.

Also included in the fully illustrated brochure is a handy connector mating chart. Switchcraft

Circle No. 140 on Reader Service Card

RELAY CATALOGUE

Four hundred types of relays, including general-purpose, sensitive, power, pulse and telegraph, special-purpose, and high-performance, are fully described and illustrated in a new 16-page catalogue. Sigma

Circle No. 141 on Reader Service Card

FILTER INDUCTORS

Over 300 types of miniature inductors, used primarily in d.c. power-supply smoothing-filter applications, are listed in a new catalogue sheet (No. FL).

Both linear and "swinging" series are offered and each series is available in seven sizes. Magnetic Circuit Elements

Circle No. 142 on Reader Service Card

QUARTZ CRYSTAL UNITS

The processes used in manufacturing finished crystal units for filters and oscillators from raw quartz are described and illustrated in a new 6-page bulletin (QX65).

The booklet focuses on the cold-welding process, which provides seals with a leak rate of 10^{-9} cm^3 of helium per second or better. Reeves-Hoffman

Circle No. 143 on Reader Service Card

PHOTOCONDUCTIVE CELL MANUAL

A new designer's guide to utilization of photoconductive cells has been published and covers photocell theory, design, and properties from the application viewpoint.

Included in the 16-page manual are sections on spectral and color temperature response, sensitivity, temperature coefficients, response speed, light history effects, and maximum voltage. Also included are tabular and graphic data on seven photocell materials, available in more than 70 different types of photoconductive cells. Clairex

Circle No. 144 on Reader Service Card

ELECTROMECHANICAL SWITCHES

A new, updated, illustrated catalogue of electromechanical switches is currently available. It is designed to serve as a handy reference tool with authoritative details on hundreds of switches to meet the needs of the OEM market. Chicago Switch

Circle No. 145 on Reader Service Card

LOGIC HANDBOOK

An elaborate and comprehensive 352-page handbook incorporating material from catalogues, a logic handbook, a lab workbook, application notes, and computer brochures has been published covering "Flip Chip" modules.

Designed to be of assistance to all those who work with digital logic—from students to original equipment designers—the handbook contains 14 application notes, specifications and price information on more than 150 "Flip Chip" modules, extensive notes on analog-digital conversion theory and techniques, and several experiments for use with the "Logic Laboratory". Digital Equipment

Circle No. 146 on Reader Service Card

SEMICONDUCTOR DEVICES GUIDE

A handy, pocket-sized semiconductor cross-reference guide covering almost 4500 JEDEC and manufacturer-numbered transistors, rectifiers, diodes, and SCR's is available.

The 28-page guide is designed to fit the shirt pocket of the hobbyist, experimenter, and professional technician. Copies of the HMA07 cross-reference guide are available on request. Motorola Semiconductor

Circle No. 147 on Reader Service Card

POWER-SUPPLY CATALOGUE

Catalogue #661 lists more than 3800 solid-state power modules and laboratory power supplies with complete specifications and prices. Categories include regulated a.c.-d.c., unregulated a.c.-d.c., d.c.-a.c. inverters, d.c.-d.c. converters, d.c.-d.c. transformers, high-power, and wide-range adjustable modules. A broad spectrum of outputs and temperature capabilities is offered. The catalogue also includes installation data with specific information on heat dissipation requirements for all modules. Technipower

Circle No. 148 on Reader Service Card

SEMICONDUCTOR GUIDE

A new guide containing 32 transistor geometries with applications and package outline dimensions is now available. Also listed are the generic family classification of the transistors with their basic electrical parameters. The guide, in 16" x 21" chart form, enables design engineers to quickly select the proper Fairchild transistor for a specific application. Schweber Electronics

Circle No. 149 on Reader Service Card

ULTRASONIC ALARM SYSTEMS

A two-color, 8½" x 11" brochure entitled "Ultrasonic Alarm Systems" is now available on request. The publication describes proprietary, local, and portable alarm systems and shows how ultrasonic equipment—transmitters, monitors, master control units, batteries and battery chargers, local control instruments, and receivers—are connected. Schematics aid in the installation of the basic alarm system and the local alarm system.

The literature describes how each system works and the equipment needed. Walter Kidde

Circle No. 18 on Reader Service Card

R.F. SHIELDING MATERIALS

A new 6-page foldout brochure covering a complete line of "Eccoshield" r.f. shielding materials has been published. Conductive plastic sheets, tubes, gaskets, and O-rings; conductive surface coatings, adhesives, and lubricants; and metallic tapes and foils are offered.

Cross-references to technical bulletins are provided, as well as performance data and a table of properties. Emerson & Cuming

Circle No. 150 on Reader Service Card

TOOL CATALOGUE

Solid joint and slip joint pliers, alloy wrenches and wrench sets, snips, punches, and chisels are among the tools and other hardware contained in a new 20-page catalogue (No. K-165).

Also described in the booklet is a series of new displays that are designed for self-service pegboard merchandising, with each tool individually blister-packaged. Kraeuter

Circle No. 151 on Reader Service Card

INDICATOR TUBES

Complete technical information on a full line of "Nixie" indicator tubes and accessories is supplied in a new 30-page catalogue (No. 616C). Miniature, large, and jumbo tubes, standard and super devices, biquinary units, alpha-numeric displays, and special tubes are covered in detail with outline drawings, performance data, and tables of electrical specifications.

Also included is a 3-page technical memorandum and a 10-page section on applications information. Burroughs

Circle No. 152 on Reader Service Card

PRODUCT CATALOGUE

A new 72-page condensed catalogue, Bulletin SF66, has just been issued covering lines of integrated circuits, silicon transistors, germanium diodes, silicon diodes, silicon references, silicon zeners, silicon regulators and rectifiers, SCR's, special products, wire and cable, precision connectors, metal-film resistors, among others.

Information is presented in tabular form for easy location. Package outline drawings and mechanical specifications are provided in a separate section. Transitron

Circle No. 153 on Reader Service Card

PERMANENT MAGNETS

Complete technical data covering the effects of temperature and radiation on permanent magnet materials is the subject of a new 16-page booklet.

Intended primarily for the design engineer, the publication includes eleven pages of schematic diagrams, tables, and curves. General Magnetic

Circle No. 154 on Reader Service Card

TAPED MUSIC

A new 12-page illustrated brochure describing a wide range of music on tape available to radio broadcasters has been published.

Listed on a color-coded master chart are seven different taped services, including contemporary, traditional pop, light classic, and classical. The chart also distinguishes fully programmed and announced series from partially programmed, unannounced series. International Good Music

Circle No. 19 on Reader Service Card

DRY TRANSFER PRODUCTS

A new 40-page illustrated catalogue of "Deca-Dry" transfer products is now available. Serif, sans-serif, italic, and miscellaneous lettering styles are offered, as well as numbers and symbols. Custom sheets can be prepared to meet exact specifications.

In addition, the catalogue describes new "Roll Deca-Dry," which comes in a handy dispenser with a built-in burnishing tool. Chart-Pak

Circle No. 155 on Reader Service Card

TECHNICAL BROCHURE ON MOSFET's

A new eight-page technical bulletin, "Designing with MOS Field-Effect Transistors" has been announced. Written by Dr. J. Leland Seely, associate director of research and engineering, the brochure details the "ground rules" for designing circuits using MOSFET's as they differ from the basic design criteria appropriate to conventional bipolar transistors.

The illustrated bulletin describes the operation of the MOSFET, the approach to obtaining useful design equations, and the operation of varied MOSFET circuits. General Instrument

Circle No. 156 on Reader Service Card

TRANSFORMER & MOTOR LAMINATIONS

The comprehensive, 92-page catalogue, PE-122, covering laminations for transformers, motors, transformer hardware, drawn metal cans and cases, magnetic shields, and special magnetic products has been expanded, revised, and redesignated PD-122A.

The newly revised version features illustrations and physical dimensions on all laminations produced from high silicon, 50% nickel, and 80% nickel alloy materials, as well as keepers, ring, and notched motor types.

The catalogue also provides pertinent engineering data consisting of magnetic material properties shown by tables and graphs for unit comparison, computation, and specification purposes for design engineers. Arnold Engineering

Circle No. 157 on Reader Service Card

HEAT SINK CATALOGUE

A new 16-page fully illustrated catalogue of heat sinks and coolers (No. 1966) is now available. Included in the brochure are snap-on devices for circuit boards, featherweight semiconductor heat dissipators, radial-fin coolers, end- and foot-mounted king-size units, and forced convection heat sinks.

Also offered are nylon and Teflon mounting devices and thermal adhesives and joint compounds. Wakefield

Circle No. 158 on Reader Service Card

INTEGRATED CIRCUITS

Over 200 different PEC integrated circuits that are currently available from electronic parts distributors are listed in a new 20-page integrated circuit replacement guide and catalogue.

The booklet is indexed by type of circuit as well as by circuit function. Detailed alphabetical listings of 191 manufacturers with 1600 replacement applications in equipment using these circuits are supplied, together with cross-references to other manufacturers of packaged circuits. Centralab

Circle No. 159 on Reader Service Card

ELECTRONIC TEST ACCESSORIES

A new general catalogue, No. 11-66, describes a complete line of molded electronic test accessories including molded patch cords, cable assemblies ½" and ¾" spaced molded banana plugs, molded test leads, connecting leads, "black boxes", shielded "black boxes", socket savers, and test socket adapters.

The 32-page publication includes photographs, specifications, dimensions, schematics, operating ranges, and prices on all listed items. Pomona Electronics

Circle No. 160 on Reader Service Card

PLUG-IN POWER SUPPLY

Information on the "Pow-A-Meter" adjustable plug-in power supply that has its own built-in voltmeter is contained in a new 4-page illustrated brochure.

The compact, lightweight instrument plugs directly into a breadboard and is completely portable. It provides a constant in-circuit check and requires no derating or additional external heat sinking. Acopian

Circle No. 161 on Reader Service Card

AUDIO/VIDEO BROCHURE

A 6-page illustrated brochure containing a varied line of audio, video, and tape products for broadcast applications is now available. Closed-circuit TV systems, vidicon cameras, low-cost videotape recorders, language laboratory equipment, and audio and video tapes are included in the folder (A-044). Ampex

Circle No. 162 on Reader Service Card

ASA 1966 STANDARDS CATALOGUE

The American Standards Association has announced publication of its new 1966 standards catalogue which is available to industry without charge.

The publication contains a listing of American Standards on subjects ranging from acoustics to zinc. Reflecting the approval during the past year of some 400 new and revised standards, the 100-page catalogue lists all standards approved through December 31, 1965, which now number more than 2700.

Copies of the catalogue are available from the Association, Room 906, 10 East 40th Street, New York, New York 10016.

CAPACITOR REPLACEMENTS

An expanded and up-to-date edition of the company's Electrolytic Capacitor Replacement Manual is now off the press. Expanded to include nearly 100 more set suppliers not found in the previous edition, Manual K-108 now covers 389 different makes from Acme to Zephyr, including TV sets as well as home, auto, portable radios; tape recorders; and antenna rotators manufactured from 1947 up to November 1965.

Copies of the 64-page manual are available free from any Sprague Electric Company distributor.

COLOR-TV COMPONENT REPLACEMENTS

A 66-page, reference-size (3¾" x 8½") booklet, ETR-4286, offers the most complete color-TV component replacement guide in the industry. The publication covers 35 manufacturers of TV sets and lists by individual chassis, G-E replacement capacitors, diodes, transistors, rectifiers, crystals, receiving tubes, and picture tubes for each original part.

Printed in two colors, the guide will enable service technicians to make color-TV calls with a much lower inventory because four of the company's picture tubes meet over 95 percent of all color replacement needs.

A copy of the guide is available only through authorized General Electric electronic components distributors.

DATA ON NBS SERVICES

Complete, up-to-date information on the many services provided by the National Bureau of Standards radio stations WWV, WWVH, WWVB, and WWVL is now being offered by Specific Products, 21051 Costanso Street, Woodland Hills, California.

The standard time and frequency transmissions of these stations provide an invaluable service to laboratories and experimenters and the proper use of these facilities can supplement the instrumentation in any laboratory.

Included in the 12-page booklet are hourly broadcast schedules with supporting data and a great circle map of the northern portion of the Western Hemisphere. ▲

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GENERAL INFORMATION: First word in all ads set in bold caps at no extra charge. Additional words may be set in bold caps at 10¢ extra per word. All copy subject to publisher's approval. **Closing Date:** 1st of the 2nd preceding month (for example, March issue closes January 1st.) **Send order and remittance to:** Hal Cymes ELECTRONICS WORLD, One Park Avenue, New York, New York 10016

FOR SALE

JUST starting in TV service? Write for free 32 page catalog of service order books, invoices, job tickets, phone message books, statements and file systems. Oelrich Publications, 6556 W. Higgins Rd. Chicago, Ill. 60656.

GOVERNMENT Surplus Receivers, Transmitters, Snooperscopes, Radios, Parts, Picture Catalog 25¢. Meshna, Nahant, Mass. 09108.

INVESTIGATORS, FREE BROCHURE, LATEST SUBMINIATURE ELECTRONIC SURVEILLANCE EQUIPMENT. ACE ELECTRONICS, 11500-J NW 7TH AVE., MIAMI, FLA. 33168.

CANADIANS—Giant Surplus Bargain Packed Catalogs. Electronics. Hi-Fi, Shortwave, Amateur, Citizens Radio. Rush $1.00 (Refunded). ETCO. Dept. Z, Box 741, Montreal. Canada.

RESISTORS precision carbon-deposit. Guaranteed 1% accuracy, ½ watt 8¢. 1 watt 12¢. 2 watt 15¢. Rock Distributing Co., 902 Corwin Road, Rochester 10, N.Y.

NEW supersensitive transistor locators detect buried gold, silver, coins. Kits, assembled models. $19.95 up. Free catalog. Relco-A22, Box 10563, Houston 18, Texas.

JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266, Spokane, Washington 99207.

WEBBER Labs. Transistorized converter kit $5.00. Two models using car radio 30-50Mc or 100-200Mc, one Mc spread. Easily constructed. Webber, 72 Cottage, Lynn, Mass.

CANADIANS, transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics (Dept. EW), P.O. Box 1437 Winnipeg, Manitoba, Canada.

TRANSISTORS—Miniature Electronic Parts. Send for Free Catalog. Electronic Control Design Company, P. O. Box 1432M, Plainfield, N.J.

METERS—Surplus, new, used, panel and portable. Send for list. Hanchett, Box 5577, Riverside, Calif. 92507.

TRANSISTORIZED Products Importers catalog. $1.00. Intercontinental. CPO 1717, Tokyo, Japan.

MESHNA'S TRANSISTORIZED CONVERTER KIT $4.50 Two models——converts car radio to receive 30-50 mc or 100-200 mc (one mc tuning). Meshna, Lynn, Mass. 01901.

R.F. CONVERTERS World's largest selection. Also CCTV cameras, transmitters, etc. Lowest factory prices. Catalog 10¢. Vanguard, 196-23 Jamaica Ave., Hollis, N.Y. 11423.

CONVERT any television to sensitive big-screen oscilloscope. Only minor changes required. No electronic experience necessary. Illustrated plans, $2.00. Relco-A22, Box 10563, Houston 18, Texas.

ELECTRONIC Ignition Kits, Components Free Diagrams. Anderson Engineering, Epsom, New Hampshire 03239.

INVESTIGATORS: PROFESSIONAL AND AMATEUR: Amazing Electronic Device inhibits radio communication and may obsolete present day equipment. For information send $1.00 to J.B. Jones Co., Box 43B, Anaheim, Calif.

SURVEILLANCE EQUIPMENT—NEW HIGH PERFORMANCE SUBMINIATURE MODELS. ELECTRONIC COUNTERMEASURE DEVICES TO PROTECT PRIVACY. FREE DATA: SECURITY ELECTRONICS-EW, 15 EAST 43RD STREET, NEW YORK, N.Y. 10017.

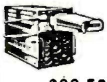
ELECTRONIC DEVICES—Kits or assembled. For **CAR, HOME** and **BOAT**. Catalog Free. **EARN MONEY** selling these useful items. Write for details. Electronic Products Co., Dept. F, Box 8485, St. Louis, Mo. 63132.

ELECTRONIC Secretary automatic telephone answering machine, $175.00. J.L. Orysen, 2025 Sunkist, Waukesha, Wisc. 53186.

ATOM Smashers. Simple construction plans for particle accelerators $3.00. Includes free booklets on radiation hazards and experiments. Formula Research. Box 147-EJ, Lafayette, Indiana 47902.

COMPUTER Building modules for Experimentors. Flip-Flops, And Or, Nand, Nor Gates. Write R. Carito, 43-17 54th St., Woodside, N.Y. 11377.

LORAN R-65/APN-9 RECEIVER & INDICATOR



Used in ships and aircraft. Determines position by radio signals from known xmitters. Accurate to within 1% of distance. Complete with tubes and crystal. IN LIKE NEW Condition.......... $89.50

Used, with all parts, less tubes, crystal and visor ....Special $29.50

Shock Mount for above...........................$2.95
Circuit diagram and connecting plugs available.

AN/APR-4Y FM & AM RECEIVER "FB" FOR SATELLITE TRACKING!

High precision lab instrument, suitable for monitoring and measuring frequency and relative signal strength of signals from 38 to 4000 Mc., in 5 tuning ranges. For 110 volt 60 cycle AC operation, built-in power supply. Original circuit diagram included. Checked out perfect. **LIKE NEW** $88.50

All tuning units for above, TN-16, TN-17, TN-18, TN-19 TN-54 in stock ......................**P.U.R.**

ARR-15 Collins Receiver. 1.5 to 18.5 Mc. Tunable, with Collins PTO and calibrator (written up in "73" mag.) Complete with tubes.
Like New **$65.00**

LORAN APN-4
FINE QUALITY NAVIGATIONAL EQUIPMENT

Determine exact geographic position of your boat or plane. Indicator and receiver complete with all tubes and crystal.
INDICATOR ID-6B/APN-4, and RECEIVER R-9B/APN-4, complete with tubes. Exc. Used **$88.50**

Shock Mount for above **$2.95**

SCR-522 2 METER TRANSMITTER-RECEIVER

VHF Transmitter-Receiver, 100-156 Mc. 4-channels. Xtal-controlled. Amplitude modulated voice. Complete with all 18 tubes, top rack and metal case. Exc. Cond. **$44.50**

AN/ARR-2 Receiver, 234-258 Mc. Complete with 11 tubes. Brand New **$11.95**
Exc. Used ....**$ 7.95**

BC1206-C BEACON RECEIVER 195 to 420 Kc. made by Setchel-Carlson. Works on 24-28 volts DC. 135 Kc. IF. Complete with 5 tubes. Size 4" x 4" x 6". Wt. 4 lbs. LIKE NEW **$12.95**
USED ....less tubes **$ 7.95**

BC-929 3-inch Scope, with all tubes,
LIKE NEW **$18.95**
Conversion instructions, with diagram for 110 V AC operation ....**$ .65**

SCR-625 MINE DETECTOR
Complete portable outfit in original packing, with all accessories. Excellent. Used **$32.50**

LM Freq. Meter, Modulated, 125 Kc to 20.000 Kc. With Calibration Book, Like New **$79.50**
As above, less Calib. Book, exc. used.......**$34.50**

BC-221 FREQUENCY METER
Equipped with original calibration charts. 125Kc. to 20,000 Kc with crystal check points in all ranges. Excel. Used with original Calibration Book, Crystal, and all tables. CHECKED OUT.
Unmodulated **$79.50**

BC-221 1000 Kc Crystal Brand New............5.95
BC221 FREQ. METER CASE, aluminum with volt. reg. supply. Shock mounted. BRAND NEW....**$3.95**

EE-8 FIELD PHONES

Checked out, perfect working order. Complete with all parts. Excellent Condition. LIKE NEW!
Each **$16.50**

SCR-274 COMMAND EQUIPMENT

ALL COMPLETE WITH TUBES Type Description	Used	Like New	BRAND NEW
BC-453 Receiver 190-550 Kc.	$14.95	$18.95	P.U.R.
BC-454 Receiver 3-6 Mc.	$15.95		$24.50
BC-455 Receiver 6-9 Mc.	$13.95	$19.50	$24.50

BC946 Receiver, 550-1500 Kc. Complete with all tubes. Brand New, in original packing **$48.50**
1.5 to 3 MC. Receiver Brand New **$24.50**

110 Volt AC Power Supply for all 274 N and ARC-5 Receivers. Complete with metal case, instructions. Factory wired, tested, ready to operate **$12.50**

SPLINED TUNING KNOB for 274-N and ARC-5 RECEIVERS. Fits BC-453, BC-454 and others. Only .... **49¢**

2.1 to 3 Mc. Transmitter. Brand New **$12.95**
BC-458 TRANSMITTER—5.3 to 7 Mc. Complete with all tubes and crystal
BRAND NEW **$13.95**
Like New **$8.95**
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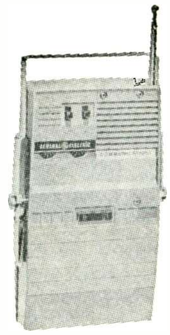

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1H5	1.50	6B4	5.95	6Y6GA	.90	14A7	2.25
1LA4	1.95	6B7	2.75	6Z4 84	1.25	14AF7	2.25
1LA6	1.98	6B8	2.66	7A4	2.25	14B6	2.25
1LB4	2.50	6BA6	.68	7A5	2.05	14B8	2.25
1LC6	1.80	6BA8	1.35	7A6	2.69	14C5	2.25
1LD5	1.95	6BE6	.81	7A7	2.70	14C7	2.33
1LE3	1.95	6BH6	.95	7A8	2.95	14E6	2.25
1LH4	2.80	6BH8	1.35	7AD7	1.25	14E7	2.25
1LN5	2.25	6BK5	1.35	7AF7	2.34	14F7	3.10
1N5	1.85	6BK7	1.20	7AG7	2.85	14F8	2.23
1P5	2.00	6BQ6	1.42	7AH7	1.95	14H7	2.25
1R4	.80	6BQ7	1.18	7AU7	.93	14J7	2.25
1R5	1.10	6BX7	1.93	7B4	2.52	14N7	2.25
1S5	1.10	6C4	.64	7B5	3.00	14Q7	2.25
1T5	.80	6C5M	1.95	7B6	1.90	14W7	2.25
1U4	1.05	6C6	2.50	7B7	2.85	14X7	2.25
1U5	.98	6C8G	2.95	7B8	2.14	14Y7	2.25
1V	2.00	6CA7	2.59	7C4	1.15	14Y4	1.75
1V2	.83	6CG7	.75	7C5	1.25	19	1.00
1V6	2.75	6CG8	.95	7C6	2.75	22	1.15
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3Q5	2.00	6DQ5	2.25	7S7	2.50	35L6	1.05
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4CB6	.82	6F6G	1.95	7Y4	2.35	36	1.50
5AM8	1.40	6F7	4.39	7Y7	1.79	37	1.25
5AN8	1.55	6F8	3.08	7Z4	2.35	38	1.25
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5AS8	1.64	6HZ8	2.38	8BQ5	1.18	41	1.50
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5X8	1.30	6L7M	2.58	12AT7	.74	50L6	1.10
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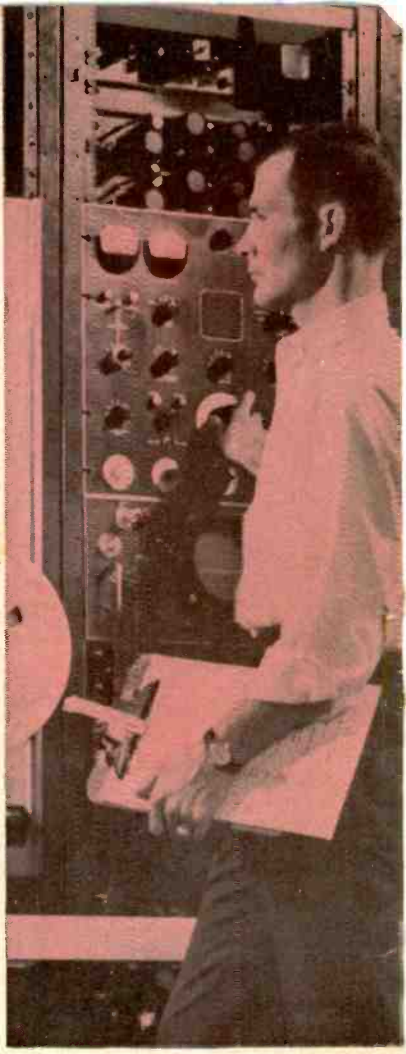

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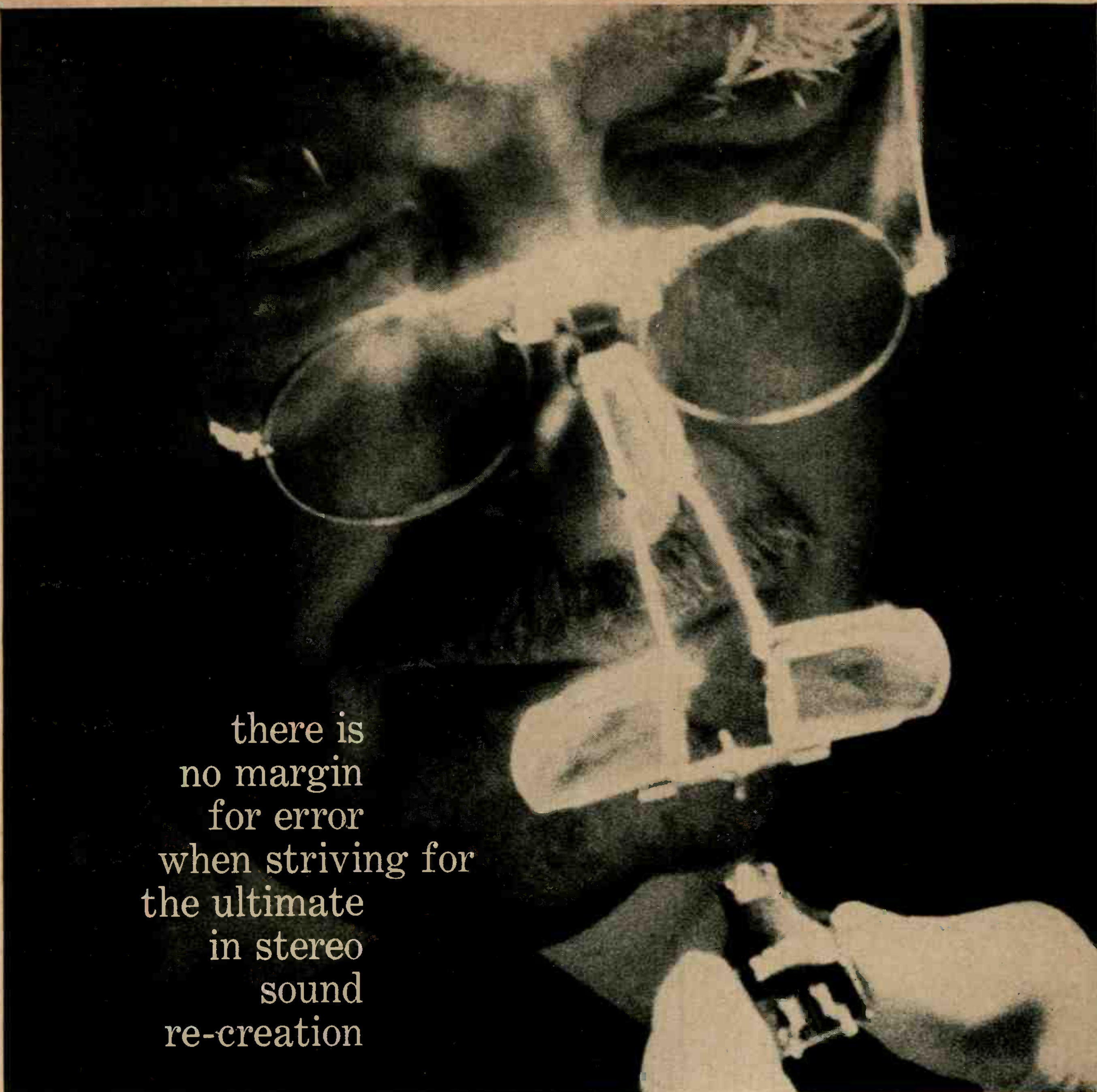

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THIS MONTH'S COVER shows a selection of five battery-powered tape recorders currently available. Progressing clockwise starting at the lower left are: the Concord F-85 "Sound Camera"; the Norelco 101; the Roberts 6000; the Norelco 150; and the Sony 6000. These five are only a small sample of a number of better-quality battery-powered tape recorders whose characteristics are covered in directory form in this issue. These machines run the gamut from restricted-range voice recorders to high-quality units suitable for broadcast use. They come either as monophonic or stereo systems and each is complete within itself, carrying its own power source and microphones. Their light weight makes them ideal for field use. Photo: Bruce Pendleton

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AUGUST 1966 VOL. 76, No. 2

CONTENTS

MONTHLY FEATURES

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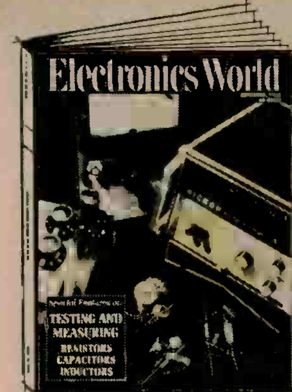
COMING NEXT MONTH



DESIGNING SILICON-TRANSISTOR HI-FI AMPLIFIERS

The first article of a three-part series by R. D. Gold and J. C. Sondermeyer of RCA covers the advantages of silicon power transistors in power output and driver stages. Subsequent articles will deal with design and performance parameters and practical circuits.

TESTING & MEASURING INDUCTORS

The methods and equipment used to measure inductance, self-resonance, distributed capacitance, and "Q" of air-core and iron-core coils are covered in this in-depth article by Sam Zwass of Triad.

SELECTING THE PROPER SWITCH

Switch materials and design are important factors in circuit performance. Bernard Golbeck of Oak outlines selection criteria and provides pertinent data on various materials used in switches.

TESTING & MEASURING CAPACITORS

R. C. Lynds and D. Quimby of Cornell-Dubilier discuss performance tests, instruments used to run such tests, and permissible tolerances for all types of capacitors in this comprehensive and informative article.

MEASURING INSTRUMENTS FOR ELECTRONIC COMPONENTS

A wide variety of general-purpose and special-purpose test equipment is available for measuring resistors, capacitors, and inductors. Fred Van Veen of General Radio sets forth guidelines for making a suitable choice for the job at hand.

TESTING & MEASURING RESISTORS

What the previously listed articles do for inductors and capacitors, this article by Fred Stern of IRC does for the resistor. In concise form, the author outlines various tests designed to insure performance within specifications.

TIME DOMAIN REFLECTOMETRY

John D. Lenk describes a useful laboratory technique for measuring transmission-line characteristics by means of a step generator and an oscilloscope.

*All these and many more interesting and informative articles will be yours in the September issue of ELECTRONICS WORLD . . . **on sale August 18th.***

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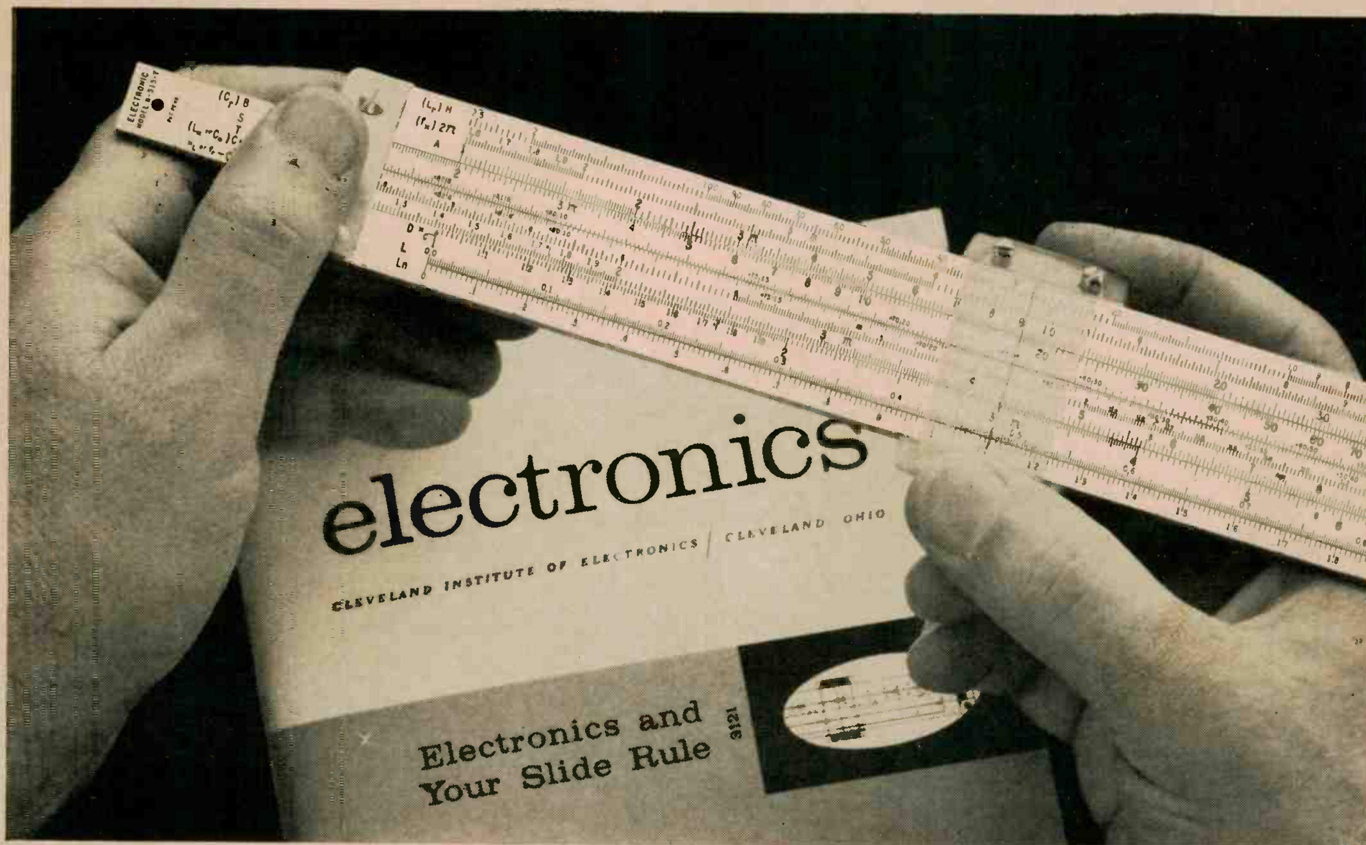

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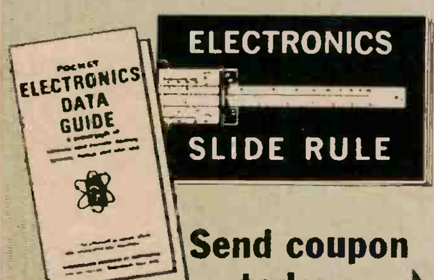

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For the record

WM. A. STOCKLIN, EDITOR

ELECTRONIC SALES SETTING RECORDS

In our editorial of March 1960, we predicted that this decade would go down in history as "The Electronic Decade" and shortly thereafter, in October, we referred to "The Soaring Sixties."

It seemed obvious at that time that the electronics industry would continue to set records, but little did we realize the degree of growth that would be attained. Factory sales of electronic products are expected to reach a fantastic total of $19.3 billion this year. Thus, in only seven years, sales will have more than doubled the $9.2 billion total in 1959.

According to Dr. Harper Q. North, president of EIA, "Business in electronics is booming." This year's sales should exceed 1965's record by 11.5% and, if the present trend continues, EIA's 5-year forecast predicting a $21 billion level will be reached in 1967 instead of 1968.

All segments of our industry showed growth. However, the greatest increase is in the consumer products area, with $4.43 billion sales predicted in 1966 compared with $3.67 billion in 1965. This represents a 20.7% growth.

Color television, of course, is playing the major role in setting new all-time sales records. EIA's most recently revised forecast estimates that about 5.4 million color-TV sets will be sold this year. This will be double the 1965 record. For the first three months 942,000 color sets were sold compared with 481,000 for the same period in 1965. Even black-and-white TV sets have been holding their own with 1.9 million sold during the first three months of both 1965 and 1966.

The sale of color-TV sets has sparked the entire components industry. Total component sales will be up 9.6% over 1965, replacement components up 2.4%.

Industrial electronic sales will be up 14.2% this year over 1965 and sales of electronic equipment to the government is running at an increased rate of 7%.

Optimism persists throughout the entire industry. It was evident at the IEEE Show in New York in March; at the Hi-Fi Institute Show in Los Angeles in April; and, more recently, at the National Electronics Week (NEW) Show in San Francisco in June.

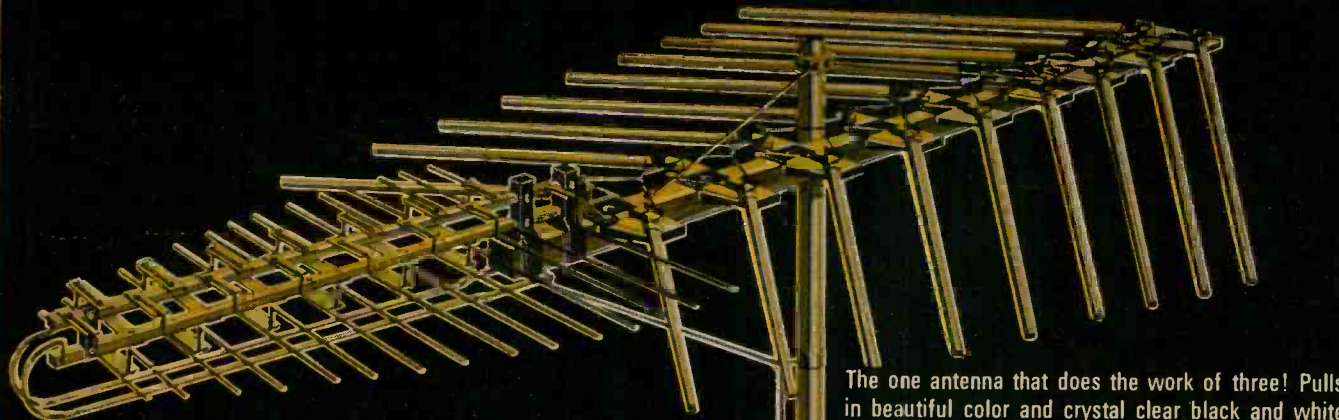
All three shows were extremely well attended, but those who had hoped to see developments of major importance or break-throughs were, for the most part, disappointed. Certainly there were changes but most of them were relatively insignificant. Of some importance was the realization of the potential markets for video-tape machines for the home and industry, and audio-tape cartridge machines for cars and boats. Most of the products themselves showed no major changes over last year, but the realization that these will add two new segments of tremendous potential to our industry is significant. It is inevitable that in any period where there is a sellers' market not much is done to redesign or develop new products.

The NEW Show, however, served a dual function. In addition to the normal exhibits, the show sponsored, under the direction of Gail Carter of NEDA, a "Profit Forum." Four simultaneous educational programs designed for electronic distributors, manufacturers, and their sales representatives took up a full day. Many of our industry's leading executives covered such subjects as modern information systems; descriptions of available business machines; explanation of a new data processing system for instant order handling; new concepts in merchandising; along with special sessions on selling. In addition, a panel of management consultants offered advice on such subjects as inventory and data processing; product control; business analysis and pre-planning; executive development and training.

This is the second year in which these Profit Forums have been presented and they were extremely well attended.

With any accelerated growth similar to what we have encountered in the past few years, problems do arise. Manufacturers are faced with expansion, automation, cost reduction, and employee training problems. Parts distributors are confronted with similar problems and also those unique to their type of operation. It is in this area that the NEW Show played a vital role.

In order for our industry to grow, it is necessary that all segments—management, sales, distribution, and manufacturing—progress simultaneously. All the help that we can get in these areas will be needed to make this decade "The Soaring Sixties." ▲



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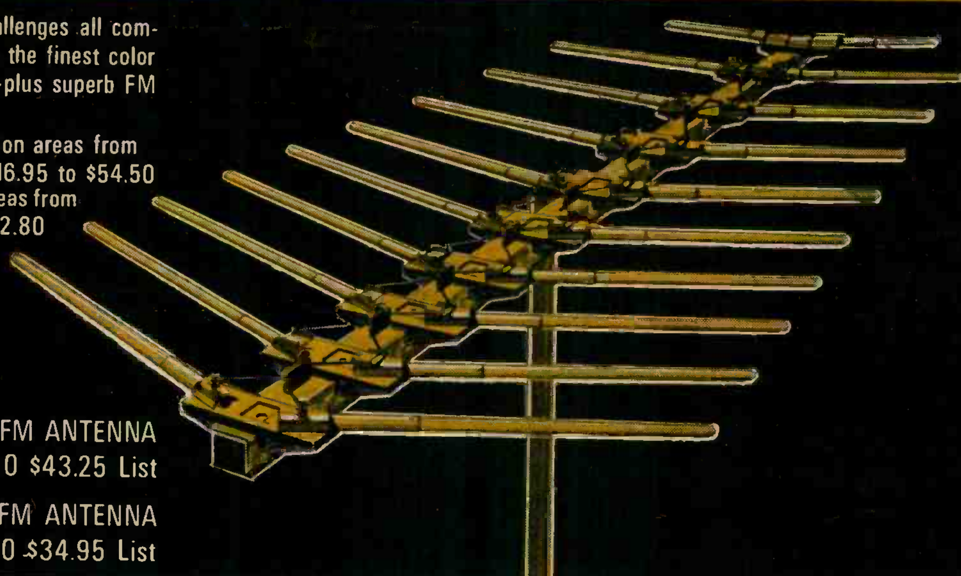

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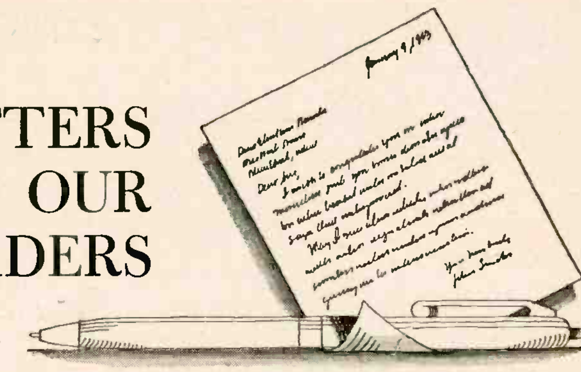
LETTERS FROM OUR READERS



TESTING DIODES

To the Editors:

I enjoyed reading the article "Testing Diodes" by Donald Ludwig (January, 1966, p. 95). Here on the Atlantic Missile Range, computers are an everyday working tool. These computers use millions of diodes of all types; therefore, a thorough knowledge of testing techniques is valuable to the technician who is required to maintain these complex devices. Don's article contributes to this knowledge with a direct, practical approach.

The subject of diode testing brings to mind an interesting experience that happened recently while a friend and I were building a limiting amplifier for a local radio station. Since the station had a fully equipped work area, we started construction with a blank chassis and a handful of components. For diodes, we selected (from the station's spare parts drawer) a number of 1N34's. Using an ohmmeter we checked forward resistance, reversed the diode to read backward resistance—and the meter needle deflected *backward*, against the peg! The same thing happened on *all* the diodes we checked: forward reading—OK; reverse reading—impossible.

At home that evening, I measured one of the diodes—forward resistance was less than 100 ohms; reverse resistance, 65,000 ohms. Obviously, our v.o.m. at the station was defective, I thought, so tomorrow I'll take my own with me.

The next day at the station, using my own meter, the same thing happened—forward resistance OK, although somewhat less than 100 ohms; reverse reading, needle pegged backwards.

Putting this resistance problem aside, we built the limiting amplifier, installed it, and checked it out. It worked perfectly (even though our 1N34 diodes measured strangely).

About two weeks later, while building an s.w.r. meter for my amateur radio station, the answer to the diode problem was found. We had neglected to consider the strong r.f. field at the radio station. Since the station's workshop was within 100 feet of its antenna, 1000 watts of power induced a considerable voltage into the v.o.m. leads. This induced voltage was rectified (by the diode under test) and effectively converted our ohmmeter into a field-strength meter, giving us the mysterious reverse-pegged meter indication.

On closing, I wish to comment on your selection of fine articles that appear every month. These articles, along with your over-all editorial policy, will keep your publication on my bookshelf for a long time to come.

FRANK J. LUTZ, JR.
Satellite Beach, Fla.

° ° °

R.M.S. POWER

To the Editors:

Why do you, along with so many other technical publications, persist in using the fictitious, non-existent term "r.m.s. power" when what you really mean is *average power?* When you measure the r.m.s. voltage across the loaded output of an audio amplifier, square it, and divide by the value of the load resistance, your result is *not* r.m.s. power at all: it is simply *average* power.

After all, the whole concept of r.m.s. voltage and current was developed in the first place to obtain effective values of voltage and current that would produce the same average heating effect or power as do similar values of d.c. voltage and current.

JOHN MURRAY
San Francisco, Calif.

Strictly speaking, Reader Murray is correct, and we prefer the more technically correct term "average power" or "continuous power." However, in a few cases, we have gone along with a good many hi-fi manufacturers in using the term "r.m.s. power" just to make sure that the reader understands that this is the power calculated from the value of r.m.s. rather than average voltage and current.

While we are on the subject, we would also like to point out that what many in the audio-recording industry call "peak power" or "power on peaks" is not *instantaneous peak power (which is double the average power for sine-wave signals). A vu recording meter, for example, does not indicate and cannot follow instantaneous peaks but rather*

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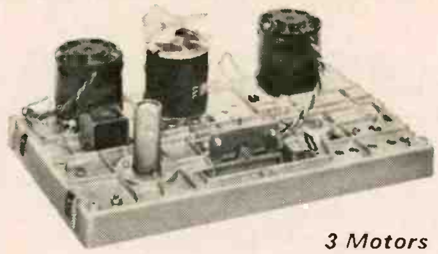

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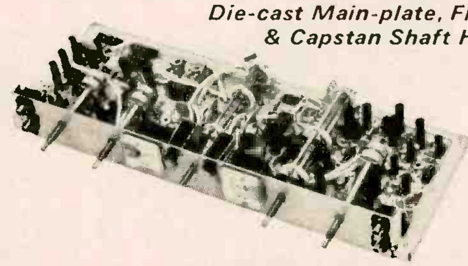

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With the 1020, you can record "live" from microphones, or from auxiliary sources like tuners, phonographs, TV's, etc., and playback . . . in 4-track stereo or mono at either 7½ or 3¾ ips. And you can make sound-on-sound, or sound-with-sound (mixing) recordings, or create interesting echo effects.

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The military-type differential band brakes are solenoid operated for instant, gentle stops. And when the tape runs out an automatic switch shuts off all motors and retracts the tape pressure roller eliminating unnecessary motor wear and prevents deformation of rollers. The tape gate and pressure roller also are solenoid-operated for positive action.

3 Professional Tape Heads

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Other Professional Features

All parts mount on a thick, die-cast main-plate that won't warp, reduces wear, provides rigid support and stable alignment. Two V.U. meters for visual monitoring of signal levels from either tape or source . . . allows quick comparision of source with recorded signal. Inputs for microphones and outputs for headphones are all front-panel mounted for easy access. Digital counter with push button reset. Low impedance emitter-follower outputs deliver 500 millivolts or more to amplifier inputs. Individual gain controls for each channel. And all solid-state circuitry . . . 21 transistors and 4 diodes . . . your assurance of cool, instant operation, long reliable life.

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RADIATION MEASUREMENTS IN SPACE

By JOSEPH H. WUJEK, Jr.

Many types of radiation are encountered in space. Here is a description of the most commonly encountered along with the techniques employed in their detection and measurement.

IN 1896, the French physicist Henri Becquerel observed that certain substances emit radiations. A photographic plate which had been stored close to some uranium salts became fogged, as though partially exposed. From this observation, Becquerel deduced that the uranium was radiating particles, or rays, which caused the photographic exposure. Two years later, the French scientists Pierre and Marie Curie succeeded in isolating a minute amount of radioactive radium from tons of pitchblende ore. Here, then, was the dawn of what writers have since called the Atomic Age.

Kinds of Radiation

Alpha (α) particles are ions of helium having a positive charge of +2. *Beta* (β) rays are free electrons, not bound to a nucleus, which have a charge of −1. *Gamma* (γ) rays may be thought of as high-energy x-rays and are uncharged. A proton is a particle of +1 charge having a mass approximately 1840 times greater than that of an electron.

Hydrogen is normally composed of atoms which have one proton and one electron as shown in Fig. 1A. An isotope of hydrogen is deuterium, which has a nucleus consisting of one proton and one neutron, and an electron outside the nucleus (see Fig. 1B). Isotopes are simply atoms of the same element which have a different nuclear mass due to the presence of more or less neutrons. Neutrons are uncharged particles which have a mass nearly the same as that of protons. An atom of deuterium which has had its electron removed is called a deuterium ion, or deuteron (see Fig. 1C). Ions of heavier elements are also found in space. One other particle also of interest in space research, the positron, has a mass equal to that of an electron but is of opposite charge, +1.

Space Radiation

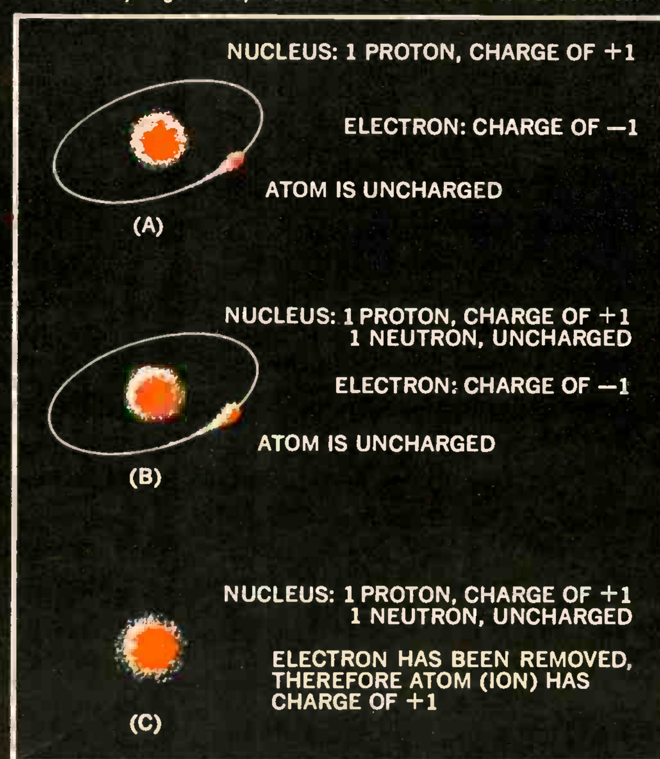
In broad terms, types of radiation may be classified as follows:

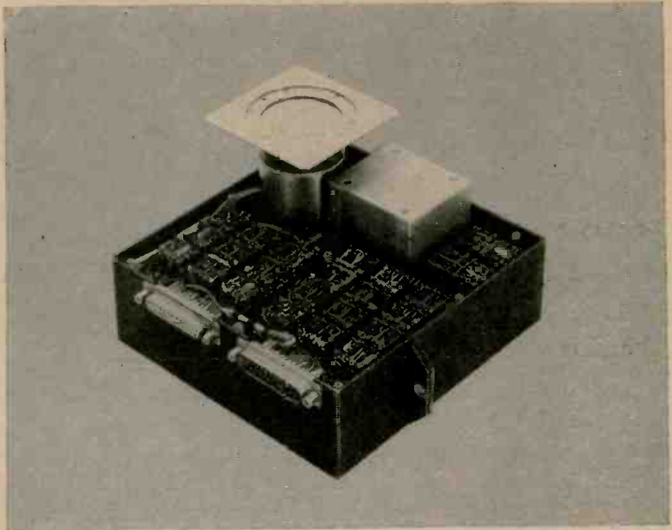
Primary Cosmics. These are particles and rays which bombard the earth from deep space. Fortunately, most of the cosmic showers are attenuated by the earth's atmosphere. Cosmic rays are a collection of protons, deuterons, *alphas*, electrons, *gammas*, positrons, and nuclei of atoms.

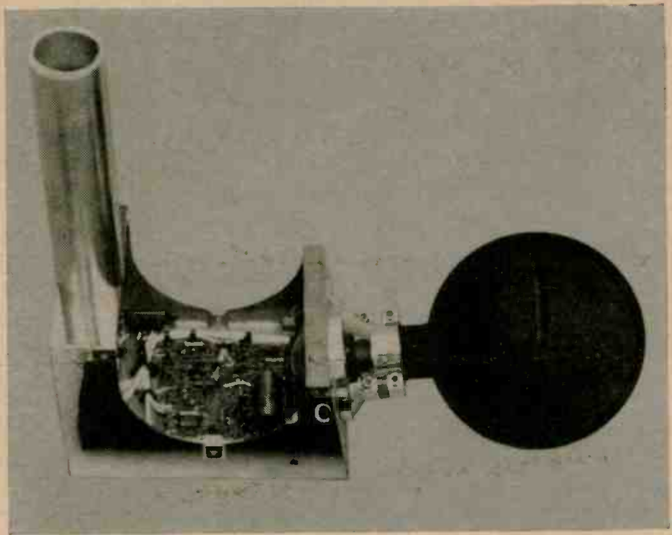
Solar Particles. These particles emanate from the sun and vary in quantity (flux) as the sun is "quiet" or "stormy." The composition is similar to primary cosmics but normally includes x-rays as well.

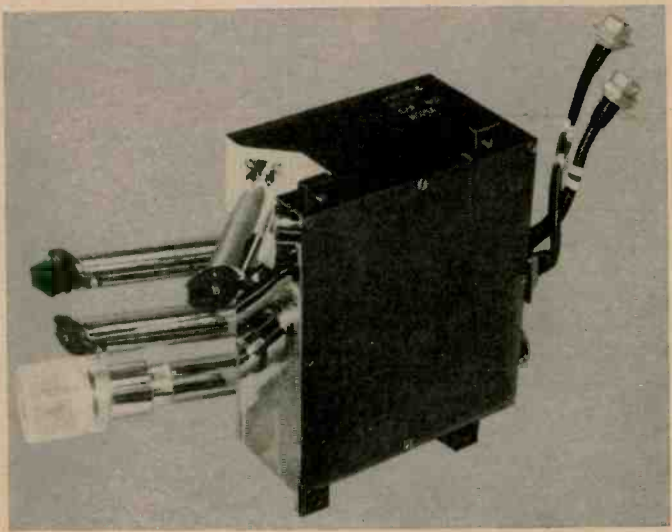
Trapped Radiation. This refers to the now-famous Van Allen belts, named for the State University of Iowa physicist who first propounded them. The belts are maintained by the action of the earth's magnetic field upon protons and electrons. Inner and outer belts are known to exist, and each is roughly doughnut-shaped, with weaker fluxes above the

Fig. 1. Variations of hydrogen. (A) Simple hydrogen atom. (B) The hydrogen isotope deuterium. (C) Deuterium ion or deuteron.









Radiation experiments carried in Mariner-IV (Mars) satellite. (Above left) Cosmic-ray telescope using solid-state detectors. (Above) Ionization chamber experiment using a five-inch stainless-steel sphere. (Bottom left) Trapped radiation experiment.

earth's poles. The belts were discovered by Explorer I in 1958.

Solar Wind. The solar wind is a swarm of protons, electrons, and possibly ions of heavy atoms which forms a lengthy plasma.

In measuring space radiation, the experimenter ideally seeks to determine what kind of particles are present, how many particles pass through a given area in a given time, from what direction in space the particles emanated and in what direction they are headed, and the energy and speed of the particles.

The energy unit most commonly used in nuclear physics is the electron-volt (eV). One electron-volt is the energy imparted to an electron when accelerated through one volt of potential. Thus, an electron which is accelerated from cathode to plate of a 15-kV electron tube has an energy of 15,000 eV, or 15 keV. An electron accelerated across one million volts has one million electron-volts (1 MeV) of energy. In space, particle energies of a few eV to about 10^{20} eV are present, but instruments are limited as to the energies which may be resolved.

The results of measurements are usually displayed as a spectrum, such as the hypothetical plot shown in Fig. 2 which illustrates electron flux. From Fig. 2, note that on the average, for a given direction, there are 1000 electrons of 1-MeV energy crossing an area of one square centimeter every second. From plots such as these, scientists can obtain some insight into what is happening in a given region of space.

Having thus discussed what it is we are trying to measure, let us see how these measurements are obtained. As is the case with magnetic measurements ("Magnetic Measurements in Space," January, 1966 ELECTRONICS WORLD), laboratory apparatus is often adaptable to space work after certain modifications aimed at reducing weight and power, and improving reliability. Since the equipment undergoes shock, vibration, and acceleration from the rocket (which, along with satellites and deep-space probes, is used to record radiation in space), experiment packages must be rugged. Temperatures may range from $-50°$ to $+160°F$ and may even go outside these limits. Thus, the demands placed upon space equipment are far in excess of those placed upon ordinary laboratory apparatus.

Measurement Techniques

A typical radiation-measuring experiment is illustrated by the block diagram of Fig. 3. Such an experiment may contain many similar channels and these may be interconnected to obtain a particular result. The transducer used for radiation detection converts the event of a particle striking the device into an electrical signal. Some means of signal amplification is usually required. If the signal is of the digital variety, *i.e.*, a series of discrete pulses, these pulses are counted and stored in a chain of flip-flops or magnetic-core memories. If the signal is an analog function, the pulses can be amplified and fed into the telemetry (TM) system directly. Some detectors put out a signal which is both analog and digital. The presence of a digital pulse indicates that a particle is striking the detector, while the amplitude of this pulse is proportional to the energy of the particle.

Detectors

Geiger-Mueller (GM) Tube. The Geiger-Mueller (GM) tube or "Geiger counter" is perhaps the simplest of all detectors. A GM tube consists of a cylinder or sphere of thin-walled conductor, with a thin wire passing through, and insulated from, the wall. Several hundred or a few thousand volts potential is maintained between the wire and wall, as shown in Fig. 4A, and the cylinder is filled with a gas, usually neon or argon. A high-energy particle passing through the wall creates a trail of positive ions and electrons. These ions and electrons are then accelerated to the negative and positive terminals, respectively. As they are accelerated, they produce more electrons and ions, or secondaries. An electrical discharge between wire and wall results, which appears as a voltage pulse. The GM tube requires little power and can be built for reliability and ruggedness. However, there are disadvantages. The GM tube does not distinguish among *alpha*, *beta*, or *gamma* particles, x-rays, or protons. The thin walls of the tube do not permit low-energy particles to penetrate into the tube interior, which limits the tube to high-energy applications. Also, the output pulse gives no information on the energy of an incident particle. Still another limitation is the relatively long duration of the output pulse. Even with the addition of so-called quenching agents to shorten the discharge time, a pulse duration is typically in the tens of microseconds. Hence, if two particles arrive up to tens of microseconds apart, they will not be resolved as two distinct events. The GM tube thus saturates at high counting rates (high flux levels).

Proportional Counter. By reducing the voltage bias of the arrangement shown in Fig. 4A, a proportional counter may be built. The voltage discharges are small and confined to a short distance along the central electrode. The pulse duration is also reduced so that particles arriving less than one microsecond apart may be resolved as two distinct events. Output pulse amplitude is proportional to the energy of an incident particle, and particle energies can be "sorted out" by the amplitudes of the pulses they produce. However, to take advantage of the proportional counter, a very stable power supply and very high gain amplifiers are required.

Ionization Chamber. Using the same mechanical arrangement of Fig. 4A but filling the tube with a gas at some higher pressure, say 50 pounds per square inch, results in an ionization chamber. Here, a few hundred volts bias the detector but not enough to produce secondary ion/electron pairs. The output current is then directly related to the total energy of the particles which arrive in a given time span. These currents are quite small, usually less than a tenth of a nanoampere, and no energy sorting of particle distinction is possible.

Scintillator. When radiation strikes certain kinds of materials, a flash of light results at the point of impact, and the material is said to fluoresce or scintillate. These flashes of light may be as long as a few milliseconds or as short as a few nanoseconds, depending upon the material. Common types of fluorescing material are cesium iodide, sodium iodide, anthracene, and polystyrene. The light flash is converted to an electrical pulse by a photomultiplier (PM) tube. The PM tube consists of a series of electrodes, called dynodes, with several hundred volts potential across each. The light energy striking the cathode causes electrons to be emitted by the photoelectric effect, as in the familiar photoelectric tube. The high potential causes the electrons to be accelerated to the first dynode, where their high velocity "kicks" out more electrons in an avalanching effect. The next pair of dynodes multiplies the process, and so on, until the final dynode collects more electrons than were emitted from the cathode.

The output pulse amplitude of the PM tube is proportional to the energy of an incident particle. Hence, by sorting pulses according to their amplitudes, a spectrum may be obtained.

Cerenkov Detector. When a charged particle moves through a transparent material at a speed faster than the speed of light in the material, a cone of light follows the particle. This is known as the Cerenkov effect. Note that the speed of light in the material is, in general, slower than the speed of light in a vacuum. The pulse of light is nearly proportional to the energy of the incident particle, so when the pulse is detected by a PM tube, energy sorting may be accomplished. Common materials used for Cerenkov counters are Lucite, Plexiglass, and lead glass. Lead glass is used to detect *gamma* radiation. The incident *gamma* generates pairs of electrons and positrons, which, in turn, produce the light cone.

Solid-State Detector. Recent developments in the semiconductor art have led to the solid-state detector. This device is composed of *p-n* junctions which are sensitive to protons and electrons and which appear as solid-state ionization chambers. An incoming proton or electron generates hole/electron pairs at the junction which then move through the crystal as in an ordinary semiconductor diode. Several types of detectors are now manufactured, including the surface-barrier, diffused-junction, and lithium-drift devices. Such devices have the advantage of requiring lower voltage bias supplies than other common detectors. They require little power and can be expected to have long lifetimes in a space environment.

Other Detectors. In addition to the principal types of detectors described above, there are (*Continued on page* 72)

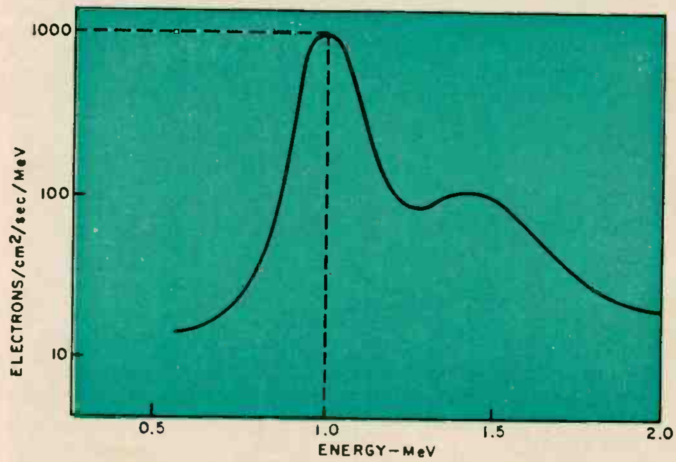
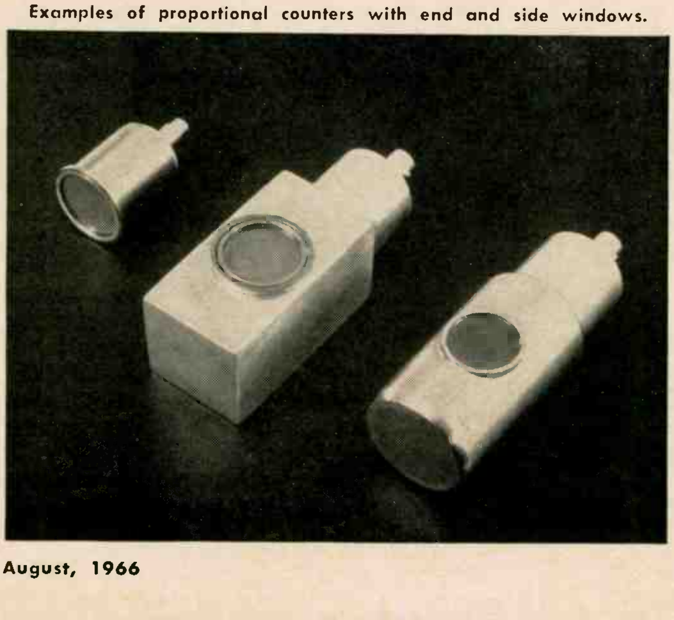


Fig. 2. Hypothetical spectrum shows that, on the average, 1000 electrons of 1-MeV cross one square centimeter every second.

Examples of proportional counters with end and side windows.



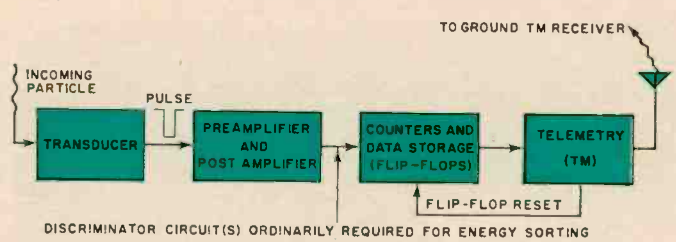
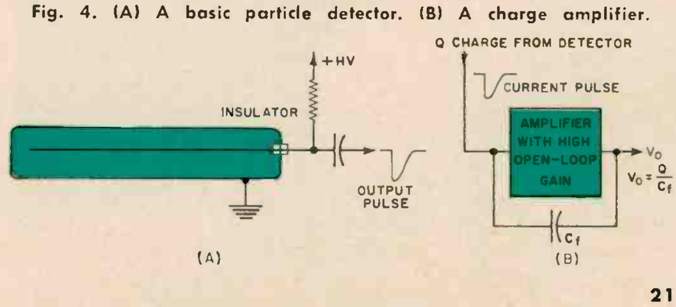
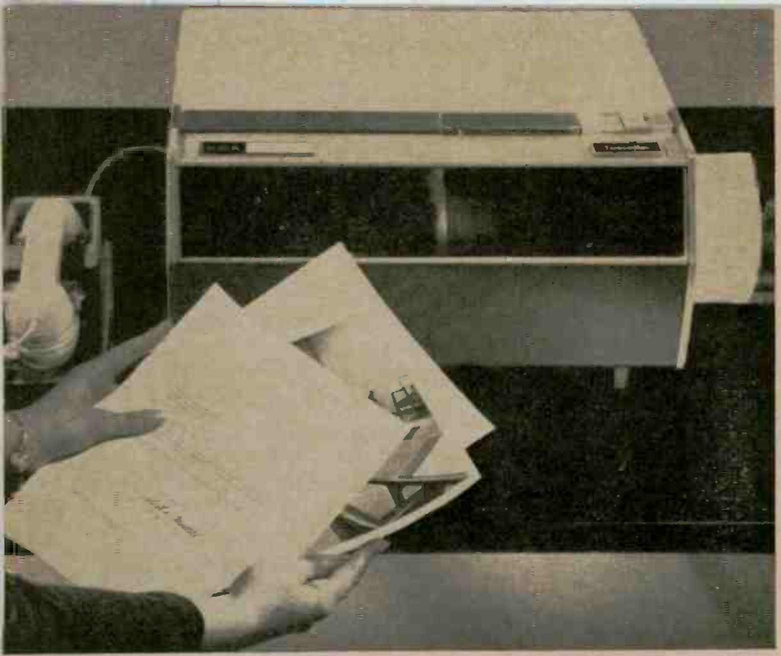
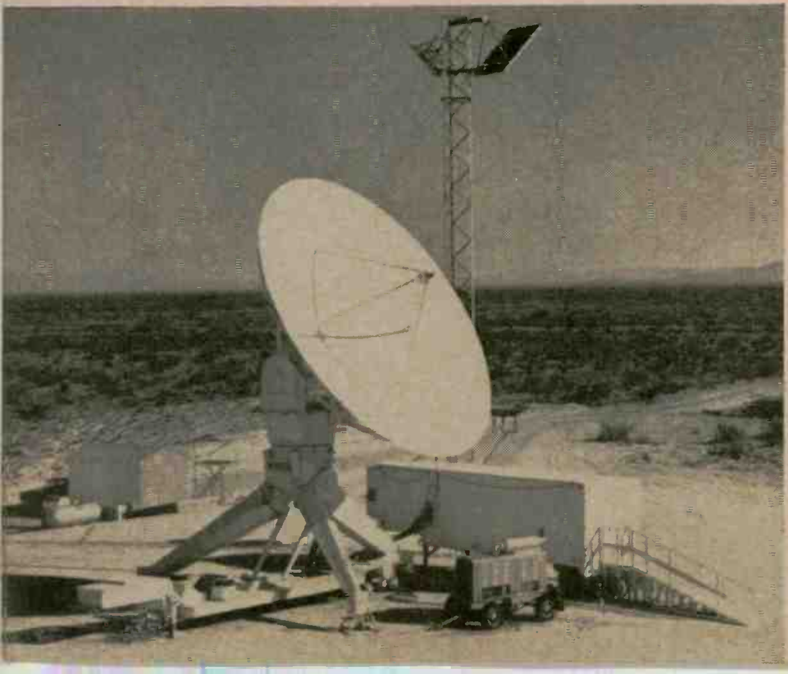


Fig. 3. Signal flow of typical radiation-measuring experiment.

Fig. 4. (A) A basic particle detector. (B) A charge amplifier.







RECENT DEVELOPMENTS IN ELECTRONICS

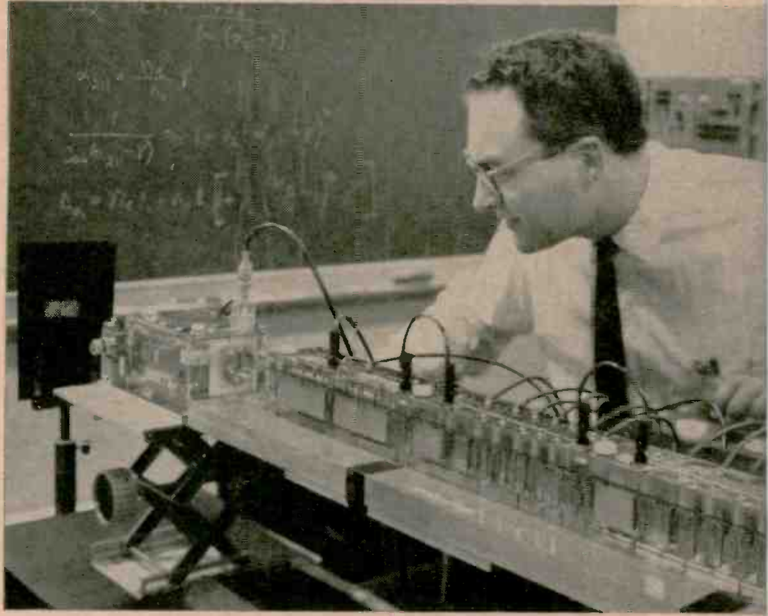
Facsimile by Telephone. (Top left) Letters, photos, business forms, and other documents can be transmitted and received with an ordinary telephone and a portable facsimile device recently introduced. The unit can transmit an 8½-in by 11-in document any distance—producing a copy on ordinary paper at the other end of the line in six minutes—just by placing a conventional telephone handset into the unit's acoustic cradle. The device, called the "Telecopier," weighs 50 pounds and is slightly larger than an office typewriter. The machine was developed and manufactured by Magnavox and is being marketed, installed, and serviced by Xerox. Initially, the unit will be leased to the user. The copier is a continuous-scanning facsimile transceiver in which a focused light source illuminates the document placed on a rotating drum. Reflected light passes through a chopper disc to a photocell. The resulting signals are converted into frequency-modulated audio that is transmitted over the phone lines. At the receiving end, two mechanical styli make contact with carbon-backed paper on which the picture is reproduced by pressure changes.

Automated Opera Stage. (Center) Stagehands at the new Metropolitan Opera House, opening this fall in New York, will use TV sets to tell how far the curtains are open on a dark stage. Feedback voltage from curtain-position potentiometers (connected to curtain-opening motors) produces a white horizontal line on the TV set which indicates the curtain opening. The positions of inner sets of curtains are also shown on the same display by means of other lines. The $45.7 million opera house will have one of the world's most automated stages. A winch system using 109 10-hp d.c. motors will be used to raise and lower scenery. The motors are driven by 30 SCR drive circuits. Large movable stages, weighing between 15 and 30 tons, are controlled by variable speed drives using adjustable frequencies. The stages can be set offstage, then wheeled on automatically. The entire system has been designed for the Met by Cutler-Hammer.

Mobile Radar System. (Bottom left) The mobile radar station shown here has been delivered to the U.S. Army by Sylvania recently. The station will be used as part of Project Defender, a program exploring defense against missiles and developing penetration aids for U.S. missiles. The system uses microwave and ultra-high frequency links to maintain communications between two sites. It consists of two 30-ft diameter dish antennas and vans with radar receivers and recorders.

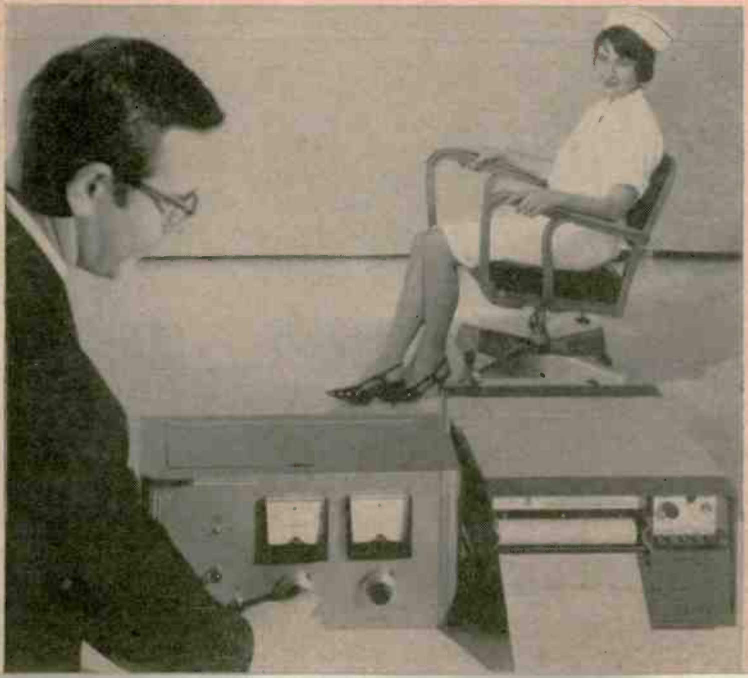
Ultrasonic Traffic Detectors. (Top right) The group of ultrasonic detectors shown are the first hardware to be delivered under a $5.4 million contract for New York's City's automated traffic control center. The radar-like devices use inaudible ultrasonic waves to detect the presence or motion of any type vehicle. Mounted above or to the side of a thoroughfare, each unit can cover one, two, or three traffic lanes. The aboveground location makes installation and maintenance less costly than devices located in the street. The compact detector uses solid-state circuits for high reliability. New York City has 1100 of the detectors on order from Sperry Gyroscope. Similar devices have been ordered for Pittsburgh, Houston, and Baltimore.

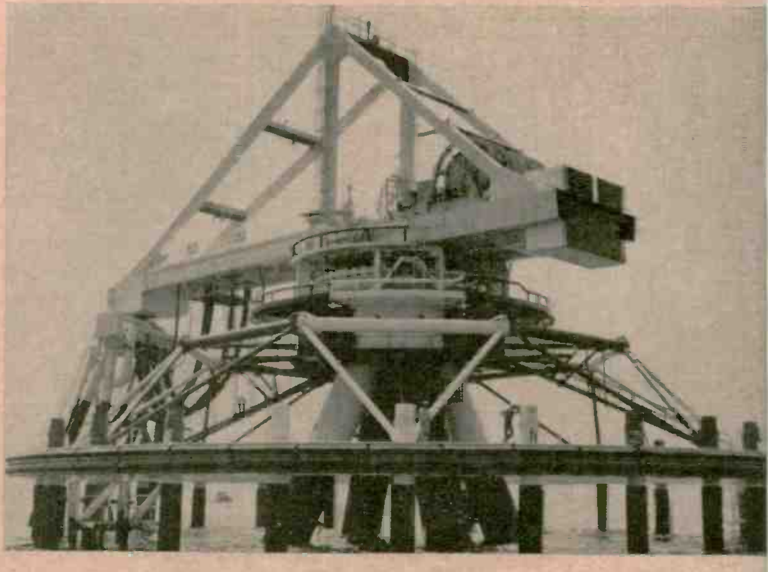
Digital Laser Light Deflector System. (Center) A new digital light deflector system that can position a laser light beam to any of 131,072 points at speeds exceeding 100,000 selections per second has been delivered to the U.S. Army Electronics Command, Fort Monmouth, by IBM. The equipment is experimental and is aimed toward use in automatic data systems for combat forces. The deflection technique permits the beam of light to be precisely focused on 131,072 distinct points within a space smaller than a match head. Deflection is accomplished by a series of electronically controlled crystals. Potential uses include print-out devices, display systems, and data handling.



Instrumented Medical Chair. (Below left) Physiological information can be obtained from a patient sitting in a new automatic medical monitor chair. No sensors are attached to the patient at all. Instead the upholstery of the chair contains a series of electrical pickups which serve the same purpose as the technician's paste and strapped-on electrodes. These pickups check pulse rate, respiration, heart sounds and impulses. The system includes a chart recorder on which all this data is displayed. The patient need only be seated comfortably in the chair, with his hands resting on conductive armrests. The monitor, designed by Philco scientists, would enable a busy doctor to have at his fingertips information that normally would require the services of a medical technician and the time-consuming use of a stethoscope, electrocardiograph, and other clinical instruments.

Strain Gages Check Offshore Oil Loader. (Below right) Semiconductor strain gages are attached to the various structural members of this offshore oil tanker loading tower in Libya. These gages are used with associated electronic equipment to determine actual stresses put on the tower by heavy seas and a moored tanker. The system is operated only during rough weather, during which time oscillographic recordings are made of the various stresses that occur. Analysis of the recordings showed that sea forces and inertial forces from a moored tanker were not enough to weaken or destroy the main tower components. The gages are weldable types manufactured by BLH Electronics.





RECEIVER NOISE MEASUREMENTS

By IRWIN MATH / Frequency Electronics Inc.

Basic approach to measurement of receiver and converter noise figures, along with some simple noise generators.

WHEN attempting to measure the sensitivity of a receiver or converter, especially one operating in the v.h.f. region, serious consideration must be given to the *noise figure*. It is this noise figure that is the true measure of the ability of the device to detect weak signals.

Normally, converters or receivers are aligned by simply adjusting them for maximum gain. This procedure is fine for the lower frequencies up to about 20 MHz or so, because here atmospheric noise and man-made noise are the primary limiting factors on sensitivity. Above 20 MHz, however, these sources of noise become minor and the over-all sensitivity of the receiver becomes dependent on the internal noise generated by the vacuum tubes, transistors, and other components. By measuring the noise figure of a device then, and by adjusting it for *maximum gain at the minimum noise point*, the best over-all sensitivity can be realized.

The two major sources of noise present in a v.h.f. receiving setup are *thermal* or Johnson noise, which is primarily generated by the antenna, and *shot* noise, which is generated by random electron motion in the vacuum tubes, transistors, and diodes of the receiver. Since all noise is produced by the random motion of free electrons, the greater this motion, the greater the noise. Thermal noise is generated by this random motion in a resistive element. Therefore, because an antenna is, and has, a definite radiation resistance, it will be a source of noise. Shot noise, on the other hand, is generated by the random motion of the electrons which leave the cathode and migrate to the plate in a vacuum tube and which flow through the semiconductor junctions in transistors and diodes.

When adjusting a receiver or converter, then, it is important to obtain the lowest additional noise (that is, the noise generated by the receiver itself). Let us now look at a method for determining the noise performance of a device.

The term "noise figure" refers to the ratio of actual output noise power available to that which would be available from an absolutely perfect device with a noise figure of 0. If we then measure the output noise of a receiver with the antenna terminals connected to a resistor equal to the input impedance, and then feed in a known amount of noise to double the output, we can then estimate the noise figure.

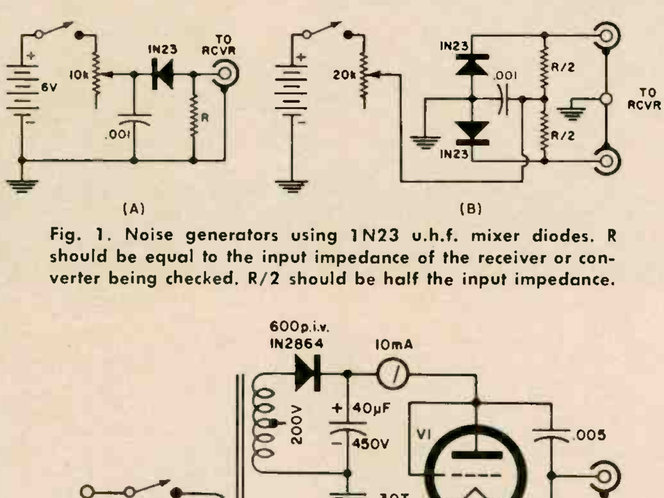


Fig. 1. Noise generators using 1N23 u.h.f. mixer diodes. R should be equal to the input impedance of the receiver or converter being checked. R/2 should be half the input impedance.

Noise Generators

Although there are many devices that can be used as noise sources, we will employ the diode because of its simplicity. By experimentation, it was found that the noise produced by a diode (especially tungsten filament vacuum ones) is almost directly proportional to the current flowing through it. This fact holds true up to about 300 GHz where components used in the noise generator become lossy and tend to reduce the accuracy of the device.

Fig. 1A shows a simple noise generator employing a 1N23 u.h.f. mixer diode. As there is no provision for monitoring current, the device is useful for comparisons only. One should first measure the output of the receiver with an audio v.t.v.m. connected across the (*Continued on page* 63)

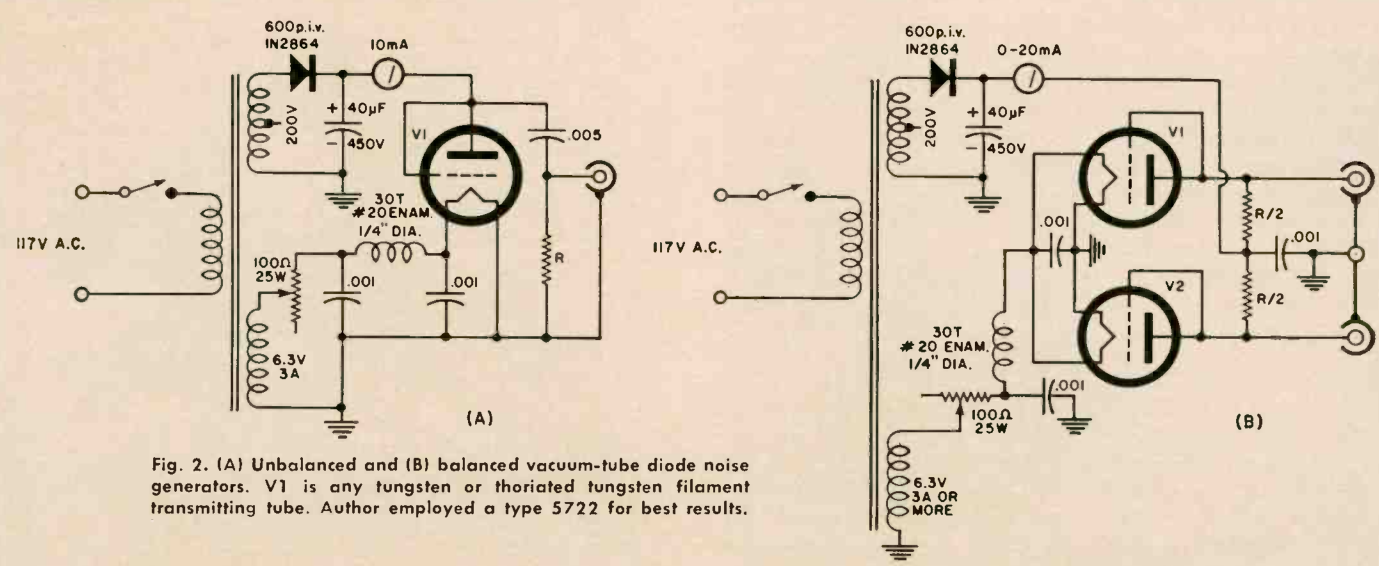
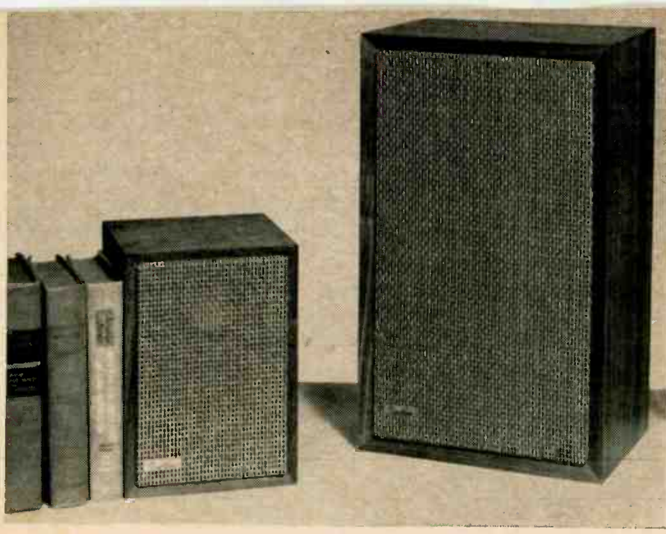


Fig. 2. (A) Unbalanced and (B) balanced vacuum-tube diode noise generators. V1 is any tungsten or thoriated tungsten filament transmitting tube. Author employed a type 5722 for best results.



Finished speaker systems using high-compliance drivers and completely sealed enclosures are quite compact. The smaller unit shown measures only 10 1/2" x 7 1/2" x 7" and includes a 4" woofer and 2" tweeter. The larger unit measures 19" x 11 1/2" x 8 1/2" and includes an 8" woofer along with a 3 1/2" tweeter.

Enclosures for High-Compliance Loudspeakers

By ROGER H. RUSSELL/ Sonotone Corp.

Design and construction of small, completely sealed hi-fi speaker enclosures. A number of practical graphs are included to determine speaker compliance and achieve best enclosure size.

DESIGN information on high-compliance speaker enclosures has been conspicuously lacking. As many manufacturers are now producing these small systems, the demand for more information has increased. This is especially true because it is now possible to purchase, separately, high-compliance drivers in all of the common speaker sizes from 4 inches on up to 15 inches.

This article describes how to design a high-compliance speaker system using one of these new speakers in a sealed cabinet. A few basic pieces of test equipment, as well as the charts to be shown later, are all that are necessary.

High Compliance

A definition of compliance will be helpful in understanding what makes these new speakers different. Compliance is the ease with which a material can be bent or stretched. In the case of a loudspeaker, if the cone is easily pushed by a small force, the cone suspension is highly compliant.

A high-compliance speaker can perform well in a relatively small cabinet. To explain this we should first look at a few simple resonant circuits. Fig. 1A shows a simple *LC* series-resonant circuit. The inductor and capacitor resonate at frequency f_0 shown in Fig. 2A. A simplified electro-mechanical equivalent circuit for an unmounted loudspeaker is shown in Fig. 1B. Here, $M_{effective}$ is the effective mass of the speaker cone and voice coil and is represented by an inductor. $C_{effective}$ is the effective compliance of the cone suspension and is represented by a capacitor. $M_{effective}$ and $C_{effective}$ again resonate at f_0. If the speaker is placed in a small, sealed box, the enclosed air has a significant compliance. This is equivalent to adding a series capacitor as shown in Fig. 1C. As in an electrical circuit, the resonant frequency is raised to f_1.

For an ordinary 8" speaker (not high compliance) whose resonant frequency is 70 Hz, mounting in a small enclosure may raise the resonance to over 100 Hz. Below the resonant frequency, response begins to roll off. Placing this speaker in a small box, then, seriously reduces low-frequency response.

Other things being equal, an increase in compliance of the cone suspension (increasing $C_{effective}$) results in a lower unmounted or free-air resonant frequency. However, if the compliance is deliberately made very high, the speaker by itself will no longer be able to handle any power at low frequencies and the cone can be easily driven to maximum excursions.

The resulting free-air resonance can, in some cases, be

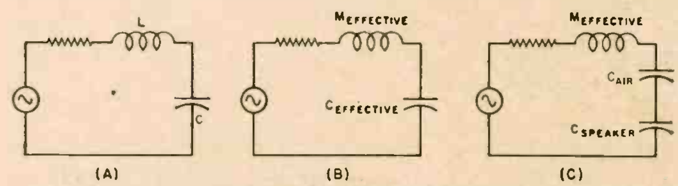
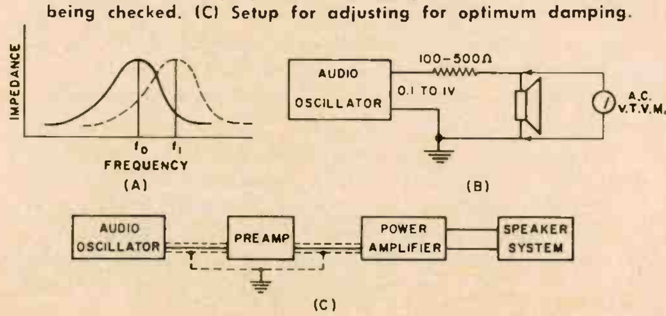


Fig. 1. (A) A series-resonant electrical circuit. (B) A simplified electro-mechanical equivalent circuit for loudspeaker in free air. (C) Simplified equivalent circuit of speaker in sealed box.

Fig. 2. (A) Shift to higher resonant frequency with added series capacitor. Note that the equivalent mechanical circuit is shown as being series-resonant, indicating maximum cone movement (minimum mechanical impedance) as resonance. Under these conditions, maximum counter-e.m.f. occurs which opposes the applied voltage. As a result, minimum current flows and the electrical impedance is at its maximum. (B) Measuring speaker resonance. In many cases, the series resistor can be omitted since the oscillator impedance is usually much higher than that of the speaker. The oscillator acts as a constant-current source (with high internal Z) and its voltage will therefore fluctuate in direct proportion to the impedance of the speaker being checked. (C) Setup for adjusting for optimum damping.



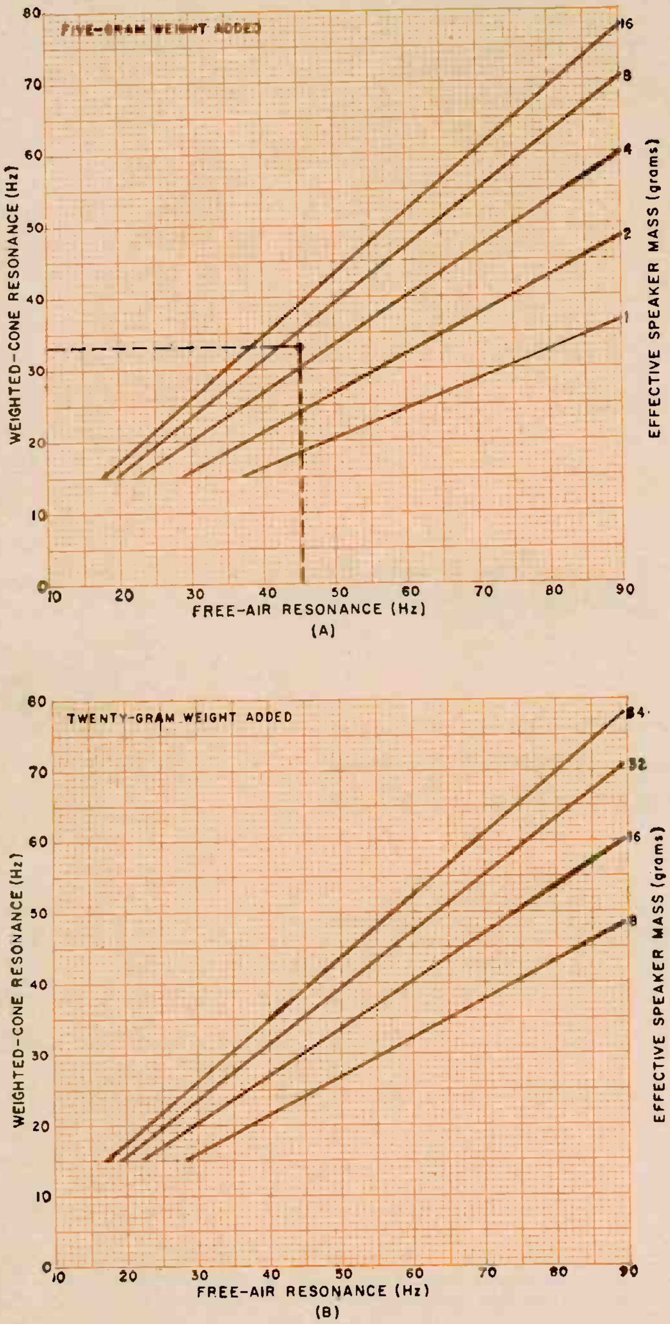


Fig. 3. Weighted-cone (free-air) resonance versus (unweighted-cone) free-air resonance for various effective speaker masses.

reduced to subsonic frequencies (below 20 Hz). Here is where a small, sealed box can be used successfully to restore some of the stiffness (reduced compliance) of the cone suspension. The stiffness is supplied by air trapped in the box and thus acts as a spring against the cone in much the same way as the original suspension. The original higher resonant frequency is also restored. This system resonance can be raised or lowered by varying the volume of the box, the smaller box producing the higher resonance. An 8″ high-compliance speaker with a free-air resonance of 30 Hz may resonate at 50 or 60 Hz in a small, sealed enclosure.

Since low-frequency response rolls off below resonance, a lower resonance usually produces better low frequencies. Useful response is usually produced down to a frequency of about 30 percent below system resonance and it can sometimes be extended down to ½ octave below the system resonant frequency by using proper damping techniques. A system resonance of 50 Hz is considered to be more than adequate for the high-fidelity reproduction of orchestral music.

Cone Excursion

A second factor limiting low-frequency output is the amplitude of cone excursion. Most high-compliance speakers are made with a voice-coil length longer than the magnetic gap, allowing longer linear excursions of the cone and reducing low-frequency distortion. A four-inch woofer, unheard of a few years ago, now becomes a reality.

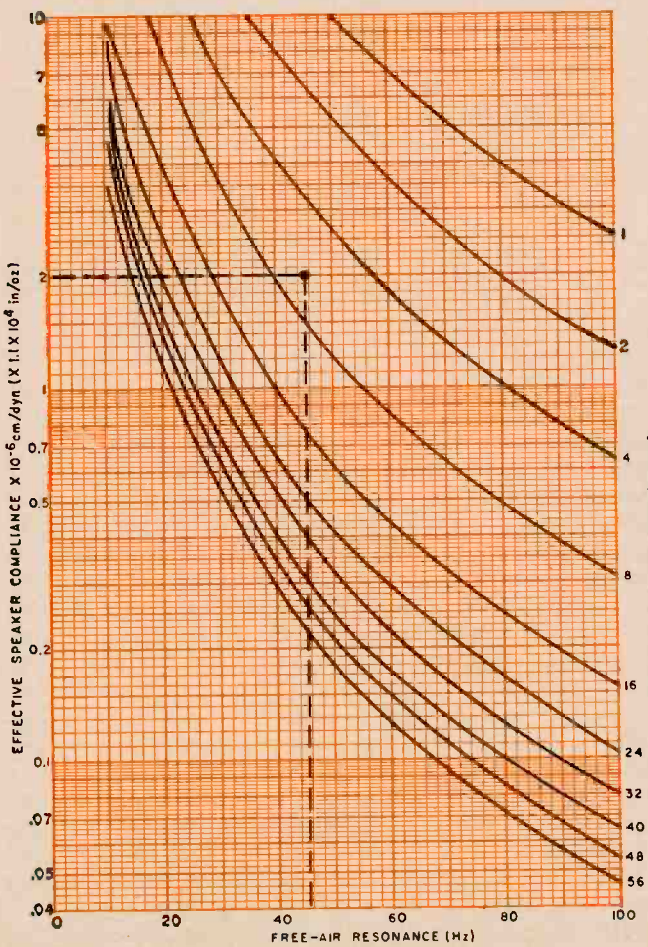
The smaller high-compliance speaker system can sound as good at low frequencies as a larger speaker system provided its power-handling capabilities are not exceeded. The larger speaker has a smaller cone excursion but a large cone area in contact with the surrounding air. For a certain excursion of the cone, this speaker moves a certain volume of air. In order for a smaller speaker to move an equal volume of air, the amplitude of its cone travel must be greater.

At high listening levels, any of the very small systems is limited to the amount of air they can move. Some low-frequency program material will drive the speaker cone to maximum excursions. In general, the smaller systems employing 4- to 5-inch woofers should be used in smaller rooms at lower listening levels. Larger speakers are required for higher listening levels as well as for larger rooms.

System Design

Design of the systems in this article is based on adjusting the cabinet compliance to be equal to the effective speaker compliance, provided the system resonance is above 50 Hz. A system resonance above this frequency is normally found for the smaller speakers (4″ to 5″) using this method. This high resonance is necessary to prevent the speaker cone from traveling beyond its excursion limits for normal listening levels. By maintaining a 50-Hz system resonance for the

Fig. 4. Effective speaker compliance vs free-air resonance for different values of effective speaker mass from Fig. 3.



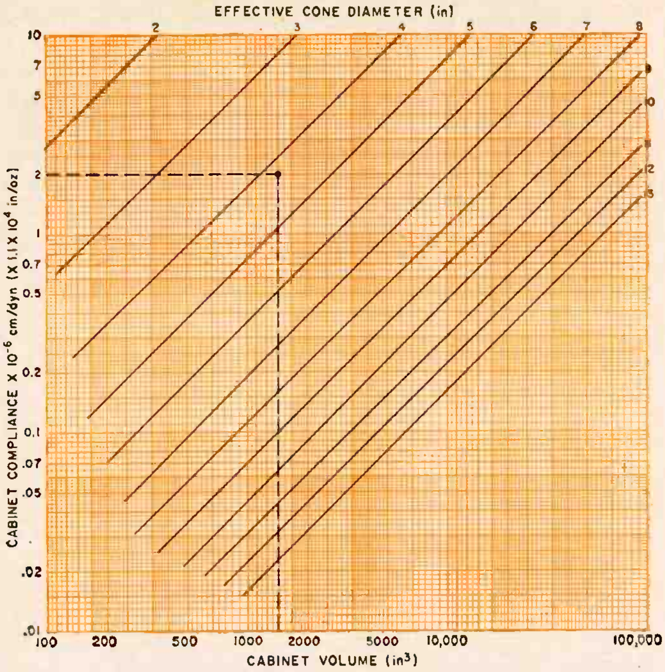


Fig. 5. Cabinet compliance versus cabinet volume for different values of effective cone diameter (excluding surround).

larger speakers (8″ and above), a relatively small cabinet can be used. In this case, the system compliance will be almost completely controlled by the enclosed air in the loudspeaker cabinet.

For either small or large speakers, a reduction in cabinet volume can be made beyond the design values in this article. The greater the reduction in volume, the more the low-frequency response will be reduced. The low-frequency power-handling capacity, however, will be increased.

If we can determine the actual value of effective mass of a high-compliance speaker in free air, we can find the effective compliance, $C_{effective}$, from the relation: $f = 1/2\pi\sqrt{M_{eff}C_{eff}}$. Knowing $C_{effective}$ of the speaker enables us to adjust the cabinet compliance (determined by its volume) for optimum system resonance.

The first step in measuring speaker mass is to connect the speaker as shown in Fig. 2B. The resistor value is not critical. Face the speaker cone upward and do not cover the cone. Tune the oscillator for a maximum reading on the a.c. voltmeter. This frequency setting is the free-air resonance of the speaker.

If the speaker is less than 8″ in diameter, temporarily attach one 5-gram weight to the speaker cone near the center. If the speaker is 8″ or greater in diameter, temporarily attach four 5-gram weights near the center of the cone. One U.S. nickel weighs exactly 5 grams and is convenient to use. The weights can be attached with a small piece of Mortite, caulking compound, or cellophane tape. When the weights are being attached to the cone, support the cone from the rear with the fingers in order to avoid moving the cone and damaging the speaker. Weights must not rattle against cone.

Again, tune the oscillator for a maximum reading on the a.c. voltmeter. This weighted-cone resonant frequency will always be lower than the free-air resonant frequency.

From the charts in Fig. 3, the effective mass of the speaker can be found. Draw a vertical line at the free-air resonant frequency (with unweighted cone) and a horizontal line at the weighted-cone resonant frequency. The intersection of these two lines will determine the value of effective cone mass. This value can be estimated from adjacent lines of known mass.

Knowing this value of effective cone mass, the effective speaker compliance can be found from Fig. 4. Draw a vertical line at the free-air resonant frequency. Place a point on this line at the corresponding value of $M_{effective}$ previously determined. Draw a horizontal line through this point to the compliance values at the left side. This is the value of the effective speaker compliance.

Knowing this value of $C_{effective}$ a cabinet volume can be found from Fig. 5. First, a value for the effective speaker diameter must be measured. The effective diameter of a speaker does not include the outside diameter of the frame or of the compliant surround, but only the diameter of the stiff paper cone. Draw a horizontal line at the compliance value found from Fig. 4. Place a point on this line at the value of the effective cone diameter. Draw a vertical line through this point to the bottom and read the corresponding inside volume for the cabinet.

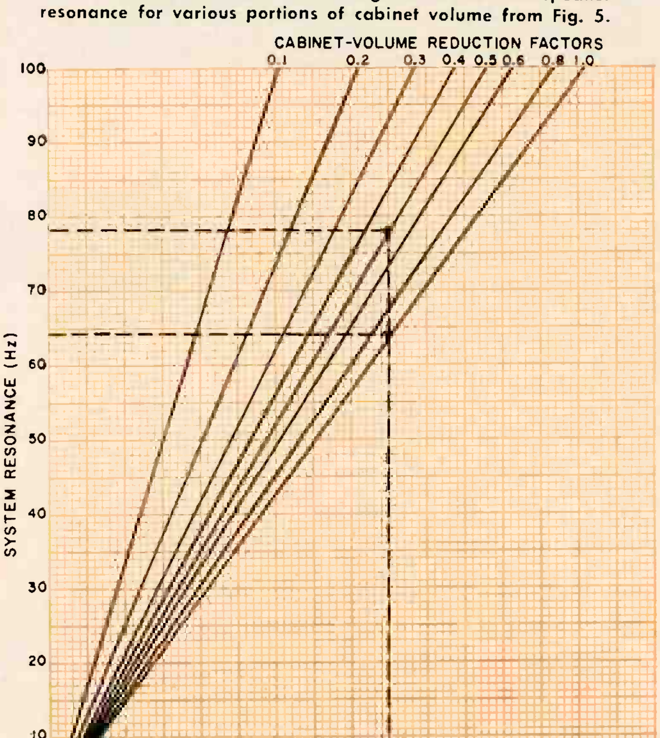
This volume may not be the best volume for the system, however, and a check using Fig. 6 should be made at this time to see if the volume can be reduced to maintain a 50-Hz resonance. Draw a vertical line at the free-air resonance frequency. Place a point at the intersection of the vertical line and the 1.0 cabinet-volume line. Draw a horizontal line from this point to the left side. This value is the system resonance when the effective speaker compliance equals the cabinet compliance.

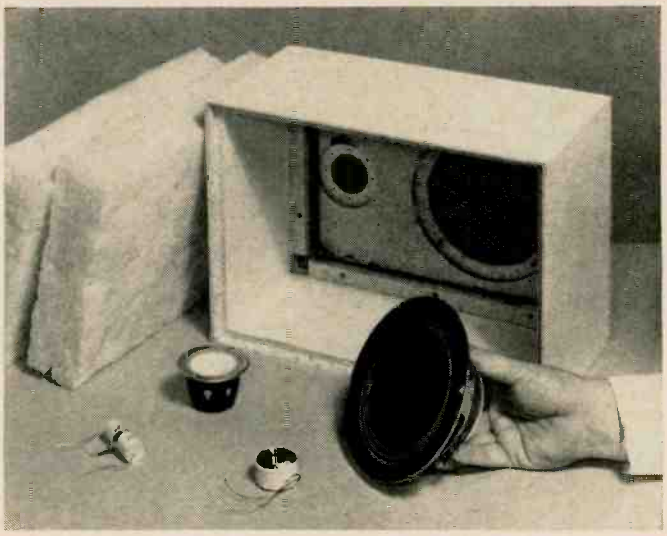
If this value of system resonance is higher than 50 Hz, the optimum volume found in Fig. 5 is satisfactory. If the value of system resonance is lower than 50 Hz, a reduction in cabinet volume can be made without a serious compromise in low-frequency performance. For example, if the free-air resonance of a speaker is 30 Hz and the vertical line on Fig. 6 intersects the 1.0 line at a corresponding system resonance of 42.5 Hz, a reduction in volume can be made to about 0.6 times the volume originally found on Fig. 5. In this case, a considerable reduction in size can be made without noticeably affecting the low-frequency performance.

Example of Design

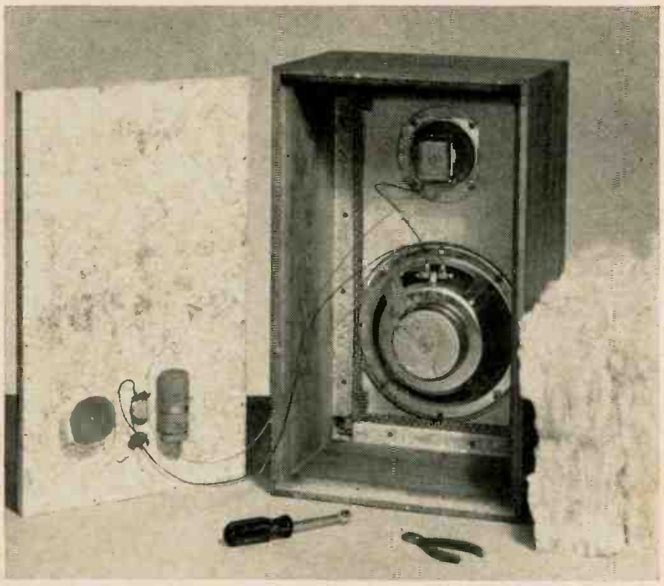
A high-compliance 6″ speaker is found to have a free-air resonance of 45 Hz. After adding a 5-gram weight, the reso-

Fig. 6. System resonance versus original free-air loudspeaker resonance for various portions of cabinet volume from Fig. 5.





Essential parts include a high-compliance woofer, tweeter and crossover network if desired, acoustic material, and a cabinet.



After the fiberglass is put in the cabinet, back is screwed on.

Typical 4", 6", and 8" high-compliance speakers are shown. The free-air resonances are 60, 50, and 30 Hz, respectively. Speakers of this type are characterized by heavy magnets, very flexible cone surrounds, long-throw voice coils, and low cone resonance. Such speakers are readily available from most speaker manufacturers and as private-label brands from some of the larger electronics parts dealers. Speaker sizes range from approximately 4" all the way up to 15".

nance is lowered to 33 Hz. The effective cone diameter is 4¼ inches. On Fig. 3A, a vertical line is drawn at 45 Hz and a horizontal line is drawn at 33 Hz. The point of intersection is close to 6.5 grams. On Fig. 4, a vertical line is drawn at the free-air resonant frequency of 45 Hz. A point is made at 6.5 grams. A horizontal line is drawn through the point to a compliance of 2.0. On Fig. 5, a horizontal line is drawn at a compliance of 2.0. A point is made at the effective cone diameter of 4¼". A vertical line is drawn through the point to the bottom of the chart indicating a cabinet volume of 1500 cubic inches.

At this time a check for system resonance should be made on Fig. 6. A vertical line is drawn at the free-air resonance of 45 Hz. A point is made at the intersection of the vertical line and the 1.0 cabinet-volume line. A horizontal line is drawn through the point indicating a system resonance of 64 Hz. This system resonance is above 50 Hz and no reduction in cabinet volume need be made from the 1500 cubic inches found previously.

However, suppose a smaller cabinet is needed to fit in a small bookcase. Suppose if only half the volume is used it will fit. On Fig. 6 extend the vertical line to 0.5 or half the volume found in Fig. 5. A horizontal line is drawn to this intersection indicating a system resonance of 78 Hz. With this system resonance, a useful response may be extended down to around 55 Hz instead of around 45 Hz and the power handling is increased.

If the speaker used is not a wide-range unit, a complementary high-frequency tweeter is also necessary. We prefer cone tweeters for low distortion, wide dispersion, and low price. Tweeters should be completely isolated from the woofers either by having a closed frame (cone not exposed from rear) or by constructing a small, sealed box within the main enclosure. The smallest volume possible should be used to isolate the open-frame tweeter. After the tweeter is installed and wired, fill the remaining volume of this small box with fiberglass. Wear rubber or plastic gloves before handling fiberglass as it can cause irritation of the skin. In addition, an appropriate crossover network should be used.

Mechanical Considerations & Damping

In constructing the enclosure, shape is not critical providing no dimension is more than three times any other dimension. Where possible, especially with the smaller enclosures, a front dimension ratio should be about 1 to 1.41. For accuracy, the total enclosure volume should be increased over the volume determined from the charts by the volume occupied by the loudspeakers. Since the speakers are usually small and the enclosure volume is not highly critical, however, no great harm will result if the speaker volume is overlooked.

Enclosures should be completely sealed for best results. Use of caulking compound is satisfactory, especially when the back of the cabinet is put in place. ¾" plywood should be used to make the larger cabinets, but for speakers less than 6" in diameter, ½" plywood is satisfactory. The sides should be cross-braced parallel to the shorter dimension if they are greater than two square feet in area.

After the speaker has been installed in the cabinet, some amount of acoustical damping will be required for optimum performance of the system. In a tuned-port (bass-reflex) system, double impedance peaks are adjusted for equal amplitudes. For the sealed system, however, only one main resonance peak occurs in the impedance. The amplitude of this peak can be adjusted to control the damping of this resonance. Fiberglass acoustic material is excellent for this purpose and it also helps to damp out reflected waves in the enclosure at higher frequencies. Addition of fiberglass will also reduce the system resonance slightly, depending on the quantity added.

A good rule for speakers smaller than 8" in diameter is to completely fill the entire enclosure with layers of fiberglass. They should be placed loosely in the enclosure, not squeezed together. For speakers 8" in diameter or larger, a layer of 2 or 3 inches of fiberglass should be used on all inside walls except the front speaker board.

An additional test can be used to determine the optimum damping for the system for best low-frequency performance. The oscillator previously used should be connected to the hi-fi amplifier (auxiliary or tuner input) as in Fig. 2C.

Set the tone controls to the (*Continued on page* 56)

SELECTING THE PROPER INDICATING LIGHT

By WARREN WALKER / Manager of Research & Development, Dialight Corp.

A comprehensive guide for specifying lamps and lamp housings used for all types of electronic equipment.

IT is the purpose of this article to suggest a logical approach to the choice of pilot lights. The first step must be a decision on the light source to be used. Every device is designed to accommodate lamps of a particular bulb size and base type and so many lamps are available for indicator service that the choice may appear difficult. Following a brief review of general data and lamp descriptions, some specific recommendations will be offered to assist the designer.

Lamps for Indicator Service

It is useful to understand some of the terminology used in the lamp industry. A lamp consists of a bulb and its base. Bulb size and shape are designated by a letter and a number; for example, S-6 or T-3¼. The letter indicates the bulb shape; S is for pear shaped and T is for tubular. The digits following give the maximum bulb diameter in eighths of an inch, thus S-6 is ¾" and T-3¼ is 13/32".

The bases used on S-6 bulbs are usually candelabra screw but may be double-contact bayonet. Only the single-contact miniature bayonet base is used on the T-3¼ bulbs discussed here. The smallest lamps of practical nature for pilot lights are T-1¾ and T-2. Both are provided with midget flanged bases. There is also in extensive use a product described as a lamp cartridge which employs T-1¾ or T-2 bulbs. They are enclosed in a close fitting tubular housing with a two-pin header at one end and a light transmitting plastic cap at the other. Internally, the bulb wires are welded to the inner ends of the pins. The device may be regarded as a plug-in lamp and the fitting as a very special base.

Ordering designations are not easy to understand because all lamps suited to pilot-light service are not treated in the same way. Miniature lamps such as the T-1¾ and T-3¼ of particular base types are assigned arbitrary numbers of 2, 3, or 4 digits by the A.S.A. (American Standards Association) and their full description and characteristics are filed under that number.

The S-6 lamps have a descriptive designation such as 6S6DC-120. The first six indicates 6 watts; the S-6 has the shape and size significance just described; DC is for double-contact base; and 120 is the rated voltage. If the base is not described, as in the number 6S6-120, it indicates that the base is candelabra screw which is the most commonly used or "standard" base.

Any discussion of indicators must include the 110- to 125-volt neon lamps. Those most often used are the T-2 and the T-3¼. The latter is always equipped with miniature bayonet base and there are two numbers, NE-51H and NE-51. The T-2 lamps are used in lamp cartridges or equipped with midget flanged bases. The NE-2J and NE-2D are the based lamps that are most often used. A changeover in designations to A.S.A.-assigned letter/number combinations is now underway. It is worth noting these equivalents although they are not in general use as yet:

Old NE No.	NE51-H	NE-51	NE-2J	NE-2D
A.S.A. Designation	B2A	B1A	C9A	C7A

Incandescent lamps provide rated hours of life at exactly rated volts. Lamp ampere limits are not closely held but filament temperature must be uniform, lamp to lamp, if life is to be satisfactory. Variations in applied voltage have a drastic effect on life; only 5% overvoltage will reduce the lamp life by half. The relation of life and candlepower to the applied voltage are shown in Figs. 1 and 2.

Incandescent indicator lamps have their greatest filament strength in the lower voltage and higher current ratings. When filaments are long, they are strung over supports, but

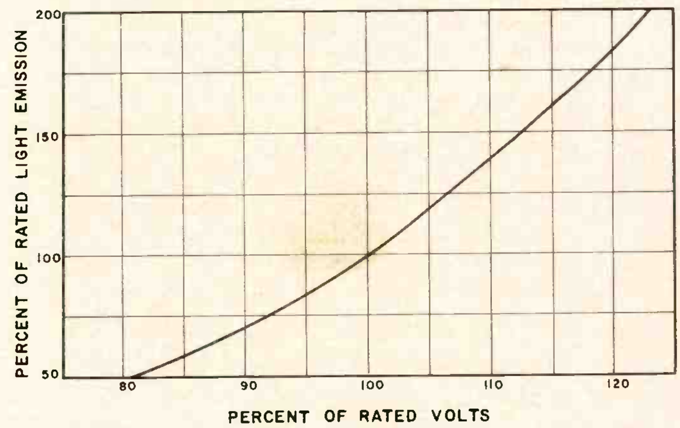
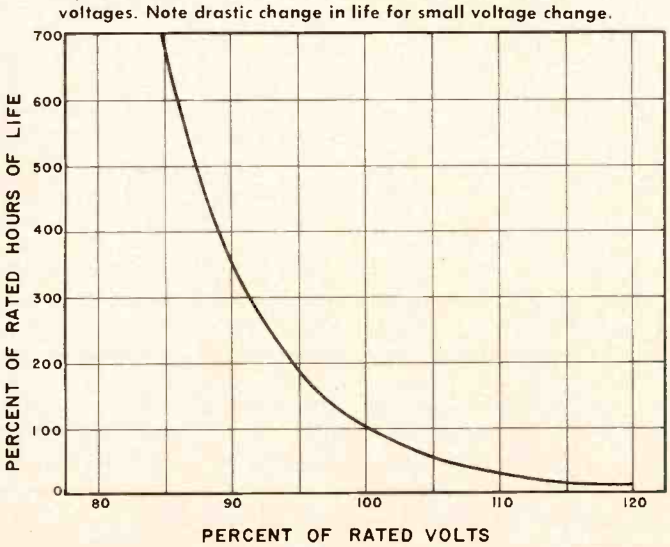


Fig. 2. Variations in light output for various voltages.

Fig. 1. Variation in life when lamp is operated at different voltages. Note drastic change in life for small voltage change.



even then strength is low in the higher voltage lamps. Current must be kept low and filaments are, of necessity, thin. It is obvious that the rule should be: always use a low-voltage lamp if an appropriate power supply is available.

Neon Lamps

These lamps are usually called neon cold-cathode glow lamps. Light is produced by a glow surrounding the unheated negative electrode. In their most common application, in 117-volt a.c. circuits, both electrodes glow. Neon lamps are always small and light output is low. Light of limited color range is emitted, but such lamps are used extensively because they are very rugged and effective and have a very long life. Reliability is high in the sense that early failures are practically unknown. When indication is needed on high-voltage circuits from pilot lights of small size, only neon lamps will do.

The recent introduction of a family of "high-brightness" neon lamps has largely obsoleted the older types now described as "standard brightness." The standard lamps should be specified only for d.c. applications in the 105- to 125-volt range.

It should be recognized that neon lamps are unlike other lamps in their electrical characteristics. They require some minimum circuit voltage to initiate any current flow and then adequate resistance to limit the current to a value that will give the desired life. The necessary starting voltage is provided by 110-125-volt a.c. (not d.c.) supplies. Pilot lights which incorporate the current-limiting resistor as an integral feature are available.

Supply Voltages

The first consideration in selecting a lamp should be the supply voltage that will light it. For all voltages below 105 volts d.c., incandescent lamps should be used. There is a "gray area" between 28 and 105 volts where there is very limited lamp availability but power supplies rarely fall into this range. A range of voltage from 1.35 volts (for a single mercury cell) to 28 volts is found in the T-1¾ (midget flanged base) series and in the two-pin, plug-in lamp cartridge line. In the somewhat larger T-3¼ (miniature bayonet base) category, the range is extended to 55 volts. The 6-watt and 10-watt S-6 lamps are made for 6 to 250 volt operation.

All of these lamps have tungsten filaments and emit "white light." They can be used with colored lenses and most of them will produce enough light for bright indication with the lenses supplied with such pilot lights.

Neon lamps of the T-3¼ and T-2 sizes, or in lamp cartridges, should be considered for all applications at 117 volts a.c. and are the only suitable choice for applications involving operation at 220 volts and over.

Selecting the Right Lamp

Before listing the specific lamps that will handle 90% of all applications, these general principles are offered to assist in making your selection. When space permits, use a large lamp rather than a tiny one. The cost of the lamp and device will be lower and life and reliability higher. Effectiveness can also be greater since the larger bulb can enclose a more powerful filament.

Select a 6-volt lamp rather than a 12 volt, and a 12-volt rather than a 28- (or higher)voltage lamp if power is available at the lower voltage. For given volt-amperes, the lower voltage filament will be stronger.

Avoid incandescent lamps of the S-6 group for voltages over 125, such as 220 to 250 volts. Wattage goes up to 10, making a hot lamp and filaments are fragile. At 440 volts, it is essential to use a stepdown transformer and a 6-volt T-3¼ lamp. Use a neon lamp if it will provide enough light of a satisfactory color.

A neon lamp is the only solution to the problem of operating under severe conditions of shock or vibration. If the necessary 117 volts is not available, the only incandescent filaments capable of surviving are those of 6 volts, with higher current ratings, in the T-3¼ size.

Select the lamp and pilot light early in the designing stage before all the space has been allotted to other components and very little left for the indicator.

When space is at a premium, use a lamp cartridge. Such cartridges may contain T-1¾ incandescent lamps and T-2 neon lamps so that the voltage range from 1.35 to 125 volts is covered. No other pilot lights require smaller panel areas.

Recommended Lamp Usage

Table 1 gives a partial listing of available lamps. First choices are shown in each case, with alternatives given, for the most common supply voltages. In each lamp series there are numerous other voltage ratings for special conditions. The approximate light output, in lumens, is given for comparison of effectiveness.

Lamps Whose Use is Discouraged

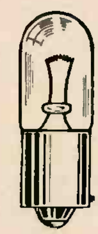
We would be remiss if we failed to mention other lamps of which the reader may be aware and which might appear to be overlooked, which are *not recommended*.

For example, the T-3¼ bulb was once used extensively with a miniature screw base. There are no electrical ratings in the

Table 1. Listing of recommended and readily available lamps.

T-3¼ MIDGET FLANGED-BASE SERIES—INCANDESCENT

Voltage Range: 6.3 to 55 volts
Useful in Group I Lights



RECOMMENDED FOR HIGH RELIABILITY

Lamp No.	Volts	Milliamps	Lumens	Rated Hours
755	6.3	150	4.1	50,000
756	14.0	80	3.9	50,000
757	28.0	80	7.7	50,000
1828	37.5	50	8.1	50,000
1835	55.0	50	13.7	50,000

Because of their long life design these lamps tolerate some overvoltage operation.

RECOMMENDED FOR HIGHER LUMENS

Lamp No.	Volts	Milliamps	Lumens	Rated Hours
44	6.3	250	11.1	3000
1815	14.0	200	17.5	3000
1820	28.0	100	20.0	1000

T-1¾ MIDGET FLANGED-BASE SERIES—INCANDESCENT

Voltage Range: 1.35 to 28 volts
Useful in Group III Lights and Some of Group V

RECOMMENDED FOR HIGH RELIABILITY

Lamp No.	Volts	Milliamps	Lumens	Rated Hours
380	6.3	40	.25	50,000
381	6.3	200	5.0	50,000
344	10.0	14	.025	100,000
367X	10.0	40	1.0	10,000
382	14.0	80	3.8	50,000
387	28.0	40	3.8	25,000

RECOMMENDED FOR HIGHER LUMENS
(and two low voltages)

Lamp No.	Volts	Milliamps	Lumens	Rated Hours
331	1.3	60	.075	500
338	2.7	60	.50	500
328	6.0	200	7.9	1000
349	6.3	200	6.9	3000
330	14.0	80	6.3	750

T-1¾ LAMP CARTRIDGE SERIES #39 —INCANDESCENT

Voltage Range: 1.3 to 28 volts
Useful in Group II Lights

There is no standard system of numbers for lamp cartridges containing these small bulbs. They are best described as #39 cartridges with lamps of the same rating as lamps of the above numbers. All of the ratings shown above for lamps with midget flanged-bases are available.

T-3¼ bulb series that are not available in bayonet-based lamps. The screw-in lamp is not really secure in its socket and is easily jarred loose. Its use should be avoided. Even less satisfactory is the T-1¾ with midget screw base whose sockets rarely have satisfactory spring contact to the solder ball. They do not stay in place.

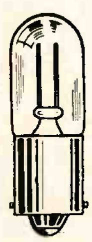
Despite their extensive use in the communications field, no new applications of the T-2 telephone slide-base lamps can be justified. The lamps are long and, while the bulb is of small diameter, all available lights require at least 9/16″ mounting holes. This spacing will accommodate the much superior T-3¼ (miniature bayonet) lamps. Also, the flat end of the T-2 bulb is the area through which all of the useful light must be emitted. But this clear area is a much smaller circle than the bulb diameter. The junction of the flat end and the side wall cylinder is substantially opaque because of refraction. Lamps of higher voltage ratings emit little of the light the filament produces. Finally, there is nothing but friction to secure these lamps in their sockets. They are likely to be pushed in too far for maximum effectiveness and they require an extractor tool to remove them.

Failure to recommend any "sub-subminiature" lamps is deliberate. The tremendous accomplishments of the semiconductor industry in miniaturization and microminiaturization have made it appear that the lamp industry is lagging. Everything seems possible, so why not small lamps? The industry has provided very small lamps for medical use, but they are lamps with very short filaments, operating on 1.2 volts from a single battery cell. Thermal efficiency of filament lamps is low but these are the lowest.

Industry demands small lamps in voltages as high as 28 V, and in bulb sizes of ⅛″ diameter and smaller. Some companies have offered such lamps but these do not usually work out. A 28-volt filament cannot be short and it cannot be thick if the volt-amperes are to be kept within the ability of the bulb to dissipate the heat. A 28-volt coiled filament put into a T-1 bulb is crowded even though the turns of the coil are closely spaced. A tungsten coil is not a stable thing when it is heated, even if the filament temperature is kept low. It squirms and turns become shorted and then the temperature is not low any more. The 60,000- and 100,000-hour ratings that are predicated on the slow evaporation rate of a low-temperature filament are not realized. Sometimes two such lamps are put into one base on the theory, apparently, that two poor lamps are better than one good one. The same base can accommodate a T-1¾ bulb of good design. Hence, all sizes smaller than the T-1¾ should be avoided.

All illustrations of lamps are shown full size in the table.

T-3¼ MINIATURE BAYONET-BASE SERIES—NEON



Voltage Ranges: 110 to 125 volts and 220 to 250 volts
Useful in Group I Lights with Integral Resistors
RECOMMENDED FOR VERY HIGH RELIABILITY
Lamp No. NE-51H

Selection of resistor from information below provides operation at either of two levels of performance and at two ranges of supply voltage.

	110-125V	220-250V
Most light and 5000 hours	22 k	56 k
Less light and 20,000 hours	33 k	100 k

Hours of life above are minimum and are not to be compared with average hours given for incandescent lamps.

T-2 MIDGET FLANGED-BASE LAMP—NEON

Voltage Range: 110 to 125 volts, a.c. only
Useful in Group III Lights with Integral Resistors
RECOMMENDED FOR VERY HIGH RELIABILITY
Lamp No. NE-2J

The use of this lamp is limited to only the lower voltage range and in lights provided with 22k resistor. Performance exceeds most needs in minimum life, and best light output is obtained.

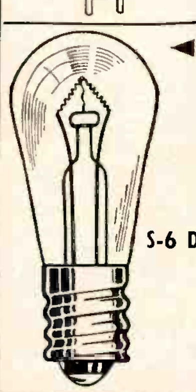
T-2 LAMP CARTRIDGE SERIES #45—NEON

Voltage Range: 110 to 125 volts, a.c. only
Useful in Group II Lights

RECOMMENDED FOR VERY HIGH RELIABILITY

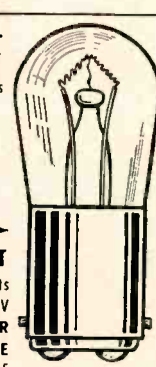
#45 Cartridge with unbased NE-2J and integral resistor of 33k.

◄ S-6 CANDELABRA SCREW-BASE SERIES—INCANDESCENT



Voltage Ratings: 125 volts and 250 volts
Useful in Lights of Group IV
RECOMMENDED FOR GENERAL SERVICE
At 90 to 125 volts Lamp No. 6S6-125
At 180 to 250 volts Lamp No. 10S6-250

S-6 DOUBLE-CONTACT BAYONET-BASE SERIES—INCANDESCENT ►



Voltage Ratings: 125 volts
Useful in Lights of Group IV
RECOMMENDED FOR GENERAL SERVICE
At 9 to 125 volts—Lamp No. 6S6DC-125

Selecting the Pilot Light

When the lamp has been chosen, it is possible to proceed to the pilot light. The several optional features of the light are dominated by the choice of the lens cap details; the nature, shape, and color of the lens, and how it is secured to the body of the light.

Lenses are generally made of plastic, although on larger lights for the hot 6-watt S-6 lamps they are sometimes made of glass. The availability of heat-resisting polycarbonate material has made it possible to replace glass in most cases. Often the lens is mounted in a metal holder which screws into the body or is a precise friction fit that is secure against vibration. The friction fitted lens caps are rotatable. This is an important feature for erecting markings on the lenses. In many screw caps, the lens is spring mounted to produce friction and is rotatable independent of its metal holder which may be tightened securely.

In the area of identifying indicators by lens color, there is the greatest possibility of error. The automatic choice of red for danger and green to indicate that all is well is a mistake too many designers make. It is time that some real thought be given to the specification of color. There are just a few fundamentals that should be kept in mind.

1. Light sources do not emit uniformly in all the colors from violet to red.

2. The eye is not equally affected by the same amount of energy in each color region.

3. The materials that change the color of light sources are subtractive. They reduce the light which is effective in stimulating the eye.

4. Color really does not provide any specific information.

How does the viewer respond to the showing of a red light? What emergency is indicated? Or to the extinguishing of a green light? If all is no longer well, how bad are things and what is to be done? Evidently, a study should be made of when color is really useful and how it can be used to convey some definite meaning. Consideration should also be given to the possibility that the observer may be color blind.

The most effective color is that to which the eye is most sensitive, *i.e.*, yellow to yellow-green. The natural color of neon lamps is nearly ideal. Incandescent lamps emit most strongly in the red region. When filtered to appear green, much light is lost and luminosity is low. The loss is so great when only blue is transmitted that it is quite ineffective.

In the seeing process, human characteristics modify any purely theoretical conclusions. Only this can account for the fact that yellow with a reddish tinge (amber) appears to many as brighter than the unfiltered light. This is the reason why yellow auto headlights are used in some European countries.

Extensive specification of amber color is recommended. Its use will assure maximum visibility. Red can be next in effectiveness but its use should be discouraged except for real emergency indication which should also be explained by an associated legend.

Since color, as such, cannot provide specific information, each indicator—especially when more than one is displayed—should have an associated legend. Assuming that there will be adequate general lighting in the operating area, the legend could be a reflective marking in light letters on a dark panel or the reverse, or a marking on a plate attached to the panel in the mounting of the pilot light. A legend lighted by the pilot-light lens is best. The legend could be applied to the face of the lens as black characters against an amber lens. In larger lenses, the usual practice is to provide a photographically reproduced transparency. The legend may appear as lighted characters against a black background or the reverse.

Stamped markings in black against light-translucent amber plastic lenses provide the most practical marking where many lights will bear different identifications. If neon lamps are used, the translucency should be lightly diffusing, which is another way of saying of low absorption, since neon lamps produce little light and none can be wasted.

Other Pilot Light Features

While occasionally other types of terminals are available, soldering terminals are preferred. Screw terminals should not be used unless the connecting wire has a closed eyelet terminal. Sometimes an optional male spade for a "quick-connection" wire terminal is offered. Their use is desirable only for high-production applications where prepared wiring harnesses are employed.

The parts of the pilot light which show on the face of the panel should be either black or polished metal. The nature of the panel usually dictates the choice.

Frequently, pilot lights are provided with a fixed flange which will rest on the face of the panel with fastenings applied from the rear. Optionally, but not in all cases, the light may be inserted from the rear of the panel and secured with a round knurled nut on the face. The user's special requirements will dictate this choice.

It may be noted that all lights are cylindrical, enclosed, and are intended for one-hole mounting on fairly thin panels.

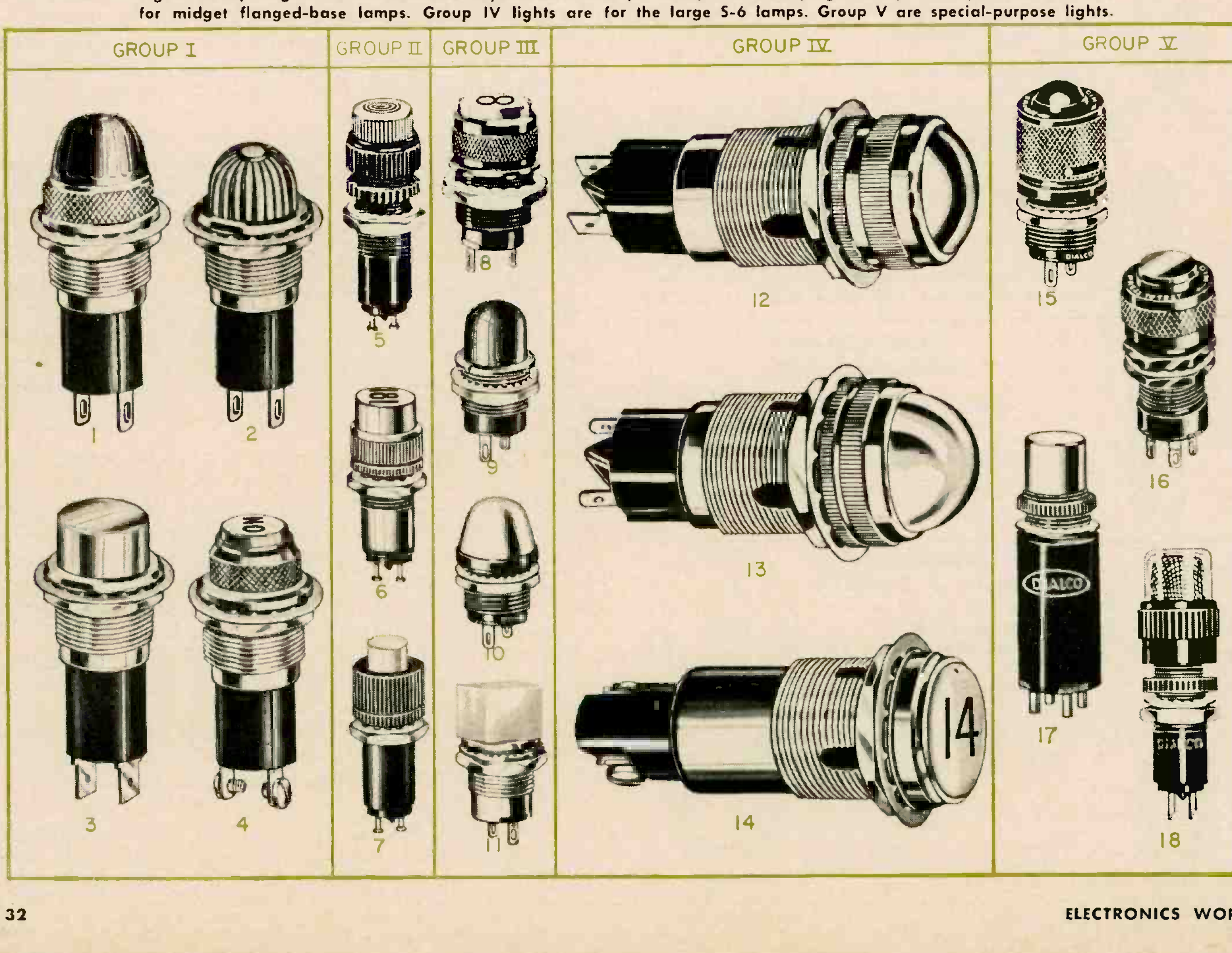
Typical Pilot Lights

Lights for miniature bayonet-based lamps, 11/16" mounting. Lights that accommodate T-3¼, miniature bayonet-base lamps are shown in Group I (Fig. 3). All of the voltages from 6.3 to 55 volts, recommended in the incandescent series, and the NE-51H neon lamp may be used in these four lights. The dome-shaped lenses of #1 and #2 are desirable with NE-51H. No. 2 is a simple all-plastic screw-in cap, useful with neon. No. 1 provides for a lens mounted in a metal holder which screws on. The lens may be of heat-resisting material recommended for use with incandescent lamps of high volt-amperes. No. 3 has an all-plastic cap and permits stamped marking. The lens is not rotatable, requiring the body to be secured to the panel with the lens in place for erect reading. No. 4 has a flat lens suitable for marking and is rotatable so that marking is readily adjusted to be erect.

The terminals shown are soldering, screw, and quick-connecting. Any terminal type may be specified for any light.

Special note: Any of the four lights may be specified with any of four recommended values of resistors built in for the NE-51H lamp. All have (*Continued on page* 52)

Fig. 3. Group I lights are for miniature bayonet-based lamps. Group II are for plug-in lamp cartridges. Group III are for midget flanged-base lamps. Group IV lights are for the large S-6 lamps. Group V are special-purpose lights.



New Low-Loss Coax for TV

Description of a coaxial lead-in for color-TV and u.h.f. that has less loss than ordinary twin-lead in many cases.

By LON CANTOR
Jerrold Electronics Corp.

THE twin-lead *vs* coax controversy has resulted in improvements in both types of transmission lines. Recently, for example, *Belden Manufacturing Company* showed a new shielded twin-lead (ELECTRONICS WORLD, October, 1965). And, now, *Jerrold Electronics* is introducing an improved coaxial cable for use in home TV antenna systems.

It is generally conceded that shielded coaxial cable causes less deterioration of signal quality than ordinary twin-lead. Coax tends to keep out interference and local pickup ghosts and to reduce standing waves, which result in line ghosts. That is why coax is used exclusively in professional installations such as TV studios and master TV systems.

But coax has usually been thought to cause more signal loss than twin-lead, at least in theory. At v.h.f. frequencies, this increased loss is generally tolerable. On u.h.f. channels, however, increased loss might easily mean the difference between good pictures and snow on the TV screen.

Called "82-Channel Coloraxial Cable," the new coax causes only slightly more than half as much loss as ordinary RG-59/U. In fact, it causes even less loss than twin-lead in most home TV installations. And twin-lead losses are known to increase considerably with age, moisture, smog, etc., while coax line losses remain virtually constant.

A Practical Example

Loss, of course, is not the most important characteristic of TV transmission lines. It is generally important only in a fringe area. Let us examine a practical system to see why this is so. Consider two similar antenna systems. Both start with 10,000 microvolts of u.h.f. TV channel-83 signal at the antenna. However, if the signal is carried through 100 feet of RG-59/U, only about 2250 microvolts will reach the TV set. On the other hand, almost 4000 microvolts reach the TV set through the low-loss coaxial cable.

On the surface, this seems like a significant difference. But both signals would look the same on most color-TV screens. This is because all modern TV sets include a.g.c. circuits. As long as enough signal is supplied to take the picture out of the snow and activate the a.g.c., no amount of additional signal results in any better picture quality.

Let us suppose, on the other hand, that the antenna picked up only 1000 microvolts of signal. In this case, the set connected to the RG-59/U would see only 225 microvolts while the other set would be fed 390 microvolts. At this level, there can be a considerable difference in picture quality.

How is the lower loss achieved? Loss in transmission line is dependent upon conductor resistance and dielectric heating—primarily the former. Therefore, the larger the center conductor of the cable, the lower its loss.

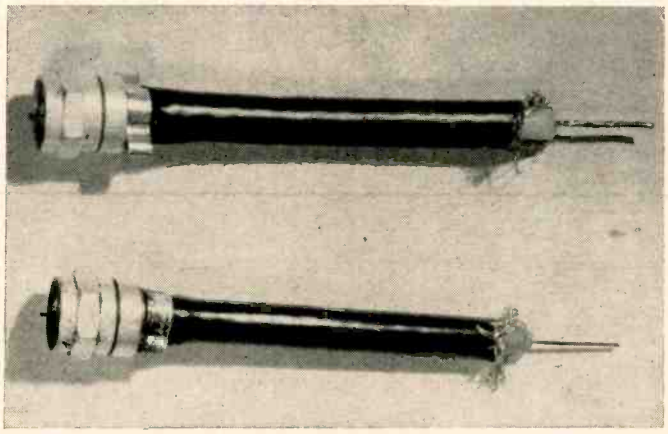
But the center conductor cannot simply be made larger and the rest of the cable left alone. This would change the characteristic impedance of the cable. Characteristic impedance is a term that describes the behavior of the cable in passing signals and the way it cooperates with the source and load. It includes both resistance and reactance, comprising both capacitive and inductive elements. The value of the characteristic impedance is determined by the following factors:

1. The ratio between the diameter of the inner conductor and the diameter of the outer conductor.
2. The dielectric constant of the dielectric.

Thus, if the diameter of the center conductor is increased, the same impedance can be maintained only by increasing the diameter of the outer-conductor shield. Obviously, this would make the cable thicker and harder to handle.

The solution was to change the dielectric, using a foam-type polyethylene (which also contributes somewhat to the reduced attenuation). The new 82-channel cable is only slightly thicker than RG-59/U (see photograph). Cost of the new cable is about 25% higher than conventional coax, and it is available in 50-, 75-, and 100-foot lengths, with fittings and weatherboot attached.

While many technicians will continue to prefer twin-lead, it seems quite likely that coax will be used more extensively in home TV antenna systems now that the loss barrier has been broken. ▲



The new coax cable is shown at the top compared to conventional RG-59/U below. The new cable is just a little thicker, it uses a larger center conductor and foam-type dielectric.

Table 1. Attenuation per 100 feet for twin-lead and coax. The figures for encapsulated and shielded twin-lead are from Electronics World, October 1965, page 29, Fig. 4. According to this figure, flat ribbon and tubular twin-lead losses are over 20 dB at channel 83 in a typical installation. Note that the losses of the new coax are about the same as those for shielded twin-lead. Note also the use of one or two matching transformers required with a coaxial installation may increase the attenuation by approximately 1 or 2 dB.

	Channel 2	Channel 13	Channel 14	Channel 83
Encapsulated twin-lead (300 ohm)	3.2 dB	5.8 dB	7.8 dB	9.8 dB
Shielded twin-lead (300 ohm)	2.1	4.1	6.0	7.8
RG-59/U coax (75 ohm)	2.8	5.8	9.0	13.0
Low-loss coax (75 ohm)	1.75	3.15	5.5	8.2

Battery-Powered Tape Recorders

Here are the technical specifications for 41 models of battery powered tape recorders made available by 19 different companies.

THE battery-operated portable tape recorders shown on these pages run the gamut from restricted-range devices used only for voice communications to portable units whose performance rivals those of quality a.c.-operated units.

Because of their light weight and slow speed that permits storing a considerable amount of information, the smaller units are finding increasing favor as "electronic notebooks," for interview purposes and for information interchange between engineers and their offices. The higher quality units are finding use as mechanical engineering aids by recording sounds made by mechanical parts making faulty contact, so that designers at remote locations will have a better idea of the problem. In some companies, the portable tape recorder is considered as useful an engineering tool as is an oscilloscope.

Most of these portable devices can be run for long hours on their internal batteries. In most cases, replacement batteries are available at the corner store. In some cases, the batteries can be recharged. Some units can also operate off the a.c. line, where it is available, while others can use a conventional car battery.

Prices of these units range from less than $25 to more

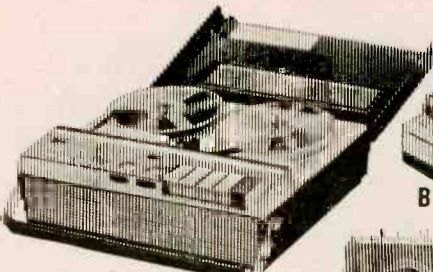
Photo	Model	Tape speed (ips)	Reel size (inches)	Playing time	Tracks: number; stereo or mono	Frequency response	Type of bias	Type of erase	Level indicator	Battery indicator
CHANNEL MASTER CORP., Ellenville, N.Y. 12428										
A	6464	1⅞, 3¾	5	N.S.	2 M	100-7000 Hz—3¾ 100-4000 Hz—1⅞	N.S.	d.c.	meter	meter[q]
B	6545	1⅞, 3¾	3¼	N.S.	2 M	N.S.	a.c.	d.c.	meter	meter[q]
C	6549	1⅞, 3¾	3¼	2 hrs.	2 M	N.S.	a.c.	d.c.	N.S.	N.S.
CONCERTONE DIV., ASTRO-SCIENCE CORP., 9731 Factorial Way, South El Monte, Calif.										
	727	15/16, 1⅞ 3¾, 7½	5	N.S.	4 S	50-3000 Hz—15/16 30-7000 Hz—1⅞ 30-10,000 Hz—3¾ 30-15,000 Hz—7½	N.S.	N.S.	meter	N.S.
CONCORD ELECTRONICS CORP., 1935 Armacost Ave., Los Angeles, California 90025										
D	F-20	Variable	2½	1 hr.	2 M	60 Hz-6 kHz	d.c.	d.c.	none	none
E	F-85	1⅞	2½	2 hrs.	2 M	60 Hz-7 kHz	a.c.	d.c.	none	none
F	300	1⅞, 3¾	4	1⅞—6 hrs. 3¾—3 hrs.	2 M	60 Hz-10 kHz	a.c.	d.c.	meter[k]	meter[q]
G	350	1⅞, 3¾	5	1⅞—6 hrs. 3¾—3 hrs.	2 M	50 Hz-10 kHz	a.c.	d.c.	meter	meter[q]
CRAIG-PANORAMA INC., 2302 E. 15th Street, Los Angeles, California 90021										
H	212	1⅞, 3¾	3¼	2 hrs.	2 M	150 Hz-7 kHz—3¾ 150 Hz-3.5 kHz—1⅞	a.c.	d.c.	[k]	none
I	490	Variable	Cartridge	32 min.	2 M	N.S.	d.c.	d.c.	meter	meter[q]
J	520	1⅞, 3¾	5	N.S.	2 M	N.S.	d.c.	d.c.	meter	meter[q]
GENERAL ELECTRIC CO., 2200 N. 22nd Street, Decatur, Illinois 62525										
K	M8000	1⅞, 3¾	3	1⅞—1 hr. 3¾—30 min.	2 M	N.S.	d.c.	d.c.	[l]	none
L	M8010	1⅞, 3¾	3	1⅞—1 hr. 3¾—30 min.	2 M	N.S.	d.c.	d.c.	meter	meter[q]
M	M8020	Variable	3⅜	60 min.	2 M	N.S.	d.c.	d.c.	[l]	none
MARTEL, 2339 S. Cotner Ave., West Los Angeles, California 90064										
N	201	1⅞, 3¾	5	N.S.	2 M	N.S.	N.S.	N.S.	meter	meter
MAYFAIR-ARCTIC IMPORT CO., 1024 West Randolph St., Chicago, Illinois										
O	JV-1	3¾, 7½	5	3¾—1 hr. 7½—30 min.	2 M	200 Hz-7 kHz	d.c.	perm. mag.	none	none
P	600	3¾, 7½	5	3¾—1 hr. 7½—30 min.	2 M	200 Hz-7 kHz	d.c.	perm. mag.	meter	meter[q]
Q	1802	1⅞, 3¾	3¼	1⅞—2 hrs. 3¾—1 hr.	2 M	200 Hz-6 kHz	d.c.	d.c.	meter	meter[q]
MIRANDA-ALLIED IMPEX CORP., 300 Park Ave. South, New York, N.Y. 10010										
	MIRANDETTE	1⅞, 3¾	3	1 hr.	2 M	200 Hz-6 kHz	a.c.	d.c.	meter	meter[q]
NAGRA-MAGNA TECH ELECTRONIC CO. INC., 630 Ninth Ave., New York, N.Y. 10036										
	NTPH	3¾, 7½, 15	7	N.S.	Full M track	30 Hz-18 kHz	d.c.	d.c.	meter	meter[q]

Footnotes: a—remote control b—a.c. line cord c—splicer d—carrying case e—also a.c. powered f—telephone pickup g—spare reel h—earphone i—voice operation j—tape counter k—automatic level l—neon light m—recharger n—motion picture/slide sync o—auxiliary input p—indicator light q—same as level meter N.S.—not specified than $1000. The prices shown are advertised list or selling price. Check your dealer for the latest prices. Machines selling for less than $25 are not listed as we consider them "toys" rather than serious tape recorders.

The bulk of these devices are not restricted to use with just a microphone. Note that a considerable number of different types of "outboard" devices are available to cover almost any recording situation. These range from telephone pickups to external power supplies.

A number of these machines are foreign-made. This should not deter the purchaser since service for these relatively high-quality devices is available in almost every major city.

The photos illustrating the directory are keyed to each model, where pictures were made available to us. ▲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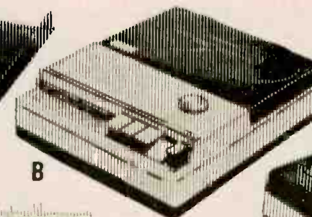
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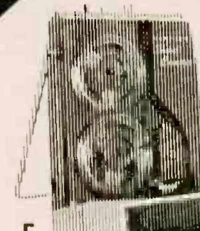
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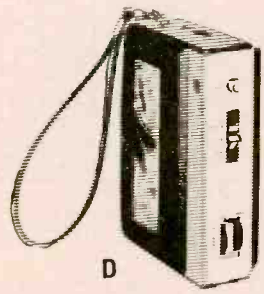
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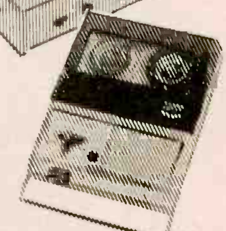
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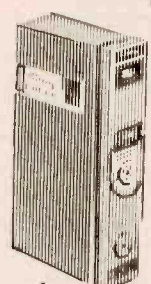
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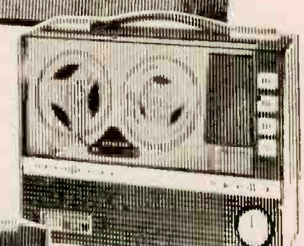
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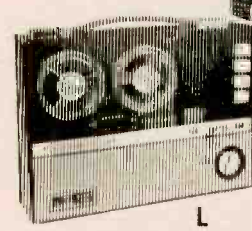
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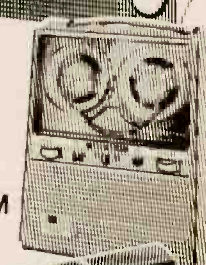
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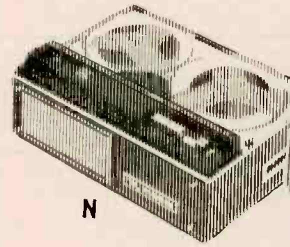
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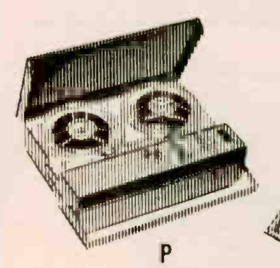
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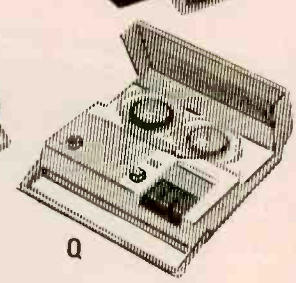
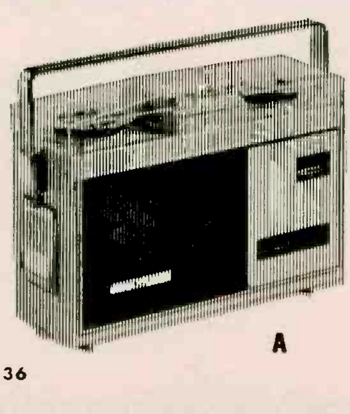

Q

Batteries: number and type	Size (inches) h.	w.	d.	Weight (lbs)	Price	Accessories (See footnotes)
6 "D"	3½	11¼	10	8½	N.S.	a,b,c,d,e,g
6 "C"	2¾	8	10	5¾	N.S.	a,c,e,f,g
6 "D"	3	10½	8½	5	N.S.	a,c,d,e,g,h
6 "D"	13½	11⅝	5⅝	16	N.S.	e
4 "AA"	6½	4½	2½	2	24.95	a,f,g,h,i
4 "C"	7	5	3	2	49.95	a,f,g,h,i
6 "D"	3	10	9	6½	129.95	a,f,g,h,i
6 "D"	4	11½	11	10	199.95	a,f,g,h,i
6 "C"	3⅛	7⅞	9¾	4½	39.95	a,e,f,g,h
4 "AA"	3¾	1⅜	6½	2	79.95	a,d,e,f,g,h
4 "D"	4½	11¼	9½	10	59.95	a,e,f,g,h
4 "D"	8	11 1/16	3⅛	4¼	39.95	e,h
4 "D"	8	11 1/16	3⅛	4¼	49.95	a,e,h
4 "D"	9¾	8	2¾	N.S.	24.95	a,d,e,h
N.S.		N.S.		7	100.00	f,j
3 "D"	4¾	12½	9½	11½	N.S.	d,h,m
6 "D"	4¾	11	8½	6	N.S.	d,h,m
4 "C"	2½	9⅜	8⅜	4	N.S.	d,h,m
4 "D"	2 15/16	9⅝	8 5/16	7¼	169.95	h,j,m
12 "D"	4⅓	14	9½	13.3	1186.00	h,m

Photo	Model	Tape speed (ips)	Reel size (inches)	Playing time	Tracks: number; stereo or mono	Frequency response	Type of bias	Type of erase	Level indicator	Battery indicator
NORELCO, 100 E. 42nd Street, New York, N.Y. 10017										
A	101	1⅞	4	2 hrs.	2 M	80 Hz-8 kHz	a.c.	a.c.	meter	meter[q]
B	150	1⅞	Cartridge	1 hr.	2 M	100 Hz-7 kHz	a.c.	a.c.	meter	meter[q]
PANASONIC, 200 Park Ave., New York, N.Y.										
	RQ-102	1⅞, 3¾	3	N.S.	2 M	100 Hz-4 kHz—1⅞ 100 Hz-7 kHz—3¾	a.c.	N.S.	meter	meter
	RQ-105	1⅞, 3¾	3	N.S.	2 M	100 Hz-4 kHz—1⅞ 100 Hz-7 kHz—3¾	a.c.	N.S.	meter	meter
	RQ-116	1⅞, 3¾	3	N.S.	4 M	100 Hz-4 kHz—1⅞ 100 Hz-7 kHz—3¾	a.c.	N.S.	meter	meter
	RQ-152	1⅞, 3¾	5	N.S.	2 M	100 Hz-4 kHz—1⅞ 100 Hz-7 kHz—3¾	a.c.	N.S.	meter	meter
RCA SALES CORP., 600 N. Sherman Drive, Indianapolis, Indiana 46201										
C	YGS 11	1⅞, 3¾	3	1⅞—1 hr. 3¾—30 min.	2 M	600 Hz-4 kHz	d.c.	d.c.	meter	meter[q]
D	YGS 21	1⅞, 3¾	3	1⅞—1 hr. 3¾—30 min.	2 M	90 Hz-3.5 kHz	a.c.	a.c.	[p]	none
ROBERTS ELECTRONICS, DIV. OF RHEEM MFG. CO., 5922 Bowcroft St., Los Angeles, Calif. 90016										
E	6000 M and S	15/16, 1⅞, 3¾, 7½	5	15/16—6 hrs., 24 min. 1⅞—3 hrs., 12 min. 3¾—1 hr., 36 min. 7½—48 min.	4 both	30 Hz-10 kHz	a.c.	a.c.	meter(2)	none
SONY-SUPERSCOPE, INC., 8150 Vineland Ave., Sun Valley, Calif.										
F	800	1⅞, 3¾, 7½	5	4 hrs.	2 M	50 Hz-6 kHz—1⅞ 50 Hz-9 kHz—3¾ 50 Hz-12 kHz—7½	a.c.	N.S.	meter	meter
G	900	1⅞, 3¾	3¼	1⅞—2 hrs. 3¾—1 hr.	2 M	90 Hz-9.5 kHz	a.c.	perm. mag.	[k]	none
STUART, MATTHEW & CO. INC., 3650 Dyre Ave., Bronx 6, N.Y., N.Y.										
H	88B	1⅞	2½	70 min.	2 M	100 Hz-6 kHz	a.c.	d.c.	none	none
I	216	2.20	3.4	70 min.	2 M	250 Hz-5 kHz	a.c.	d.c.	none	[l]
TANDBERG OF AMERICA INC., 8 Third Ave., Pelham, N.Y. 10803										
	11	15/16, 1⅞, 3¾, 7½	7	N.S.	N.S. M	40 Hz-16 kHz—7½ 60 Hz-9 kHz—3¾ 80 Hz-5 kHz—1⅞ 100 Hz-2.5 kHz—15/16	a.c.	a.c.	meter	none
TELEFUNKEN-AMERICAN ELITE INC., 48-50 34th St., Long Island City, N.Y.										
J	MAGNET-OPHON 300	3¾	5	3 hrs.	2 M	40 Hz-14 kHz	a.c.	a.c.	meter	meter
K	MAGNET-OPHON 301	3¾	5	3 hrs.	4 M	40 Hz-14 kHz	a.c.	a.c.	meter	meter
UHER-MARTEL, 2339 S. Cotner Ave., West Los Angeles, California 90064										
	4000-L	15/16, 1⅞, 3¾, 7½	5	N.S.	2 M	50 Hz-22 kHz—7½ 70 Hz-5 kHz—15/16	a.c.	a.c.	meter	meter
V-M CORP., 305 Territorial St., Benton Harbor, Michigan 49023										
L	760	1⅞, 3¾	3¼	1⅞—1 hr. 3¾—32 min.	N.S. M	200 Hz-6 kHz	a.c.	d.c.	meter	meter
WESTINGHOUSE ELECTRIC CORP., TV-RADIO DIV., Metuchen, New Jersey										
M	27R1	Variable	3	20 min.	2 M	N.S.	d.c.	d.c.	none	none
N	28R1	Variable	3	N.S.	2 M	N.S.	d.c.	d.c.	meter	meter[q]
	29R1	Variable	Cartridge	35 min.	2 M	N.S.	d.c.	d.c.	meter	meter[q]
O	32R1	1⅞, 3¾	3¾	1⅞—80 min. 3¾—40 min.	2 M	N.S.	d.c.	d.c.	meter	meter[q]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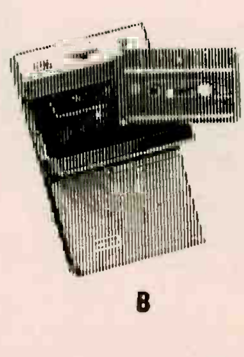
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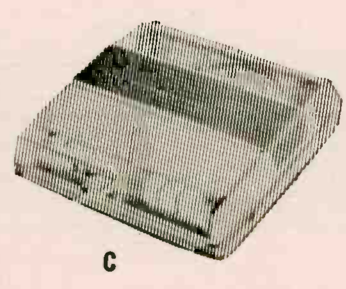
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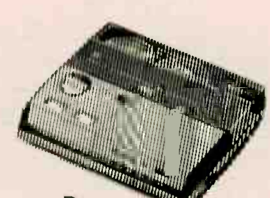
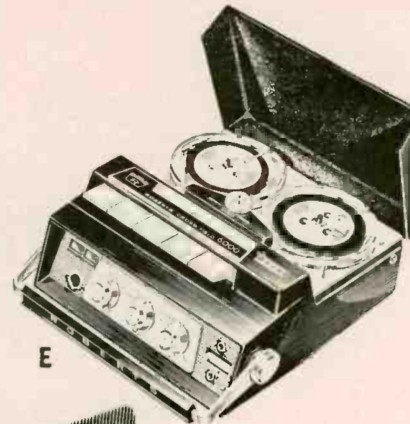

D

Batteries: number and type	Size (inches) h.	w.	d.	Weight (lbs)	Price	Accessories (See footnotes)
5 "D"	8	11	3¼	7	79.50	h,m,o
5 "C"	7¾	4½	2¼	3	89.50	h,m,o
6 "C"	3	9⅝	8½	4½	59.95	a,e,g,i,m
4 "C"	2½	10¼	7¾	4½	49.95	a,g,i,m
12 "AA"	2½	7¾	7¼	4⅛	129.95	a,e,f,i,m
6 "D"	3⅓	11⅗	10¼	7½	99.95	a,g,h,i,m
4 "C"	2¾	9¾	9¼	4.9	49.95	e,h,o
6 "D"	3½	10⅜	8½	6.5	N.S.	d,e,h,o
4 "D"	4	9⅜	10	11	M-299.95 S-359.95	j,m
8 "D"	4¼	12¼	10½	13	199.95	a,e,j,k
4 "D"	3¾	8¾	8¾	5.5	67.50	d,i
3 "C" 3 penlight	1⅞	4¼	7¾	2¾	69.95	a,d,f,h,o
2 recharge.	3½	7½	13	6¼	179.95	a,f,h,i,o
10 N.S.	10	13	4	7	595.00	e,k,o
5 "D"	3	10¾	10⅞	7½	139.95	e,d,m
5 "D"	3	10¾	10⅞	7½	169.95	e,d,m
N.S.	3¼	10½	8½	7	440.00	a,d,e,i,j,m,n
rechargeable	2¾	10⅝	6	5	129.95	a,d,f,h,m
2C 4AA		N.S.		N.S.	N.S.	N.S.
3C 6AA		N.S.		N.S.	N.S.	N.S.
4 "AA"		N.S.		N.S.	N.S.	N.S.
4 "D"		N.S.		N.S.	N.S.	N.S.



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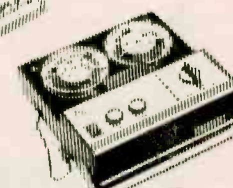

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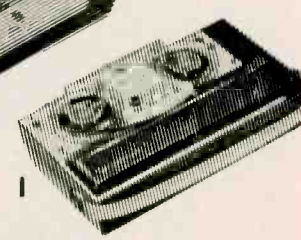

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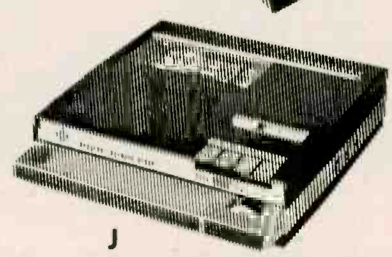

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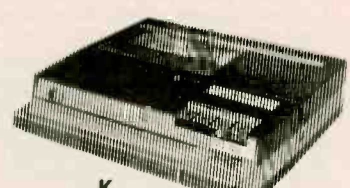

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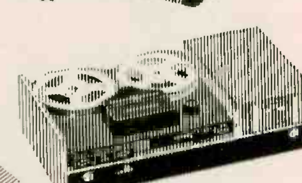

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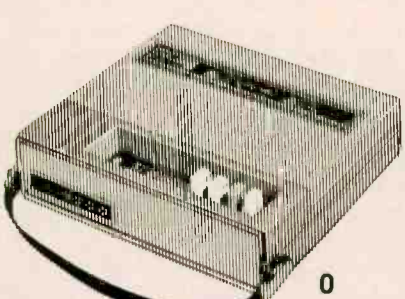

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Convergence Circuits of Color Sets: RCA

By WALTER H. BUCHSBAUM

Special circuitry is necessary for shadow-mask color CRT's to assure that the three electron beams will correctly converge at the shadow-mask holes to strike their respective phosphor dots.

IN addition to the deflection coils, several other factors determine the path of the three electron beams in a conventional three-gun, shadow-mask color CRT. The first of these factors is the purity adjustment, a constant magnetic field which affects all three electron beams. The second adjustment, known as static convergence, controls the coincidence of the three electron beams near the center of the picture-tube active-screen area. This static convergence is achieved by adjusting the fields of three permanent magnets, each controlling one electron beam as illustrated in Fig. 1. The final convergence of the three beams, however, requires a fourth motion, and this is produced by the blue lateral magnet which permits static adjustment of the blue beam in the horizontal direction. This allows all three beams to converge exactly.

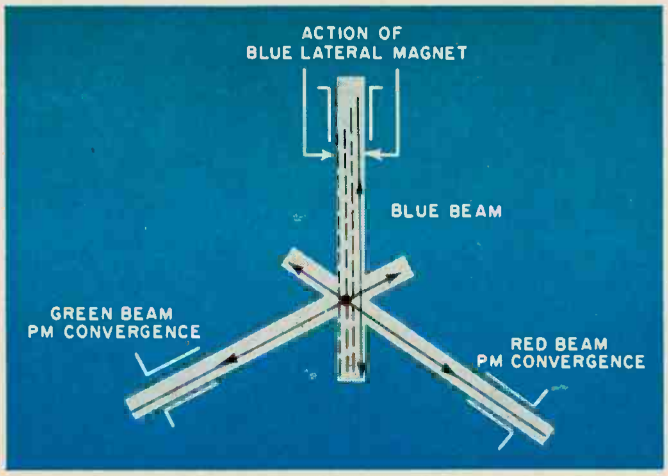
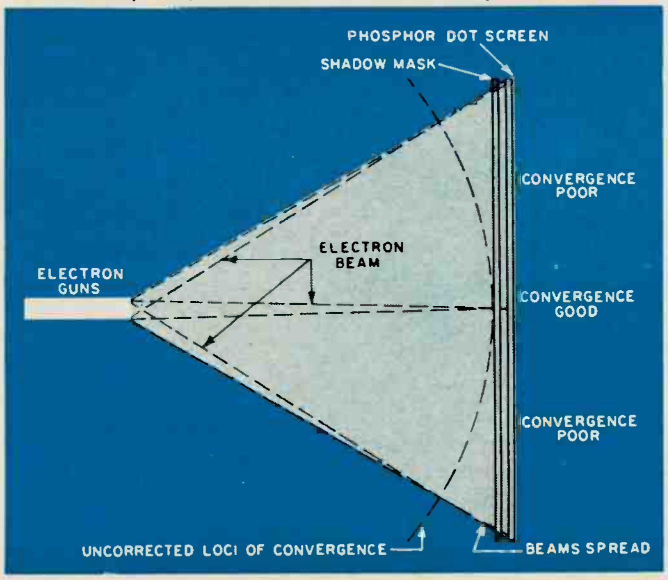


Fig. 1. Permanent magnet convergence and the blue lateral magnet adjustment is used to set purity of the color CRT screen.

Fig. 2. The electron beam convergence (and focus) point describes an arc about the deflection center. As the shadow mask is relatively flat, some form of correction signal is needed.



The third, and by far the most complicated, convergence requirement, is that the three electron beams converge at the top, bottom, and sides of the screen area as the electron beams scan across the face of the screen. The electron-beam convergence, or focus point, moves through an arc as shown in Fig. 2, and since it is intended to strike an almost flat area, the phosphor dot screen, corrections must be made for the focus point so that it changes as the three beams are deflected across the screen. This is called dynamic convergence.

Without proper static and dynamic convergence, good black-and-white and color pictures are impossible. Poor convergence is most easily visible on black-and-white reception when the areas appear to overlap with red, green, and blue borders, similar to misregistration on a color print. Many service calls are due to poor convergence, and it is no wonder that color-TV manufacturers pay special attention to the design of reliable and stable convergence circuits which are also easy to adjust. In the *RCA* CTC19 and CTC17 series of color models, new and improved convergence circuits are used, and adjustments are simplified by reference to specific areas of the screen which each adjustment is designed to control. This article will not go into the details of the convergence adjustment procedure but will concentrate instead on the new features of the dynamic convergence circuitry and on understanding the principles used in their operation.

Purity

The new *RCA* receivers use the same purity magnet assembly that has been employed for the past few years. Two permanent-magnet rings are rotated against each other, or as an assembly. The purity magnet rings are adjusted until a reasonably pure red screen is displayed. *RCA* points out that the static convergence must be set before any purity adjustments should be attempted. The company also advises that no purity or convergence adjustments should be made until after the set has been operating for at least 15 to 25 minutes.

Each of the three convergence magnets in the purity ring assembly contains a permanent magnet which is adjusted to converge the red, green, and blue electron beams

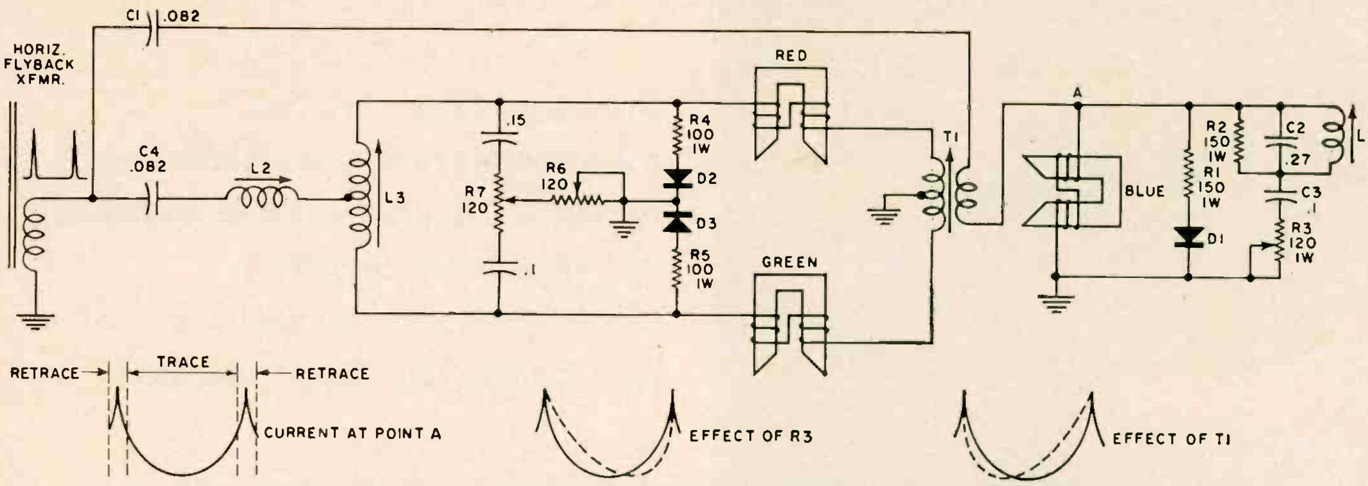


Fig. 3. The waveshapes show how the blue convergence current is affected by adjustment of certain controls. The other two currents (red and green) are affected by adjustment of controls that determine only their particular current flow. The circuit shown is a simplified schematic of the dynamic horizontal circuits used in the RCA CTC17 and -19.

at the center of the screen. The blue lateral magnet is set separately to bring the blue beam into convergence. These are mechanical adjustments, and since no circuitry is involved, they will not be described any further.

Dynamic Horizontal Convergence

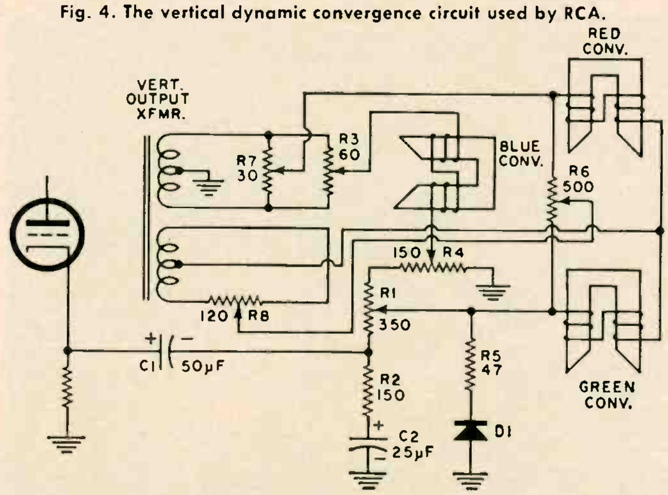
As the red, green, and blue electron beams are deflected across the screen, the point at which they converge changes. If the static convergence is adjusted correctly, the electron beams will converge properly in an area around the center of the screen but, as they move away from the center, some correction is necessary at either side (see Fig. 2). As in all shadow-mask picture tubes, this correction is provided by a shaped current passing through a coil wound over the convergence magnet. This changes the magnetic field as a function of current flow. In many early color sets, a single coil carried both vertical and horizontal dynamic convergence signals; however, new models use separate horizontal and vertical convergence coils. To provide convergence correction, a current which corresponds in frequency to the horizontal deflection signal is passed through the horizontal coils. The current waveshape is parabolic, as shown in the Fig. 3 waveforms, and provides the correction between the flat phosphor dot screen and the radius which the convergence point would describe without these corrections. The amplitude of this correction current will determine the extent of correction that will be present at both sides. As long as this current waveshape is symmetrical as shown in the lefthand waveform of Fig. 3, it will provide equal correction at the left and right. If more correction is required on one side than on the other, tilting or unbalance is achieved, causing the current to appear as shown in the other two waveforms.

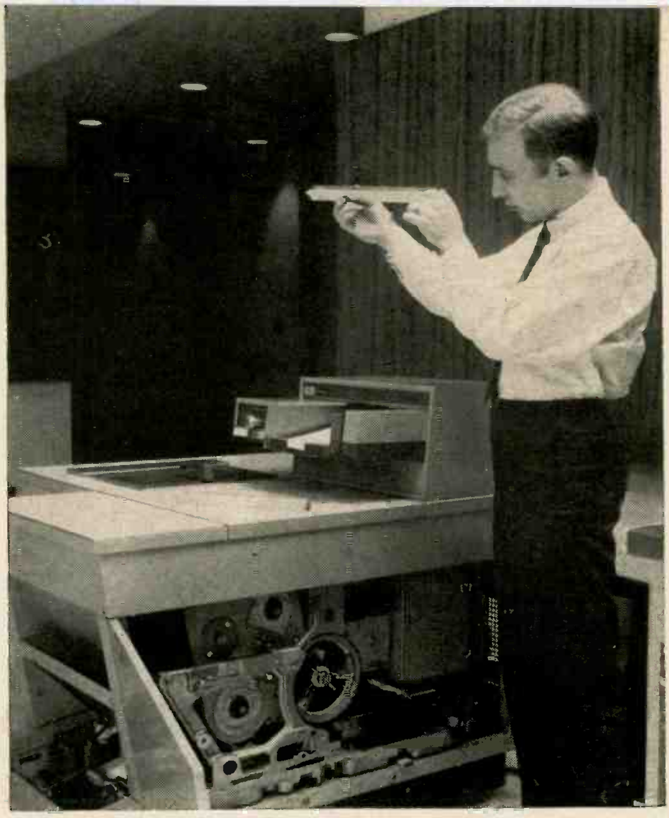
One of the inherent problems in convergence circuitry is the interaction among the three convergence signals, their magnetic fields, and the three electron beams. It is difficult to provide adjustment for the red electron beam without also affecting the green and the blue. What makes this matter even more complex is the problem of determining, in the case of misconvergence, which of the three is really wrong. In the *RCA* models, this has been solved to some extent by using one set of circuitry and controls for the blue electron beam and another set of controls for both red and green.

All horizontal convergence signals are obtained from the same source, but to analyze the circuit functions in detail, examine the blue horizontal convergence circuit as shown in Fig. 3. A 235-volt (approximately) peak positive pulse (the same signal which is used for gating the burst amplifier, the color killer, and the keyed a.g.c.) from the horizontal flyback transformer is the source of the horizontal convergence signal. This pulse passes through capacitor *C*1 and the primary of *T*1. Then the current is divided, at point "A," into the coils of the blue convergence magnet assembly, the tuned circuit of *L*1 and associated components, and the combination of *R*1 and diode *D*1. This latter is a selenium diode, part of a four-section selenium-diode assembly. It should be remembered that the waveform shown as a series of positive pulses is a voltage waveform and that this is different from the actual current passing through the coils of the convergence magnet. It is the current, not the voltage, that determines the convergence action because the electron beam is affected by magnetic flux. Diode *D*1 limits the peaks and prevents ringing. Also across the horizontal convergence coils is an *RLC* circuit (*R*2, *L*1, and *C*2) which acts as a broadly tuned resonant network. Inductor *L*1 is adjustable and its function is to shape the signal. In effect, *L*1 determines the load that the convergence circuits reflect back to the flyback transformer. The adjustment of *L*1 is not part of the convergence procedure but affects the linearity and efficiency of the flyback section. It should be changed only when major repairs have been made, and the detailed procedure described in the service manual should be followed. Both *C*3 and *R*3 determine the amount of amplitude at the left side of the screen, while adjustment of *T*1 determines the amplitude at the right side of the screen. Fig. 3 shows the effect of these two adjustments. (We have assumed here that the left side of the page facing the reader corresponds to the left side of the picture-tube screen.)

The red/green horizontal convergence circuit shown in Fig. 3 is recognizable as some kind of balanced arrangement. It is this balanced circuit that makes adjustment of the red and green horizontal (*Continued on page 74*)

Fig. 4. The vertical dynamic convergence circuit used by RCA.





The Xerox Corp. Tech Rep is
a trouble preventer, troubleshooter,
customer educator, goodwill ambassador,
and engineering consultant
whose reports and suggestions
lead to important design changes.

Looking for flaws in the corotron assembly used in a copier This assembly gives the selenium drum a positive charge that prepares it to receive the electronic image.

By GENE SMITH

The Technical Representative

STEPHEN Levit is a technical representative for *Xerox Corporation,* and he is proud of being one. If he worked for *International Business Machines,* he would be known as a customer engineer. And if he and his *IBM* counterpart had been working in the immediate post-World War II years, they would have been called servicemen.

But Levit really is much more than that. His very appearance points that up. He makes his calls in a business suit; there are no coveralls for him with the company name embroidered on the back. He carries the tools that he needs in two sleek-looking attaché cases. He is clean-cut, neat, well-spoken, for when he calls on a client he *is* the company.

The tech rep is actually a vital member of the company's marketing team. The work he does, the service he renders, the contacts he establishes, go hand in glove with the efforts of company salesmen. It is up to the TR to maintain customer satisfaction and to help promote the other machines and services offered by his company.

Levit is typical of this new breed that has sprung up to service the complicated business machines that are today leased all over the country in ever-increasing numbers. Company revenues depend on all the Stephen Levits it employs, since the leased machines are metered, with the customer paying only for the copy that is actually produced. Downtime, when a machine is out of action, is thus an important item in the balance sheets. How well the TR's do their work is reflected in the all-important earnings of the company.

So, an accurate description of what Levit does proves the importance of his position. He is at one and the same time a trouble preventer, a troubleshooter, a customer educator, a

Using a pyrometer to check the temperature of the fuser heat pressure roller. This roller fuses the toner into the paper.

Steve Levit (center, front row) joins other tech reps in an after-hours class in electronics conducted by the company.

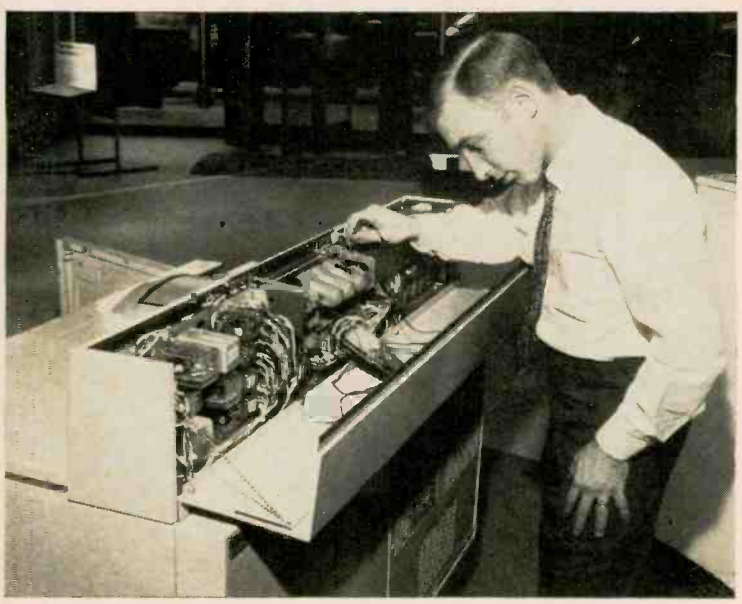
goodwill ambassador, and an engineering consultant, whose reports and suggestions lead to design changes incorporated in new machines or retrofitted into earlier models.

Background and Training

He joined the company five years ago upon his release from the United States Navy, in which he had been an Electronics Technician Second Class. It was only natural that a young veteran should seek work in a field in which he was best qualified, so he tried to locate a job in the radar field. There was little available. So he went to an agency and they told him about *Xerox*.

His electronics training fitted him neatly for the job, and he went to work as one of about 20 TR's whose territory then covered the entire uptown area of New York's Borough of Manhattan, above 42nd Street. Their responsibility: to maintain customer installations of copiers and equipment for producing offset printing masters.

Levit spent his first two weeks in intensive training on the fundamentals of xerography and the machines. He learned all about corona discharge of positive ions and the corotron units that produce it to put an electrostatic charge on a selenium drum or plate. He learned about photoconductivity, the property that enables a material like selenium to act as an insulator and store an electrical charge in darkness and then become a conductor, surrendering the charge in the presence of light. He was thoroughly indoctrinated in the electrical, mechanical, and optical complexities of the devices for which he was to be responsible.



Employing a v.o.m. to check programmer assembly on copier. This assembly sets up a relay switching sequence in the copy cycle.

The next two weeks saw him in the field, actually working with an experienced tech rep on machines at customer installations.

So well did he take to his job that he was subsequently the first TR selected to attend a new company school at Garden City, Long Island, for instruction in the then-new desk-top copy machine. After two weeks there, he was placed in charge of maintaining the first such machines that were installed in New York City.

Today he is also qualified on a number of other machines. These include the highly sophisticated electronic facsimile communications system known as LDX (long-distance xerography). Levit is as much at home troubleshooting the circuitry of an LDX scanner (transmitter) or an LDX printer (receiver) as he is checking out the bias voltage adjustment on a more conventional copier.

Preparing to tune up a long-distance xerography scanner, Levit traces a supervisory signal through the computer logic schematic.

Typical of many TR's, he has shown that he wants to advance himself. He is working hard to earn promotion and to prepare himself for it now by acquiring extra skills. Twenty-six-years old and married, he is an evening student at City College of New York. His company foots half the bill for such outside courses if they are job-related, and more than half the company's TR's take advantage of the opportunity.

While Levit at first aimed at a major in engineering, he has switched to psychology. "I changed because it fits in with the possibilities of getting into management work," Stephen explains. "I have found that a great part of my job is really customer relations. I feel that I have the proper technical background, and this new field teaches me how to deal correctly with people problems."

He points out that this was a personal decision. Other tech reps might prefer to go ever deeper into the technical side, perhaps with an engineering position as a goal.

Even to him, "the most important thing is to have a good background in electronics."

This is truer than ever today for tech reps. The company recently announced that it will (*Continued on page* 73)

Using an oscilloscope to check the width of video blanking pulses that are employed in long-distance xerography unit.

Electromechanical Choppers

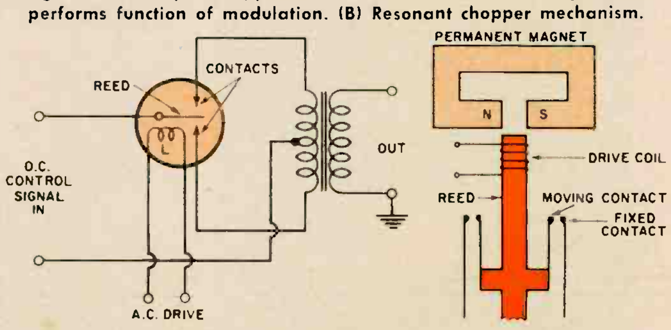
By SIDNEY L. SILVER / B. Eichwald & Co.

Widely used in industrial electronic instrumentation, these contact modulators convert slowly varying signals or changes in d.c. levels into a.c. square waves that can be handled more easily by amplifiers.

IN the field of electronic instrumentation, it is frequently necessary to convert low-level d.c. or very-low-frequency signals to a.c. pulses that bear a definite relationship to a driving sine wave. The driving signal serves as a carrier which is modulated or "chopped" by the original d.c. or slowly varying signal. This function is performed by a switching device, or chopper, which produces an output square wave whose level corresponds to the d.c. signal. The resultant square wave may then be amplified by a conventional a.c.-coupled amplifier, and reconverted to d.c. at a higher level by means of a demodulator and filter.

The use of the chopping technique in the amplification of low-level d.c. signals arises from the fact that d.c. amplifiers, while permitting response down to 0 Hz, introduce drift. This undesirable characteristic is caused by random fluctuations in tube and transistor parameters due to the aging of components and also by the gradual shift of the operating point due to temperature changes. As a result, an output error signal is produced which cannot be distinguished from normal changes in the output caused by the input signal. In control applications where zero reference must be maintained, it is essential that the output of an amplifier be zero when no input signal is present.

Fig. 1. (A) Simple chopper circuit in which the switching action performs function of modulation. (B) Resonant chopper mechanism.



The d.c.-to-a.c. conversion process overcomes these limitations by utilizing simple a.c. amplifiers (*RC* coupling between stages) which can easily be designed for high-gain stability and freedom from drift. After synchronous rectification and filtering, further amplification in d.c. form may be provided by high-level d.c. amplifiers to obtain the desired output voltage.

Modern choppers may be classified as electromechanical, semiconductor, magnetic, or photoelectric—all of which serve useful purposes for specific applications. This article deals exclusively with the electromechanical type, also referred to as the contact modulator. The mechanical chopper has been developed to a high degree of perfection which enables it to perform efficiently under conditions of shock, acceleration, and vibration. Its use is essential in low-level circuitry where electrical noise must be minimized and positive switching action is required.

In industrial electronics, mechanical choppers have found application in feedback control systems, analog computers (differential analyzers), chopper-stabilized amplifiers, precision test equipment (level recording devices), data reduction systems, and medical instrumentation (electrocardiographs).

Mode of Operation

The basic elements of a mechanical chopper consist of a contact-bearing metal reed, positioned between fixed contacts, and a polarized drive coil. In the simple chopper circuit shown in Fig. 1A, an a.c. excitation signal is applied to the drive coil (*L*) which gives rise to an alternating magnetic field, thus causing the reed to vibrate at the frequency of the applied voltage. The vibrating reed alternately deflects toward each fixed contact in synchronism with the drive frequency, so that contact motion is determined by the polarity of the coil.

When the d.c. control signal is applied to the contacts, the switching action of the reed periodically interrupts or chops the d.c. so that induction occurs in the transformer. Thus a rectangular a.c. pulse is developed across the second-

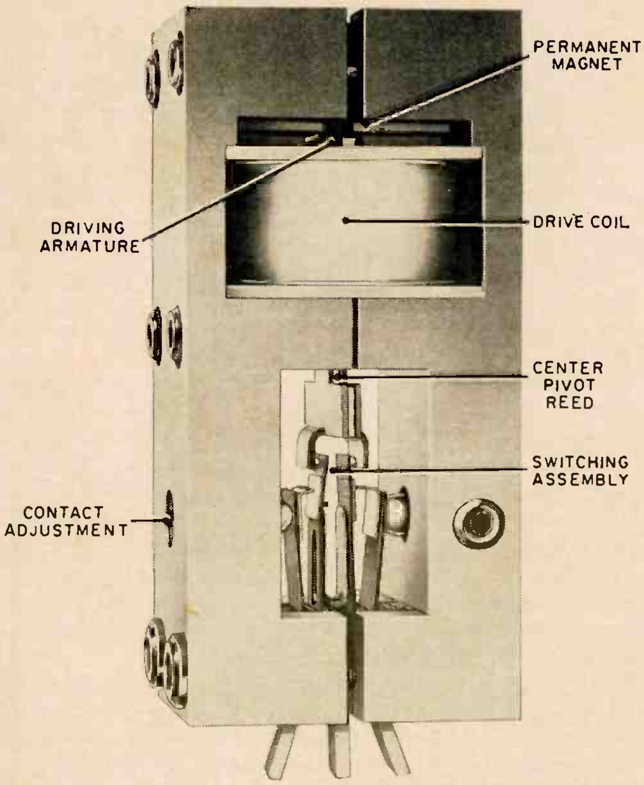


Fig. 2. Basic mechanism of a miniature non-resonant chopper.

ary, the amplitude of which is dependent upon the amplitude of the d.c. input and the step-up ratio of the transformer. The frequency of the output pulse is equal to the driving sine-wave frequency and may be reversed in phase by changing the polarity of the d.c. input signal. Since the transformer cannot pass the d.c. component of the waveform, the a.c. output is effectively isolated from the d.c. input.

Basic Types

In the mechanism of a mechanical chopper, a weight and spring relationship exists in the moving structure of the device to form a mass-compliant system If the natural frequency of the metal reed is used to achieve contact motion, the device is referred to as a "resonant chopper." To make the chopper operate at the same fundamental frequency as the excitation, a d.c. polarizing field is provided by a permanent magnet.

Fig. 1B shows the basic elements of a resonant-type chopper in which the drive coil current polarizes the end of the reed north or south, depending on the direction of the coil current. When the end of the reed is polarized north, it is deflected toward the south pole of the permanent magnet. A reversal of coil current causes the reed to reverse polarity and deflect toward the north pole. In this manner, the coil excitation alternately increases and reduces the magnetic field of the polarizing magnet so that the vibrating reed causes the contacts to make and break once for each oscillation of the drive voltage. The reed vibrates at the coil excitation if this frequency is near the natural resonant frequency of the reed.

Since the "Q" of the mass-compliant system is high at resonance, any variation in temperature, drive frequency, or drive voltage may produce large phase shifts between the reed oscillation and the reed drive. To stabilize these operating characteristics, the resonant chopper is designed to operate with a drive frequency which is near, but not equal to, the natural resonant frequency of the reed. In a typical 60-Hz chopper, for example, the reed frequency is frequently on the order of 80 Hz.

Most resonant choppers are designed to operate at either 60 Hz or 400 Hz with a nominal drive coil rating of 6.3 volts r.m.s. High voltages, up to 100 volts, may be switched intermittently across the contacts, since the resonant-reed principle permits adjustment for large contact motion. When adjusted for large contact motion, the resonant chopper produces high contact pressures which contribute to positive switching action.

A variation in chopper design is the non-resonant type or "driven chopper." In this configuration, the mechanical resonance of the moving contact assembly is considerably higher than the operating frequency range of the chopper. Switching action is achieved by a stiff armature which is deflected solely by the energy derived from the magnetic fields of the permanent magnet and the drive coil. The stiffness of the armature requires that a high driving force be exerted on the moving contacts to obtain contact motion. This high-force-to-mass ratio enables the chopper to operate efficiently under extreme conditions of shock and vibration. Driving waveforms for non-resonant choppers may be sinusoidal, square, step function, or even irregular pulses of a repetitive nature. The use of drive voltages with steep wavefronts, however, is generally undesirable since they contain high-frequency components which may cause contact chatter.

Fig. 2 shows the internal construction of a commercial chopper with a non-resonant driving system, which can accommodate a span of drive frequencies above or below its nominal frequency. In this design, the driving armature is separated from the switching circuit by a center pivot reed which permits extensive shielding between the driving system and the low-level switching circuit. This mode of construction also balances the armature and minimizes the effects of external mechanical forces. Since the frame mass is made high in relation to the driving system, there is a low vibration transmission to adjacent components so that no shock mounting is required.

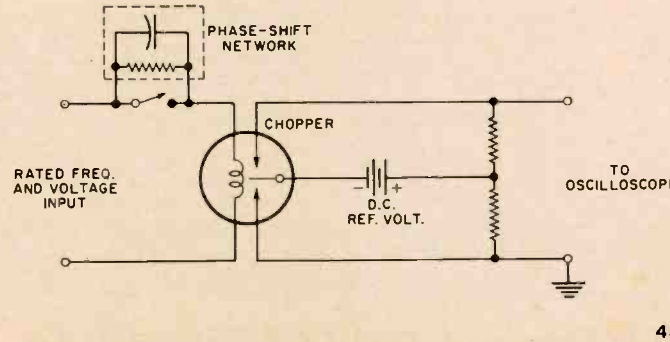
To eliminate a possible source of noise generated by electrochemical action, all component parts are gold plated. The contacts are made with a special gold alloy in order to avoid erratic contact resistance when switching very-low-level signals. Adjustment is made by glass-tipped screws which fix the position of the stationary contact arms.

Electrical Characteristics

An important factor which determines the useful life of a chopper is its ability to function within specified limits. In general, choppers remain within their ratings for at least 5000 hours of continuous operation. Since the circuitry used has a considerable bearing on performance, it is difficult to specify precisely the life of a chopper. In order to evaluate electrical performance a measuring circuit, as shown in Fig. 3, may be used, in which the driving voltage is a perfect sine wave and the output signal is developed across a resistive load. Fig. 4 illustrates the important parameters which can be determined by this method.

One of the operating characteristics of a chopper is the time in electrical degrees that each contact is closed, in relation to the sinusoidal reference wave. This factor is called

Fig. 3. Measuring circuit for determining contact action. Phase-shift network provides optimum phase stability.



the *dwell time* and it occurs twice each cycle. Any difference in closure time of two contacts opposite each other results in a different dwell time (asymmetry) of the two halves of the square wave.

Dwell time changes when the chopper approaches the end of its life so that the device fails to function within certain tolerances. For example, a decrease in dwell time caused by changes in the time interval between the initial engagement of the movable contact and the fixed contacts is equivalent in many chopper circuits to an effective loss in gain. This limitation may be overcome by using circuits with a substantial margin of gain so that the chopper may deliver useful performance for several times its rated life.

The interval of time during which neither contact of an opposing pair is closed is referred to as the *transit time*, or "off" time." This interval of no electrical contact occurs twice each cycle and is a characteristic of a break-before-make chopper. During transit time the presence of undesirable pickup currents may permit inductive spikes to appear in the output signal.

Another parameter of interest is the precise timing relation between the opening and closing action of the con-

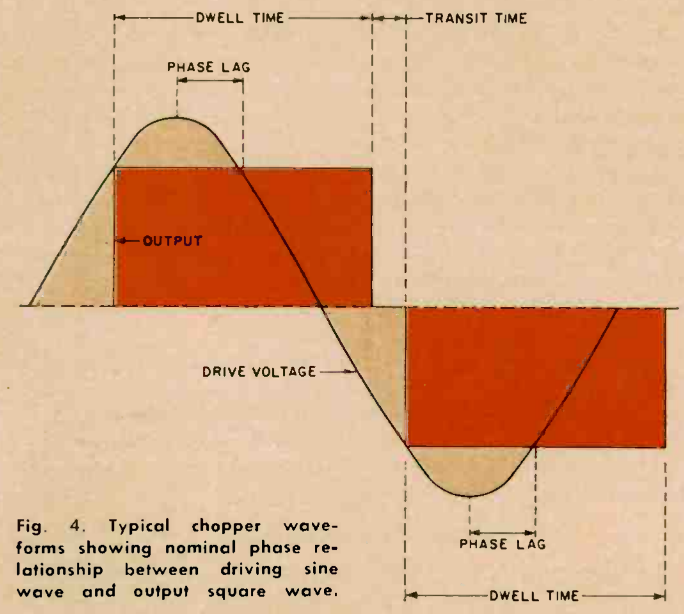


Fig. 4. Typical chopper waveforms showing nominal phase relationship between driving sine wave and output square wave.

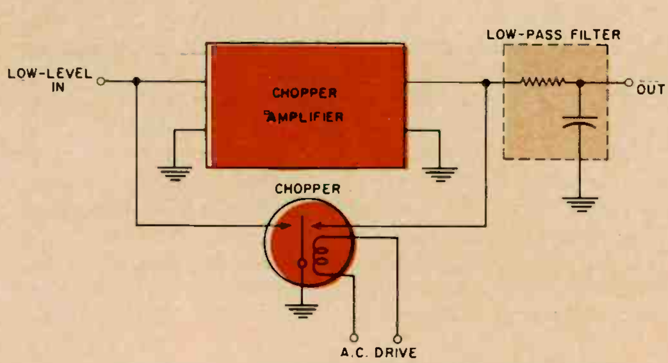


Fig. 5. Block diagram of chopper amplifier with s.p.d.t. chopper.

tacts and the driving sine wave. This relation is called the *phase lag* and is defined as the displacement in electrical degrees between the peak of the sine wave and the midpoint of the corresponding dwell time. Phase angle is measured between the 90° (or 270°) point of the sine wave and the square-wave center. The inherent phase lag is caused by the drive coil inductance and the mechanical mass of the moving armature assembly. An increase in the driving frequency increases the phase angle, while a rise in driving voltage reduces the angle. Effective phase may be changed by external circuitry. To adjust a chopper for a phase angle of 0°, for example, a phase-shifting network may be connected in series with the drive coil, which introduces a leading current and provides optimum phase stability.

An important chopper characteristic is the presence of unwanted signal, or residual noise, which is generated within the chopper. Chopper noise is the voltage appearing between each contact and ground which is measured across a resistive load, with the driving signal applied to the coil and no control signal at the contacts. The noise component in phase with the drive voltage, termed "offset," is rectified and appears as d.c. at the output of the synchronous rectifier. This noise element can be measured by applying a d.c. input and chopping the signal both in the plus and minus direction, the difference being the offset.

A major source of noise inherent to a mechanical chopper, especially in high-impedance circuits, is electrostatic noise caused by capacitive coupling between the drive coil and the switching assembly. The value of the coupling impedance is much higher than the load impedances employed in chopper circuits, so that electrostatic noise is directly proportional to the external load.

Another type of spurious signal is magnetic noise caused by stray leakage currents originating in the drive coil and induced into the switching circuit. Magnetic noise has a source impedance much lower than the external load impedances generally used in chopper circuits, and is nearly constant and independent of circuit loading. Noise can also take the form of thermal e.m.f.'s produced at the junction of dissimilar metals due to a temperature gradient. These bimetallic junctions exist in the switching circuit connections and also at the chopper base terminals.

Low residual noise levels are obtained by electrostatic and electromagnetic shielding between the drive coil and the contact assembly. Further isolation is maintained by feeding the drive coil leads out through the top of the chopper enclosure and bringing the contact leads out through the base. To resist the effects of moisture and dust contamination, most choppers are hermetically sealed in metal enclosures (brass or Mumetal). Some choppers, however, are designed with removable covers to permit cleaning and adjustment of the contacts in order to extend its useful life.

In modern chopper design, noise has been reduced to a negligible value, with noise figures obtainable under one microvolt when operating into a high-impedance load.

Chopper Applications

The primary function of a chopper in most circuits is to modulate and demodulate a signal in conjunction with a

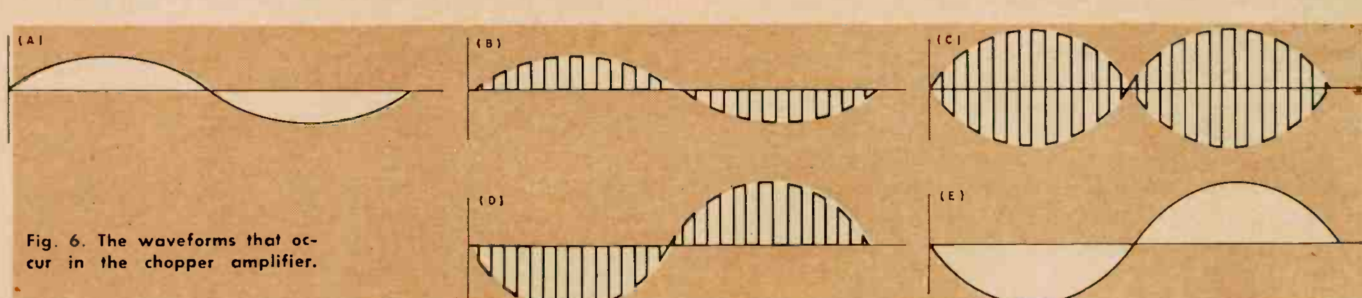


Fig. 6. The waveforms that occur in the chopper amplifier.

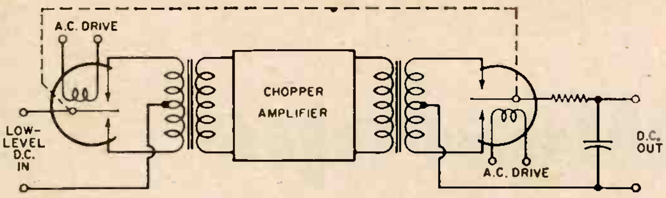


Fig. 7. Amplifier with d.p.d.t. chopper for full-wave demodulation.

high-gain a.c. amplifier. In the chopper amplifier shown in Fig. 5, a single chopper acts as a s.p.d.t. switch to perform the function of both the modulator and demodulator. The operation of the circuit may be analyzed by assuming the input control signal to be a very-low-frequency sine wave, as shown in Fig. 6A. When the signal is applied to the input contacts, the amplifier is modulated at the drive frequency by being alternately shorted to ground to produce the waveform shown in Fig. 6B. Assuming that the low-frequency signal does not lie within the passband of the a.c. amplifier, the amplified voltage output will have the form shown in Fig. 6C. The output is half-wave rectified (Fig. 6D) and fed to the low-pass filter during the interval of time that the output contacts are open. Thus, either the input or the output of the amplifier is always grounded. The filter serves to reduce the chopper frequency ripple to a negligible value so that the final output voltage in Fig. 6E is an amplified reproduction of the input. A 180-degree phase reversal exists between the input and output voltage due to the fact that the chopper applies the input signal to the amplifier at the same time that it shorts the output, and *vice versa*.

To obtain an output voltage free from harmonics introduced by the modulator, the cut-off frequency of the filter must be low compared to the modulation frequency. This limits the frequency response of the system to a few cycles, in the case of a 60-Hz chopper, which is sufficient for small bandwidth requirements. Where a wider bandwidth and faster response time is required, a 400-Hz chopper may be employed.

The use of a single chopper to modulate and demodulate a signal may introduce a source of undesirable feedback since the input and output terminals are in close proximity. To avoid oscillation, it is necessary to employ a make-before-break type of chopper so that at least one end of the amplifier is grounded at any instant. In this way, capacitive coupling between input and output contacts is avoided.

For high gains, it may be feasible to employ a d.p.d.t. chopper with one section used for modulation and the other for demodulation. Fig. 7 shows a chopper amplifier in which a full-wave demodulator rectifies the output signal in synchronism with the modulator contacts at the input. The split-reed construction of this type of chopper isolates the two sets of contacts from each other, thereby avoiding a possible source of feedback. Since both sets of contacts are in the same case, any phase angle variations caused by changes in temperature affect both sections alike, so that the two sets of contacts remain closely synchronized with each other. The tracking between the moving contacts and the fixed contacts must be closely matched in order to hold the chopper dwell time and phase relationships precisely constant. Any major differences in these operating characteristics will affect the d.c. gain of the chopper amplifier.

To overcome the disadvantages of restricted upper frequency limit of the chopper amplifier, a chopper-stabilized system is used in circuits that require a very high gain over a wide frequency range. As shown in Fig. 8, this technique consists of a two-channel arrangement in which the low-frequency components of the input signal are fed to a chopper amplifier through a low-pass filter ($R1$, $C1$) and appear at one input of a d.c. differential amplifier. The high-frequency components of the signal bypass the chopper section through a high-pass filter ($R2$,$C2$) and are fed to the

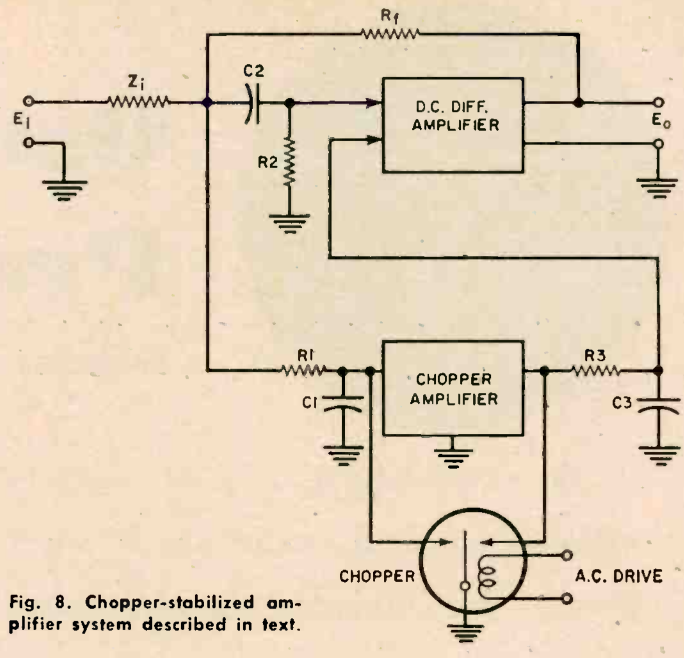


Fig. 8. Chopper-stabilized amplifier system described in text.

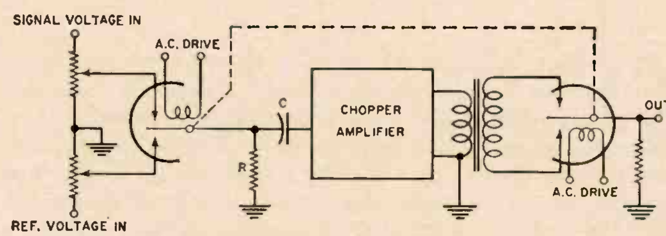


Fig. 9. Comparison circuit measures difference in d.c. values.

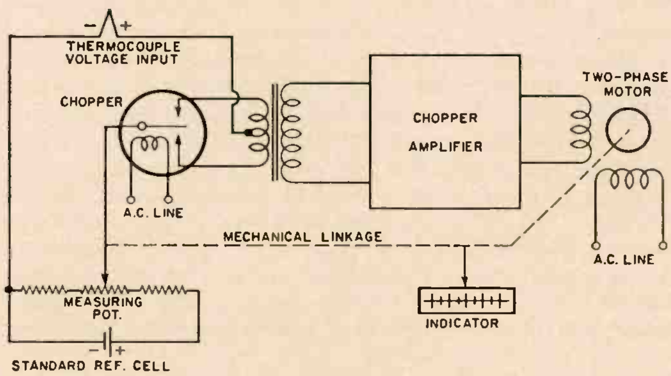
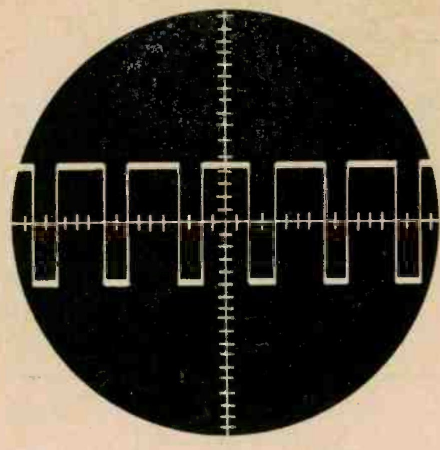


Fig. 10. Electronic null-balance temperature recorder circuit.

other input of the d.c. amplifier, where they are reunited with the low frequencies. By adjusting the crossover frequency of the filter networks to a sufficiently low value, negligible energy at the chopper frequency enters the modulator. Over-all negative feedback is employed to stabilize the gain and provide a flat, uniform response ranging from d.c. to the upper frequency limit of the d.c. amplifier.

The reduction of drift, which may be regarded as a very-low-frequency noise component, is made possible by the large amount of negative feedback used in the low-frequency channel. Any drift component which is developed across the output of the d.c. amplifier is fed back through the feedback resistor (R_f) and passed through the chopper amplifier to the input of the d.c. amplifier. Since the drift is inversely proportional to the chopper amplifier gain, the effective drift level becomes exceedingly small compared to the enormous amount of stable low-frequency amplification available from the chopper amplifier. In effect, the chopper amplifier serves as a high-gain, (*Continued on page* 56)



Oscilloscope Probes

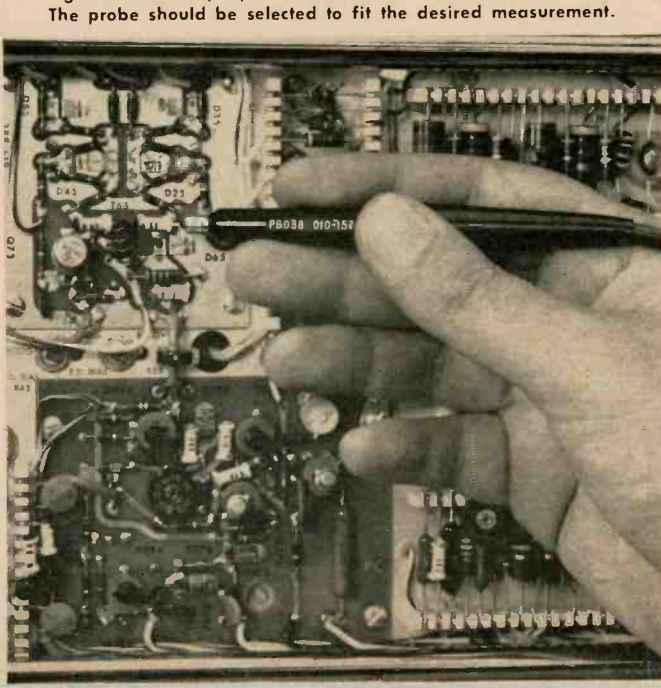
By WALTER H. BUCHSBAUM

While probes are only an accessory to the scope, they have a strong influence on the accuracy of any measurements. Choosing the correct probe, and knowing its characteristics, then becomes very important.

ONE of the basic principles in electronics is that every measurement somehow always affects the measured quantity. When a particular voltage is measured, for example, some of the energy must be diverted to the voltmeter itself, thereby lowering the actual voltage. In practical testing and measurement, this amount is so small that it can be neglected. There are many instances, however, where the amount of energy drained off by the measuring device is great enough to cause trouble. Voltmeter resistances are given as 1000 or 20,000 ohms per volt, which is the resistance represented by the meter circuit when it is shunted across the point at which the voltage is measured. Knowing the circuit, we can calculate the error due to meter loading, but for most practical purposes, even a 3% loading effect can be neglected, especially since it is always present and repeated measurements with the same instrument will always produce the same results.

When an oscilloscope is used to measure a.c. signals, the loading effects of capacitance, resistance, or inductance can seriously distort the shape of the signal. This distortion can be especially severe at the higher frequencies, with complex waveshapes, or with very high voltages. For this reason, practically all manufacturers of oscilloscopes provide special test probes to assure that the measurement of the signal does not cause any distortion in itself. This article deals with the various types of oscilloscope probes, their circuitry, and their proper use in making measurements.

Fig. 1. Oscilloscope probes enable convenient circuit testing. The probe should be selected to fit the desired measurement.



Mechanical Probes

Probes provide convenient mechanical methods of reaching various test points without danger of accidental shorts. Fig. 1 shows a typical probe in use and illustrates the convenience of a particular type of tip. When tracing through a circuit, where quick connections to one point after another must be made, a simple needle-point probe is usually best. When the oscilloscope probe is to be attached to a terminal or a piece of wire, alligator clips, hooks, or springs are more convenient. Fig. 2 shows some of the different tips which can be used with a particular *Tektronix* probe. The popular "Klipzon" probe tips combine a needle point with a spring-loaded hook for clipping the probe to a terminal or bare wire lead. Another probe tip consists of two parallel springs which come apart to form a clip when the insulating sleeve is pulled back. Still other inexpensive probes have tips over which a small alligator clip can be fitted to provide attachment to a terminal or wire.

The coaxial cable that is connected to the probe is, of course, grounded at the oscilloscope chassis, and it is usually best to bring a short lead from the cable or probe ground directly to the chassis ground nearest the point under test. This grounding arrangement will prevent undesired pickup by the probe cable but requires shifting the ground lead as the probe is moved around. In testing lower frequency circuits, a common ground between the oscilloscope and the chassis under test may be sufficient. This makes it easier to move the probe around but can cause pickup trouble.

D.C. Probes

If the shielded test cable were connected directly to the point being measured, this would shunt the capacitance of the cable and the scope input circuit directly across the circuit under test. To avoid this, an isolating resistor can be connected in series with the test cable. This is usually a one-megohm, ½-watt resistor mounted inside the probe case. Because most oscilloscope input circuits have a very high impedance input, this isolating resistor has the effect of attenuating the signal amplitude. The shunt capacitance of the cable and the scope input circuit increase the attenuation at the higher frequencies. A simple isolation probe can only be used on signals below 10 kHz and does not permit really accurate measurements.

For accurate amplitude measurements, the probe attenuation must be known precisely, and the effects of cable and scope input capacitance should be at a minimum. The amount of attenuation depends upon the circuit of the particular oscilloscope probe and will vary from 10× to 1000×. A typical probe circuit, such as shown in Fig. 3, provides 100× attenuation as determined by the ratio of $R1$ to $R2$. The probe itself, the cable, and the input to the oscilloscope all have capacitance which means that at higher frequencies, $R2$ is shunted by the capacitance of the coaxial cable, $C2$.

To appreciate the importance of this shunt capacitance, assume that the combined capacitance of the probe handle, the coaxial cable, and the scope input circuit all add up to 50 pF. When a 10-kHz square-wave signal is applied to the probe, the reactance of $C2$ will be about 300,000 ohms at the 10-kHz fundamental. A rise time of 10 microseconds equals a frequency of 100 kHz at which the reactance of $C2$ will be about 30,000 ohms. The wavefront of the square wave will therefore be attenuated almost ten times as much as the 10-kHz fundamental, resulting in a much-rounded-off square-wave display on the oscilloscope screen. Neglecting the small resistance of $R3$, the basic attenuator consists of $R1$ and $R2$. Since $R2$ is shunted by $C2$, $R1$ can be shunted by a capacitor to compensate for the effect of $C2$. Using the same ratio of capacitor reactance to resistance, $C1$ turns out to be approximately .5 pF. When a 100-kHz signal appears at the probe input, $C1$ will shunt $R1$ with a reactance of approximately 3 megohms, while $C2$ will shunt $R2$ with 30,000 ohms. The attenuation then remains a constant 100×, regardless of frequency. Capacitor $C1$ is made adjustable because the capacitance of the oscilloscope input and the length of the cable will vary slightly.

During the calibration process (of $C1$), the square wave viewed on the oscilloscope should be capable of being adjusted from insufficient compensation as shown in Fig. 4 (left), to the over-compensation of Fig. 4 (center), to the correct adjustment of Fig. 4 (right).

As previously pointed out, it is important that the signal power taken by the oscilloscope probe be relatively small compared to the power available in the circuit under test. This means that the impedance presented by the oscilloscope probe must be at least ten times greater than the impedance level of the circuit. If the input impedance of a typical vacuum-tube circuit being tested is on the order of one megohm, the oscilloscope probe, in order not to present appreciable loading, should have an impedance of at least ten megohms. Oscilloscope probes using special electrometer tubes or subminiature triodes in cathode-follower circuits provide very high impedances without having the great attenuation of resistance probes. Separate power-supply subassemblies and compensating boxes are usually furnished with these vacuum-tube probes. They are intended for precision, laboratory-type measurements, particularly at the higher frequencies, rather than general test and troubleshooting work.

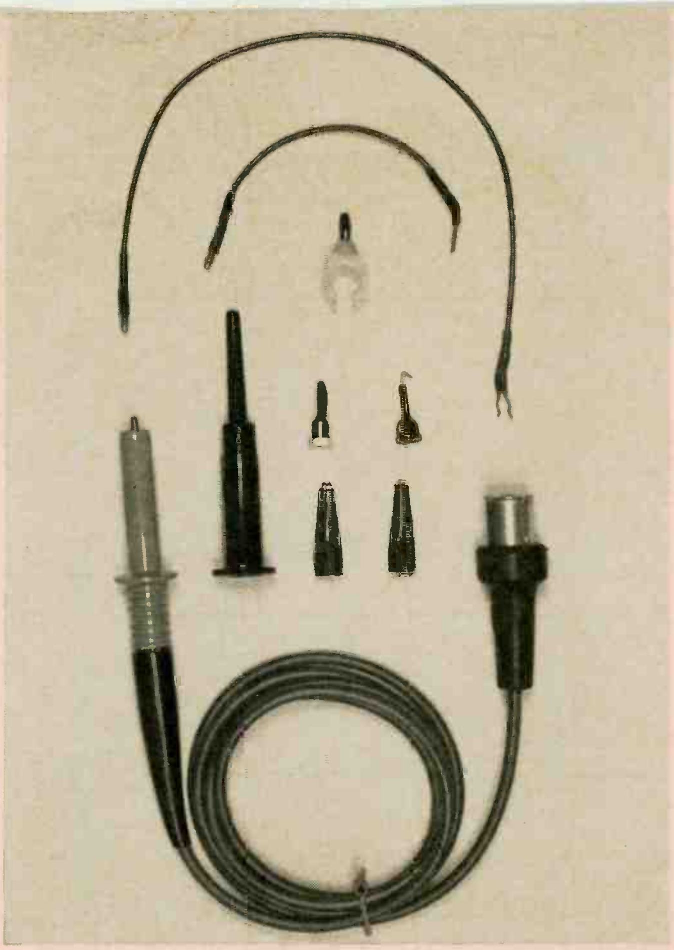


Fig. 2. Some probes come with a variety of interchangeable tips.

In transistor circuits, the impedance between stages is much lower, generally on the order of 100 to 10,000 ohms. It is therefore possible for transistor circuits to use oscilloscope probes which have only a one-megohm input impedance; in many instances, no isolating probes are required because the input impedance of the oscilloscope is so high. The capacitance due to the coaxial cable and the scope input may, however, be high enough to load certain high-frequency transistor circuits so that some isolation probe is still needed.

High-Voltage Probes

TV technicians have often observed the "caution" on sche-

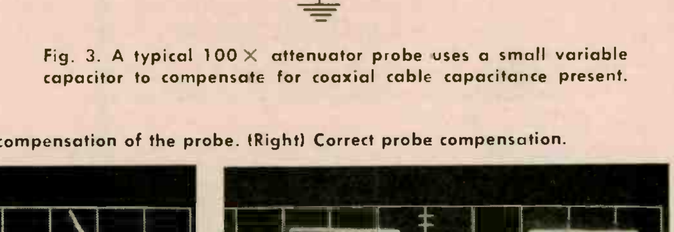
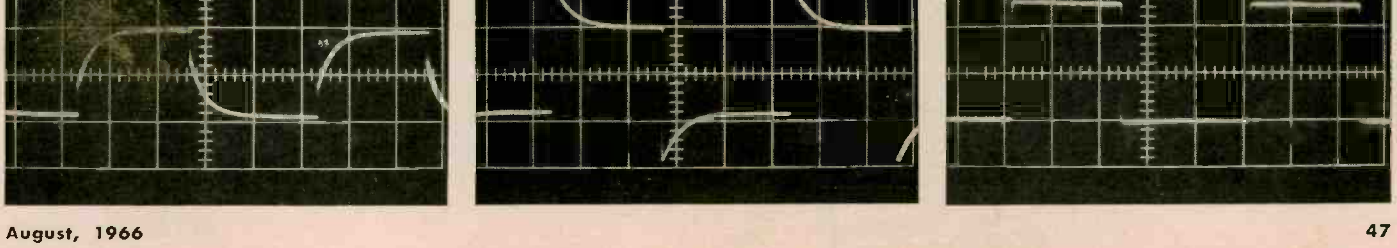


Fig. 3. A typical 100× attenuator probe uses a small variable capacitor to compensate for coaxial cable capacitance present.

Fig. 4 (Left) Insufficient compensation of the probe. (Center) Overcompensation of the probe. (Right) Correct probe compensation.



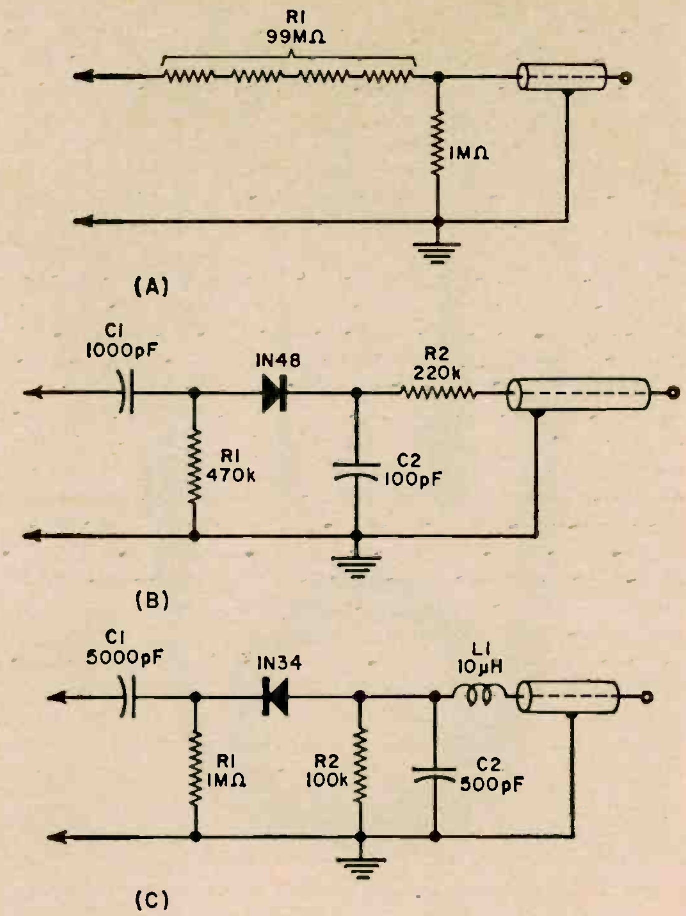
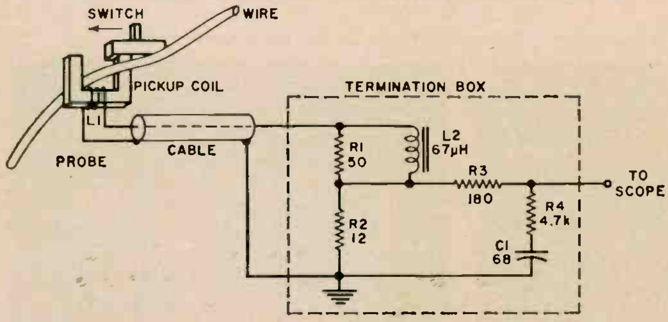


Fig. 5. (A) High-voltage (100×) probe. (B) Typical demodulator probe. (C) One variation of the demodulator probe.

matic diagrams not to measure the pulse at the plate of the horizontal output tube. The reason for this is that the high voltage at that point would break down an ordinary probe or else damage the oscilloscope input circuits. High-voltage pulses are also found in radar, telemetry, and many other fields so that a high-voltage probe, specially designed for oscilloscopes, has become important. The circuit of a simple high-voltage probe having an attenuation of 100× appears in Fig. 5A. This probe could be used with a v.t.v.m. as well. Note that *R*1, the series resistor, does not contain a means for compensating for the shunt capacitance. A compact and adjustable capacitor, capable of withstanding the high voltage, would be difficult to construct. When this high-voltage probe is used with an oscilloscope, a separate compensating box connected at the cable end will contain the adjustable features. High-voltage probes are available in attenuations of 100× and 1000×, and in operating voltages up to 40 kilovolts. With such probes, it is possible to make oscilloscope observations and measurements of high-voltage pulses at the output tube of the horizontal output transformer in a television set, or at the output modulator stage of a radar transmitter. If it is desired to observe the output of the transmitter or look at the r.f. circuits of a receiver, it is necessary to rectify the r.f. signal to observe the modulation envelope.

Fig. 6. An a.c. current probe senses current flow through wire, enabling measurement without direct circuit contact.



Demodulator-Type Probes

Wherever the signal to be observed is amplitude-modulated on another (usually r.f.) signal, a special demodulator-type probe must be used. Such probes are commonly used with vacuum-tube voltmeters when it is desired to measure r.f. voltages. In tracing audio or video signals through the r.f. and i.f. stages of a receiver, it is particularly useful to use a detector between the circuit under test and the oscilloscope because the modulated signal (audio or video) can then be observed directly. Demodulator probes are either part of the oscilloscope probe package or can be obtained separately.

The circuit of the *Eico* demodulator probe, shown in Fig. 5B, appears similar to the detector circuit in a superhet AM receiver. Because of the relative values of *R*1 and *R*2, some attenuation of the detected signal occurs which must be compensated by the scope amplifier. The circuit of Fig. 5C shows another version of a demodulator probe that uses a small r.f. choke (*L*1) to help filter the i.f. or r.f. while providing very little attenuation to the demodulated signal. This is helpful when signal tracing i.f. sections where millivolt or even microvolt signals must be demodulated. Almost any diode can be used equally well in these circuits. The polarity of the diode affects only the polarity of the demodulated signal.

The demodulator probe input impedance is determined largely by a shunt resistor (*R*1 in Figs. 5B and 5C) and the forward impedance of the diode during conduction. In general, detector probes are used in r.f. or i.f. circuits where the circuit impedances are much lower than the probe impedance. The capacitor at the output of the probe (*C*2) affects the frequency response of the detected signal. To get sufficient filtering and yet keep this capacitor small, the circuit of Fig. 5B uses a series resistor (*R*2), while a small r.f. choke (*L*1) is shown in Fig. 5C. Most demodulator probes are designed to have an output impedance which is reasonably flat up to frequencies of about 1 megacycle.

A.C. Current Probes

Many professional oscilloscopes make a.c. current probes available to permit picking up signals without direct electrical contact. A small ferrite-core coil is placed over the wire that carries the signal and coupled to the oscilloscope. To get maximum coupling, the ferrite core must enclose the wire, and this is accomplished, as illustrated in Fig. 6, by making a portion of the ferrite core movable so that the wire can be enclosed. The probe contains only the pickup coil, *L*1, and the movable ferrite switch for closing the magnetic loop. Between the cable and the scope a termination box must be used to get the required flat frequency response. The termination-box circuit shown in Fig. 6 is designed for current of 10 mA per millivolt of signal to the scope. A different termination box is available for smaller currents and, for very weak signals, a special transistor amplifier box can be used.

The great advantage of the a.c. current probe is that no direct electrical connections are required and individual wires can be monitored in situations where there is no access to the signals inside the chassis. Because the size of the wire carrying the signal and the position of the wire within the pickup loop may vary, exact signal-amplitude calibration is usually difficult with this method. The efficiency of the pickup coil also depends upon the magnetic path within the over-all ferrite core. If dirt gets into the gap between the U-shaped piece and the movable piece, or for some reason the gap is not entirely closed, the resistance in the magnetic path may be increased sufficiently to reduce the picked-up signal below usable strength. To assure correct measurements with the a.c. current probe, some comparison measurements with a wire carrying a signal of known amplitude can be used. ▲

JOHN FRYE

First- or second-semester performance in college has proven to be the best indicator of a student's final achievement.

PREDICTING ACADEMIC SUCCESS

BARNEY and Matilda were taking a Coke break with Mac, their employer, on this hot and humid August afternoon. The office girl traced a wavy line on the frosty bottle with a finger tip and spoke above the whirring of the air conditioner: "The boy next door is getting ready to go to college. He's going to take up mechanical engineering, and I'll bet he's a whiz at it. Every spare minute he has is spent fooling around with lawn mowers, old cars, and other mechanical things."

"I hate to disagree, especially with a lady on such a hot day," Mac drawled; "but I doubt your neighbor's incessant tinkering with things mechanical is a very reliable indication of how he will do in college. About a month ago I read an article in *Backgrounder*, a publication of Purdue University's Schools of Engineering, that knocked a big hole in this hallowed theory—which, incidentally, I had always held right along with you, Matilda.

"The article discussed findings made by Professor William K. LeBold, Professor of Engineering and Assistant to the Dean of Engineering at Purdue. Prof. LeBold has a Ph.D. in psychology, so he is well equipped to evaluate the ten-year study he made of the characteristics of engineering and science students and graduates. In a nutshell, Prof. LeBold found the most reliable indicators of what a youth can be expected to do in college are not the grades he made in high school, are not the scores he racked up on College Entrance Examinations Board tests, and are not interests he may have that are similar to those of people in the profession he intends to take up. The fact that he likes math or fools around with cars means little in forecasting how he will do in engineering."

"If none of these things are reliable indicators, what are?" Barney demanded.

"What a boy does in his first year, or even his first semester of college, is a far, far better sign of what you can expect of him during the remainder of his college years. Let me quote you some facts and figures from the article to back this up. When combined high school grades and CEEB scores are compared with actual college achievement, a correlation coefficient of .5 or lower turns up repeatedly, not only at Purdue but at other universities and colleges. You square the correlation coefficient to translate it into percentages; so that means that high school rankings and CEEB scores have only 25% in common with actual college achievement. In other words, if you used high school grades and College Entrance Exam Board scores to guide you in 'guessing' how a youngster would do in his college career, you would be right only one-fourth of the time.

"But when you compare what he does in his first semester with his final cumulative index (final grades), you come up with a correlation coefficient of .7. The percentage of right guesses has increased to 49%. And when you compare the correlation between second semester achievement and the final index, the correlation coefficient goes to .9. This should enable you to predict success or failure with 81% accuracy.

"Several theories have been advanced to try to explain the poor correlation between high-school-grades-plus-CEEB-scores and actual achievement in which various 'non-cognitive' factors—motivation, home influences, study habits, personality, interests, etc.—are credited with causing the discrepancy. In one Purdue study, students were assessed on the basis of 150 of these non-cognitive variables to see if personality, attitudes, interests, or some other factor could be used as a key to future academic performance. All attempts to measure and make use of such factors proved largely fruitless. There was little relationship found between any of them and actual performance.

"One rather bizarre result turned up in the testing. In the well-known Strong Vocational Interest Test, a student's score on the Mortician Scale portion was found to be the best indicator of engineering performance—in reverse! The more the student's interests approach those of a practicing mortician, the more likely he is to be an engineering dropout. But his performance on the Engineering Scale portion has no more value. It has zero correlation with first-year academic performance in engineering. Prof. LeBold carefully points out that failure to find some reliable non-cognitive indicator does not necessarily mean no such indicator exists. But if it does exist, it has not yet been found.

"The professor is a positive thinker. He believes a student who wants to go into engineering should not be too easily discouraged because of mediocre high school grades or CEEB scores. He says, 'It's clear that if you . . . exclude from college those who have less than a B average in high school and who fall below 450 on the CEEB, you inevitably are going to exclude many who might be able to perform satisfactorily if given the chance.'

"If, because of increasing college enrollments, they cannot get this chance in a four-year school, they should have it in a junior college or some similar institution, according to LeBold. Students starting there, he says, will not be handicapped when they transfer later. Repeated checks at Purdue and other institutions show that students entering after two years of junior college work usually require only one semester of adjustment before it becomes difficult to tell they haven't spent their whole careers in the university.

"He doesn't discount the stiff competition the youngster will encounter in an engineering course in a university such as Purdue. For example, one-half of all high school seniors score below 430 on the CEEB quantitative examination, but only two percent of Purdue freshmen engineers score below 430. This is especially significant when you remember Purdue is a state university open to most Hoosier students wishing to go to college.

"On the other hand, he points out there is less attrition in college than is generally believed. Many people believe more than half the students who enter college never finish. A recent University of Illinois study of male students shows that three out of four eventually graduate, although not necessarily from the institution where they began or even in the field in which they started. At Purdue, 60% of beginning engineering students go on to graduate from Purdue, and another 20% graduate elsewhere.

"One thing you must keep in mind is that college education is no longer the classical four-year process. An increasing number of students take more than four years to get that bachelor's degree. In cities where there is opportunity for part-time work, it is not unusual for half of all students to take six years to graduate. Obviously, if you list all students who have not graduated in four years as dropouts, you get a misleading attrition figure. Prof. LeBold thinks attrition figures should be based on six, seven, or even ten years instead of four."

"Well, you have certainly made some quick changes in my thinking," Matilda admitted. "As I get it, about the only way to tell if a student can handle an engineering course is to give him a chance to try it. At the end of the first year, you'll pretty well know if he can cut the mustard."

"Yeah," Barney chimed in, "and it certainly will behoove him to give that first year all he's got. But I hate to give up the idea that I can't make a good guess about who will make an engineer and who will not, even before he completes the first semester. I've always believed that one type of radio amateur is a 'natural' to become a good electronics engineer. This is not just a hunch. I've watched many hams go through college and on into good jobs in electronics."

"You speak of 'one type of ham' as being good engineer material," Mac observed. "I take it from this that a person's having a ham ticket is not enough to make your crystal ball light up optimistically."

"You take it right. The rag-chewing, traffic-handling, plug-in appliance operator—one who buys his equipment ready-built and knows just enough about it to plug it in—may or may not make an engineer; but his ham activity is useless as an indicator. By the same token, the fanatic who eats, drinks, and sleeps amateur radio is quite likely to flunk out. His brain is too obsessed with hamming to permit the entry of anything else. He is the sort who takes a transmitter along to college so that he can 'keep in touch' with the folks at home—or so he says. Actually he will be hamming when he should be studying. Providing him with a telephone credit card for 'keeping in touch' would be an excellent investment on the part of his parents who are paying for his college education.

"The kind of ham I have in mind is the one who is continually probing into the 'why' and the 'how' of the apparatus he uses. He is constantly experimenting and building new equipment—not just to use it, but to find out if it works and how it works. He doesn't get his technical information by chatting on the air with other hams—I don't know a better way to become misinformed—instead, he ferrets out the answers he wants by studying technical journals, magazines, and books. He takes pleasure in operating his gear, maintained in top-notch condition, and in keeping records of its performance, but hamming to him is not an end in itself. Instead, it is just an early stepping stone in his quest for knowledge about the field of electricity and electronics that is so fascinating to him.

"When this ham enters college and finds himself surrounded by knowledgable instructors, excellent laboratory equipment, a wonderful technical library, and bright stimulating fellow students, he no longer needs ham radio any more than a 'swinger' at a party needs the hostess after she has introduced him around. He may continue amateur radio as a fine relaxing hobby, but he doesn't insist on making it a major part of his life's work."

"Okay, but I doubt you've found a non-cognitive indicator Prof. LeBold overlooked," Mac said. "Actually your non-typical ham is a self-taught budding engineer before he ever enters college. Already he is well-grounded in the experimental approach, in technical research, and in record-keeping."

"Well, you guys and Prof. LeBold can fool around with your variation coefficients and other mumbo-jumbo all you want," Matilda said as she started collecting the empty Coke bottles, "but I'm still sure Tommy next door is going to make a fine engineer. My woman's intuition tells me so."

"And *that* is *that*!" Mac murmured with a broad grin. ▲

SOLDER INACCESSIBLE JOINTS

By A. A. MANGIERI

REPLACEMENT of components deeply buried within a TV tuner or compact assemblies can often be handled without disconnecting interfering wires and parts which would otherwise be burned or damaged by heat. First, try bending the wire tip of the soldering gun to one side or the other in a radius to clear and avoid contact with nearby wires and parts. Of course, parts replaced in TV tuners must be placed and dressed in the same position as the part removed.

In some cases, the soldering gun tip may be too short to reach the soldered joint. In this case, fashion a longer tip of #12 or #14 gauge solid copper wire. Shape and bend it as required. Tin the tip. Sufficient heat will be developed to handle all but the heavier junctions. Wire gauges as small as #18 were used with success for delicate soldering operations although such wires lack the rigidity of the heavier gauges.

All tips should be no shorter nor heavier than the original. Many seemingly impossible soldering jobs were handled easily by these substitute tips, thereby avoiding unnecessary disassembly or complete replacement of an assembly. ▲

Selecting Indicating Lights

(*Continued from page* 32)

Underwriters Listing for 125 volts or 250 volts.

Lights for plug-in lamp cartridges, ⅜" mounting. The Group II lights accept plug-in lamp cartridges containing T-1¾ lamps of the incandescent series, rated from 1.35 volts to 28 volts, and T-2 neon lamps with 110 to 125 volts a.c. to the terminals of the light. The lights illustrated accept #39 series with incandescent lamps. The lights for #45 series with high-brightness neon lamps and resistors enclosed are longer and the lights have somewhat more back projection but identical front-of-panel features. Nos. 5 and 6 are preferred types with screw-on cap over the lens of the cartridge. No. 7 is an older type with the lens of the cartridge displayed as it projects through the knurled nut which secures it. The newer lights with caps are recommended for almost all applications.

The lens of #5 is always transparent with lenticular inner surface to control the light and to obscure bright filaments or neon electrodes without light loss. This cap makes low-powered incandescent lamps and neon lamps very effective. For cases where the light needs identification, the rotatable lens of #6 is recommended. It is effective with amber translucent lenses and black stamped marking except with low-lumen incandescent ratings and neon with long-life resistor. Identification should be on the panel for those lamps and #5 should be used.

All of these lights are shown with turret terminals for soldered wiring and no other type connection is recommended.

Attention is called to the fact that these lights cover almost the complete voltage range and permit closer spacing than any of the other lights shown or generally available.

Lights for midget flanged-base lamps, mounting 15⁄32". Group III lights accommodate T-1¾ incandescent lamps with midget-flanged bases. Some models, with somewhat longer lenses and greater front projection, employ the NE-2J neon lamps. They are available with integral resistors for application of 110 to 125 volts to the terminals of the light.

Lights of this group are ruggedly made and have military and aeronautical applications. No. 10 is waterproof and oil-proof at the front of the panel. The metal mechanical parts are of aluminum and the usual finish is black anodized. The exception is #11 which has a square plastic cap which is friction fitted to the body so as to be rotatable. Nos. 9 and 10, dome shaped, provide wide visibility and good effectiveness. No. 8 has rotatable lens and is the recommended choice in the group for identification by stamped marking. No. 11 may be similarly used for non-military applications on panels where the square style presents a more desirable appearance. Round caps may also be chosen.

Large lights for S-6 lamps, 1" mounting. The lights for large lamps of the 6S6 series, with either candelabra screw sockets (or double-contact bayonet) provide brightly lighted lenses of about 1-inch diameter. These are shown in Group IV.

A selection may be made among three types of terminals for combination with any other option.

Nos. 12 and 13 lenses provide very bright concentrated light with plano-convex lens or for wide spread with the dome. It is recommended that a diffusing surface be specified for these lenses, which are mounted in screw-on holders.

No. 14 is friction fitted to the body to permit rotation for erection of the legend. This light well is adapted to very crisp display of bright legends presented as negative or positive by the use of photo-transparencies under the flat lens.

All members of this group have Underwriters Listing.

Special-Purpose Features

No discussion would be complete without mention of some lights with special features, shown in Group V.

No. 15 is typical of mechanically operated dimming devices that reduce the emitted light by rotating the front part of the cap. Some have shutter action and some have superimposed polarizing disks which display the full aperture in changing intensity. Their use has been almost exclusively aeronautical or military and is declining.

No. 16 answers the question, "Will it light if an emergency arises?" It is a press-to-test light (combined with a dimmer) that contains two paths for current to the lamp. The circuit, through the actuating device to the supply, is normally closed. Pressure on the lens cap moves the whole lamp and socket and cylinder to complete connection directly to the supply and the lighting of the lamp gives the assurance.

No. 17 is a pilot light with transistor drive. When available voltage or current, or both, are very low and a source of power is available for lamp operation, this combination is useful. Indication is possible on small "signals."

No. 18 answers the problem of how to reduce emission of electrical and r.f. interference. More and more tight limits are being applied to reduce the "noise" that is causing interference with communications. The pilot light shown is designed to house a plug-in cartridge. The cap is equipped with fine mesh screen, well grounded to the cap and with provision for good contacts to a knurled nut and, in turn, to the grounded panel. Quite satisfactory attenuation is obtained in this light and others operating on the same principle.

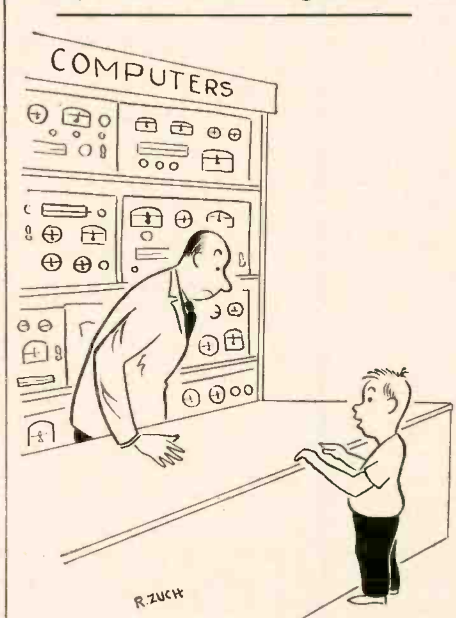
Military Specifications

The broadest specification affecting applications of indicator lights is MIL-L-3661A entitled: "Lampholders; Lights, Indicator; Indicator-Light Housings; and Lenses, Indicator Light." This specification treats the panel-mounting base portion of the device separately from the lens cap. It is in error in many instances and is under revision. It is the current spec but exceptions are necessary to make parts operate together and to permit use of more up-to-date components.

Two other specs of the vintage of the forties are applicable. They are MIL-L-7961B entitled: "Light, Indicator, Press-To-Test" and MIL-L-6723B: "Lights, Aircraft." These are applicable. There has been little need to change these but usage has declined as new aircraft replace older designs.

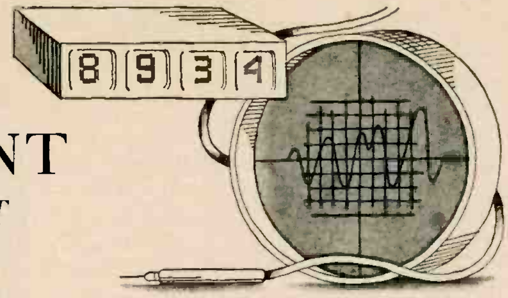
In general, the MIL Specs have lagged behind modern practice and insistence on following old specs can only lead to obsolescence.

There have been a few cases where specifications and MIL-Spec drawings have been issued to cover light sources. In general, these have described lamps with A.S.A. status that are included in the rather adequate and complete Federal Specifications used for purchases by the General Services Administration. There is much duplication and it is being eliminated only gradually. Cooperative action by lamp manufacturers through the American Standards Association has kept the situation in order as far as designations and descriptions of miniature lamps is concerned. Military drawings usually refer to these designations. ▲



"Do you have a fourth-grade computer?"

TEST EQUIPMENT
PRODUCT REPORT



Eico Model 715 "Trans/Match" Ham-CB Tester

For copy of manufacturer's brochure, circle No. 28 on Reader Service Card.

THE Model 715 is a flexible, multi-purpose instrument that can be used to check CB transmitters and low-power ham rigs. Requiring no batteries or other power sources, the compact, portable tester performs all its functions using the transmitted signal only. (See diagram.)

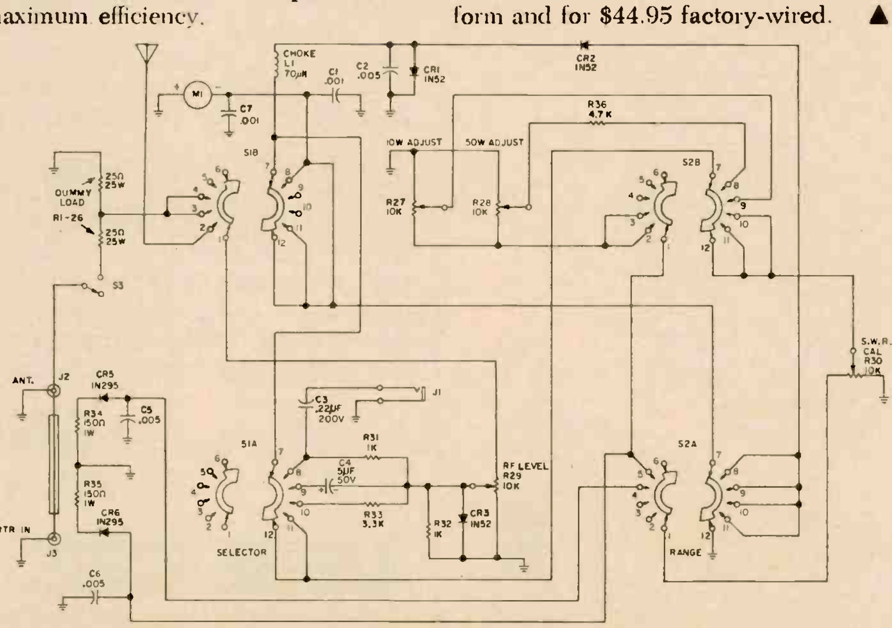
When inserted into a 50-ohm coax feeder between the transmitter output and the antenna, the tester will check the standing-wave ratio of the antenna and transmission line. This is done by comparing the incident power with the reflected power using a simple r.f. directional coupler circuit. The s.w.r. should be as close to 1 as possible for maximum efficiency.

The second function the tester will perform is measurement of the r.f. power output. Two scales are provided: 10 watts and 50 watts. During this test, a built-in resistor load is used which will handle up to 50 watts intermittently and 25 watts continuously. The power output is read directly on the three-inch meter.

A third function provided is a measure of modulation percentage. This also employs the built-in load and takes advantage of the power increase that occurs during modulation to produce a direct meter indication of percent modulation. A set of phones can be plugged in to check the audible quality of the modulation.

A fourth function, which is particularly useful in comparing different antennas or different rigs, is taking field-strength measurements. Now the unit is used a short distance from the transmitting antenna and its collapsible, 2½-foot antenna is extended. A simple crystal detector and meter (100 μA) circuit is used to show relative field strengths. Antenna radiation patterns along with the locations of lobes or nulls can be readily checked.

The tester measures only about 5x8x3½ inches. It sells for $34.95 in kit form and for $44.95 factory-wired. ▲

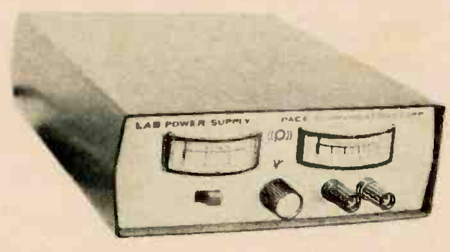


Pace Communications Model 5803 Power Supply

For copy of manufacturer's brochure, circle No. 29 on Reader Service Card.

THIS power supply was developed to fill the need for precisely regulated d.c. power as required on the service bench, in the radio or electrical laboratory, or for any application where excellent regulation is necessary at load currents up to 2.5 amperes and voltages from zero to 15 volts. The supply is immune to damage from short circuit, overload, high temperature, or almost any other abuse that may be encountered on the service bench or in a school or industrial lab. Its compact size enables it to be readily moved or placed anywhere on a crowded bench. All silicon transistors ensure long-term reliability.

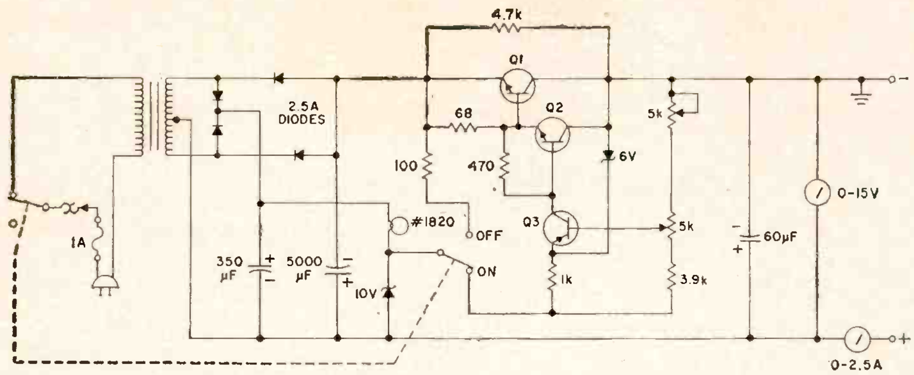
The circuit (see diagram) consists of the familiar series or passing transistor driven by amplifiers using a zener diode reference. The six-volt zener diode is connected between the regulated output and the emitter of Q3. Therefore, the emitter of Q3 will "follow" any change in output with a constant difference of six volts. Assume that a sudden increase in load current causes the output voltage



to decrease. This decrease occurs both at the base and emitter of Q3, but because of the six-volt zener diode, a much greater change occurs at the emitter. As a result, Q3 is turned on more and increased current flows in both Q2 and Q1. This reduces the resistance of Q1 and increases the output voltage until the difference between the base and emitter of Q3 is restored to its original value.

Under short-circuit conditions, both ends of the output-adjusting potentiometer are effectively grounded. As the voltage drops below the zener voltage, the zener diode opens and the emitter of Q3 is grounded through its emitter resistor. Because its base and emitter are grounded, Q3 does not conduct, with the result that no base current flows in Q2 and Q1, turning them off. This feature provides instant automatic short-circuit protection.

A disadvantage of this basic regulator is its inability to operate at output voltages lower than the zener voltage. To overcome this difficulty, Q3 emitter resistor can be returned to a positive volttage point. This voltage is supplied from an auxiliary ten-volt zener-regulated



supply. Because the auxiliary supply is of opposite polarity to the main supply, a change in its zener voltage due to temperature effects tends to offset temperature effects in the main supply.

A #1820 lamp bulb is used as a ballast to supply relatively constant current to the ten-volt zener diode over a wide range of input voltages. This prevents excessive dissipation in the diode and provides a zener voltage that is more stable.

Because the 5000-μF filter capacitor is much larger than the 350-μF filter, turning the supply off under low-current load conditions could result in a momentary increase in output voltage. To prevent this, when the power switch is turned to "Off" position, a 100-ohm resistor is switched in to discharge the larger capacitor immediately.

A thermal protector is bolted to the chassis next to Q1. This protector will open at 100°C and protect the supply from any possibility of thermal runaway or other damage due to the effects of the temperature.

This supply will be very useful to the shop or lab working with such transistorized equipment as CB transceivers or auto radios and is very useful for hi-fi and general audio work. It will also charge batteries, operate plating tanks, and perform a multitude of other tasks wherever it is necessary to use very low ripple, precisely regulated d.c. power.

The 5803 lab power supply measures 6½x8½x2⅝ inches, weighs 4½ pounds, and rests on four plastic legs that provide an attractive "tilt-up" appearance. The price is $59.95. ▲

Data Instruments SSVM-1 FET Voltmeter

For copy of manufacturer's brochure, circle No. 156 on Reader Service Card.

THE industry's first broadband FET voltmeter is the Model SSVM-1 by *Data Instruments*. The new device has extremely high input impedance and can make measurements over a very wide frequency range. Input impedance on d.c. is greater than 100 megohms, and on a.c. it is about 15 megohms shunted by 2 pF.

Design of a solid-state a.c. probe was a major factor in the development. The probe has a bandwidth of 20 Hz to 700 MHz ±1 dB, and 50 Hz to 100 MHz at ±2%. Since the probe does not have a sharp cut-off, usable indications can be obtained that are much higher than 100 MHz. For example, useful comparative readings have been obtained at 1200 MHz with the use of a special coax T adapter.

The d.c. measuring circuit consists of a pair of "n"-channel silicon field-effect transistors arranged as a differential amplifier. The power supply is two 6.75-volt mercury batteries. The drain on these batteries is so small (750 μA) that the operating life is essentially the shelf life of the batteries. The accuracy of the instrument is unaffected by battery aging up to the point where the meter indication on the battery-check position shows that replacement is necessary. A single 1.35-volt mercury cell powers the ohmmeter circuits.

An important feature of the design is that the circuit ground is insulated from the case and brought out to a "common" binding post. The metal case and chassis are connected to a ground terminal. Because of this and because the instrument is not connected to the a.c. power line, it is possible to take measurements of voltages where neither side is grounded.

Price of the meter is $215 including probe. ▲

Choppers

(*Continued from page* 45)

drift-free preamplifier ahead of the main d.c. amplifier which reduces the drift arising in the d.c. amplifier to a negligible value.

In a chopper-stablized amplifier, the internal loop gain at d.c. and very-low frequencies is equal to the product of the chopper amplifier gain and the d.c. amplifier gain. For high frequencies, the internal loop gain is equal to that of the d.c. amplifier alone. Since the d.c. amplifier delivers very high gain, however, the over-all gain characteristic is independent of the open-loop gain and is determined by the ratio of the feedback resistance (R_f) to the input impedance (Z_i).

Electromechanical choppers are frequently used in precision measurement where a difference is observed between a standard and an unknown quantity. Fig. 9 shows a typical comparison circuit of a d.c. voltmeter in which the unknown voltage to be measured is compared to a standard reference voltage. When the two signals are adjusted for equal values, the input capacitor (C) becomes charged to the common potential so that the difference signal applied to the input of the a.c. amplifier is zero. The input signal and reference voltage are alternately sampled by one section of a d.p.d.t. chopper to produce the characteristic chopper square wave. In addition to its modulating function, the chopper prevents interaction between input signal and reference circuit, especially when they are at greatly different impedance levels.

The input capacitor should have a high insulation resistance compared to the input resistance (R) in order to block stray leakage currents in the amplifier input, which may be modulated by the chopper along with the desired signal. To produce a reconstructed d.c. voltage at the amplifier output, the second section of the d.p.d.t. chopper acts as a balanced demodulator to synchronously rectify the signal.

Although a demodulator is necessary to extract the information from the carrier, it need not have an electrical output, but may be an a.c. servomotor whose output is angular motion. This principle is employed in the design of electronic null-balance recorders to provide an accurate record of changing temperature.

Fig. 10 shows a temperature recorder which responds to tiny voltage changes (less than $\frac{1}{10}$ mV) produced by a thermocouple. These d.c. voltage changes are converted to a.c. by the chopper at the chopper's driving frequency and at a phase which indicates the polarity of the d.c. signal. The amplified output signal excites the control winding of a two-phase servomotor, while the other winding continuously draws power from the a.c. line. Since the shaft of the motor is mechanically linked to the slider arm of a potentiometer in a bridge divider, the balancing motor turns in a direction that will balance the measuring circuit. When the measuring circuit is in balance, no d.c. current is fed to the chopper and hence no a.c. current flows through the control winding. Under these conditions, the motor stops and the system is at rest, so that the slider indicates correct temperature.

Potential applications of electromechanical choppers are so varied that constructional designs call for special choppers to fit specific applications. There is a current trend for more and more miniaturization of chopper units in sophisticated instrumentation, in which extremely low noise characteristic and high stability are combined with ruggedness and a resistance to extreme environmental conditions. ▲

Speaker Enclosures

(*Continued from page* 28)

flat position and switch out the loudness control and any rumble filter. Place the speaker system where it will normally be used in the room. With 1 or 2 volts at the terminals of the speaker system at 400 Hz, gradually reduce the frequency of the oscillator. The loudness of the tone should remain reasonably constant as the frequency decreases. Pay particular attention when passing through the vicinity of system resonance. If the loudness suddenly increases in this area, more fiberglass should be added to the system. If the loudness decreases noticeably before reaching the resonant frequency, some fiberglass should be removed from the system. Some fiberglass should always remain in the enclosure to absorb reflected waves at higher frequencies. The tone should retain a constant loudness down to or slightly below system resonance.

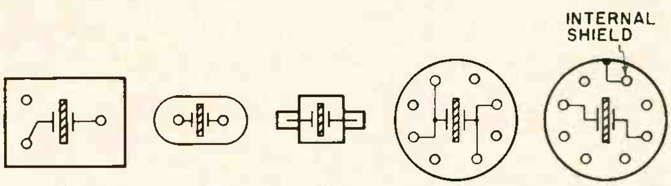
If the low-frequency power handling ability of the system is still considered inadequate for the use intended, reduce the volume of the enclosure. The volume can be experimentally reduced by adding a stack of books or magazines in the enclosure and resealing the back. When the power handling is satisfactory, the volume of the enclosure should be permanently reduced by this amount. The damping should be readjusted for best low-frequency performance from the speaker system.

Several different sealed speaker systems have been constructed using the data in this article and their performance has been excellent. ▲

IDENTIFYING SURPLUS CRYSTALS

By IRWIN MATH

At the present time, there are still a large number of surplus military crystals available. While frequencies are occasionally marked on these crystals, there is little other information given. The table was compiled to provide a reference for most crystals used by the military from 1940 to the present. Electrical characteristics and basing are provided. ▲



1 2 3 4 5

Type (CR—/U)	Holder (HC—/U)	Base	Freq. Range	Tol. (%)	Load Cap. (pF)	Over-tone[a]	Drive (mW)
15	5	1	80-200 kHz	.01	32	1	2
16	5	1	80-200 kHz	.01	[b]	1	2
18	6	2	.8-1.6 MHz	.005	32	1	7
19	6	2	.8-20 MHz	.005	7	1	7
23	6	2	10-70 MHz	.005	[b]	3[c] 5[d]	3
24	10	3	15-50 MHz	.005	[b]	3[e] 5[c]	2
25	6	2	200-500 kHz	.01	[b]	1	2
26	6	2	200-500 kHz	.002	[b]	1	2
27	6	2	.8-15 MHz	.002	32	1	3
28	6	2	.8-20 MHz	.002	[b]	1	3
29	5	1	80-200 kHz	.002	32	1	2
30	5	1	80-200 kHz	.002	[b]	1	2
32	6	2	10-75 MHz	.002	[b]	3[f] 5[g]	1
33	6	2	10-25 MHz	.005	3	3	2.5
35	6	2	.8-20 MHz	.002	[b]	1	3
36	6	2	.8-15 MHz	.002	32	1	3
37	13	2	90-250 kHz	.02	20	1	2
38	13	2	16-100 kHz	.012	20	1	.1
39	15	4	160-330 kHz	.003	[b]	1	.1
40	15	4	160-330 kHz	.003	[b]	1	.1
42	13	2	90-250 kHz	.003	32	1	2
43	16	5	70-100 kHz	.01	45	1	2
44	6	2	15-20 MHz	.002	32	1	1
45	6	2	455 kHz	.02	[b]	1	2
46	6	2	200-500 kHz	.01	20	1	2
47	6	2	200-500 kHz	.002	20	1	2
48	6	2	.8-3 MHz	.0075	32	1	10
49	6	2	.8-3 MHz	.0075	32	1	10
50	13	2	16-100 kHz	.012	[b]	1	.1
51	6	2	10-61 MHz	.005	[b]	3	20
52	6	2	10-61 MHz	.005	[b]	3	3
53	6	2	50-87 MHz	.005	[b]	5	20
54	6	2	50-87 MHz	.005	[b]	5	2
55	6	2	17-61 MHz	.005	[b]	3	2

Notes: [a]An overtone of 1 indicates a fundamental crystal. [b]Series resonant operation. [c]To 50 MHz. [d]To 70 MHz. [e]To 25 MHz. [f]To 52 MHz. [g]To 75 MHz.

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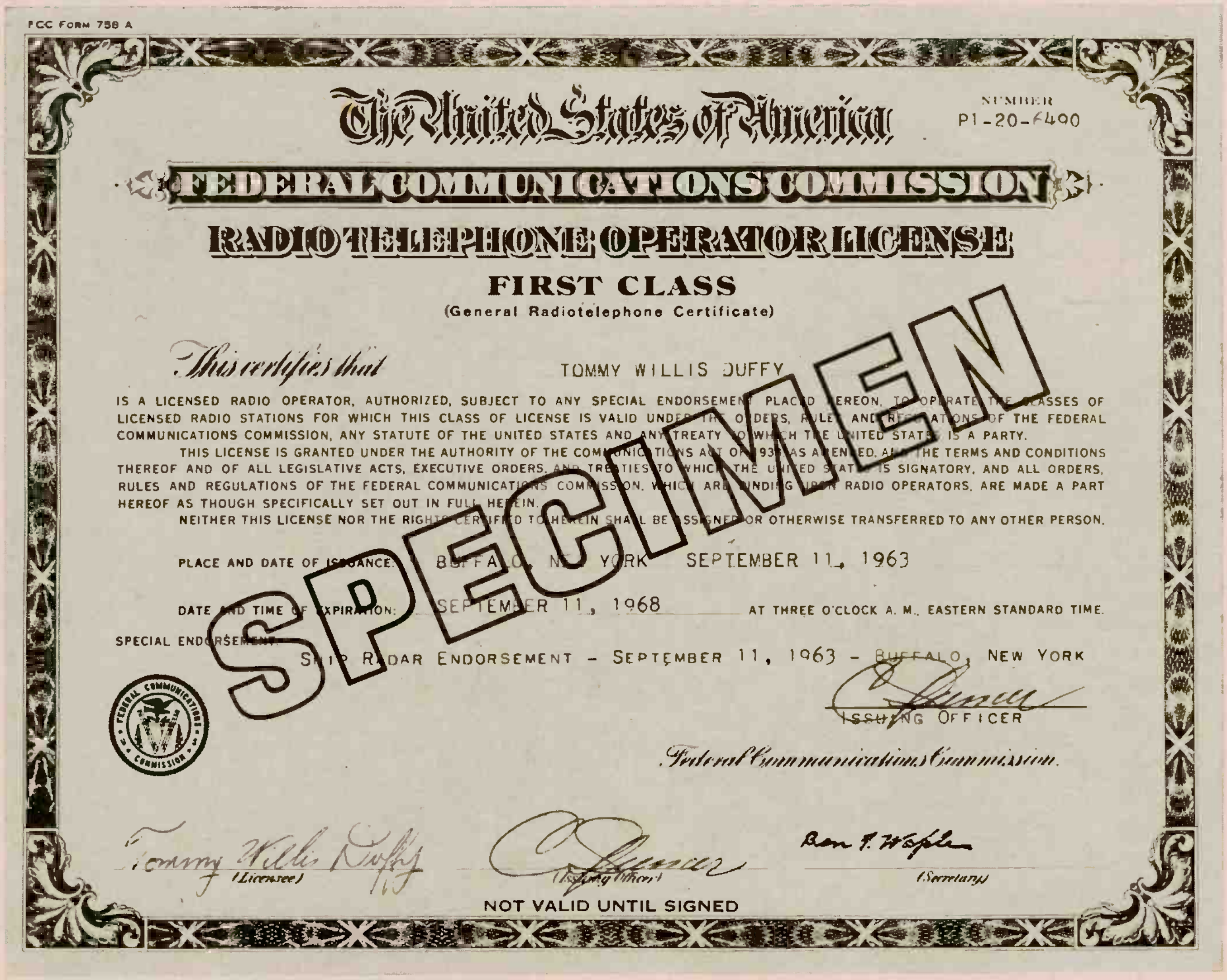
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The United States of America

NUMBER P1-20-6490

FEDERAL COMMUNICATIONS COMMISSION

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FIRST CLASS

(General Radiotelephone Certificate)

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PLACE AND DATE OF ISSUANCE: BUFFALO, NEW YORK SEPTEMBER 11, 1963

DATE AND TIME OF EXPIRATION: SEPTEMBER 11, 1968 AT THREE O'CLOCK A. M., EASTERN STANDARD TIME.

SPECIAL ENDORSEMENT: SHIP RADAR ENDORSEMENT - SEPTEMBER 11, 1963 - BUFFALO, NEW YORK

ISSUING OFFICER

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If you had active duty in any branch of the Armed Forces after January 31, 1955, you may be entitled to Government-paid tuition for any CIE course.

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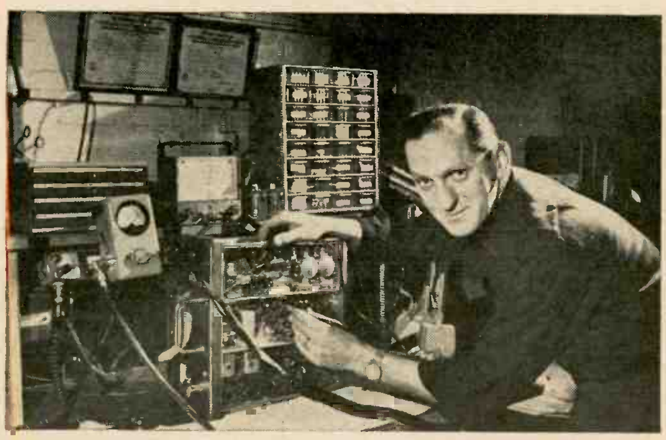
Ted Barger, Electronic Technician, Smith Electronics Co. "I've been interested in electronics ever since I started operating my own Ham rig (K8ANF). But now I've turned a hobby into a real interesting career. Cleveland Institute of Electronics prepared me for my Commercial FCC License exam . . . and I passed it on the first try. I'm now designing, building and testing all kinds of electronic equipment . . . do a lot of traveling, too. It's a great job . . . and thanks to CIE and my FCC License, I'm on my way up."



Chuck Hawkins, Chief Radio Technician, Division 12, Ohio Dept./ Highways. "Cleveland Institute Training enabled me to pass *both* the 2nd and 1st Class License Exams on my *first* attempt . . . even though I'd had no other electronics training. (Many of the others who took the exam with me were trying to pass for the eighth or ninth time!) I'm now in charge of Division Communications and we service 119 mobile units and six base stations. It's an interesting, challenging and extremely rewarding job. And incidentally, I got it through CIE's Job Placement Service . . . a free lifetime service for CIE graduates."

Glenn Horning, Local Equipment Supervisor, Western Reserve Telephone Company (subsidiary of Mid-Continent Telephone Company). "There's no doubt about it. I owe my 2nd Class FCC License to Cleveland Institute. Their FCC License Program really teaches you theory and fundamentals and is particularly strong on transistors, mobile radio, troubleshooting and math. Do I use this knowledge? You bet. We're installing more sophisticated electronic gear all the time and what I learned from CIE sure helps. Our Company has 10 other men enrolled with CIE and take my word for it, it's going to help every one of them just like it helped me."

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1776 East 17th Street, Dept. EW-20, Cleveland, Ohio 44114

EW Lab Tested

(*Continued from page* 16)

firmed the impressive specifications of the KG-415. Its record/playback frequency response was ±0.5 dB between 200 and 18,000 Hz and over-all was within ±4 dB from 27 to 19,000 Hz at 7½ ips. Even at 3¾ ips, the frequency response was ±1 dB from 37 to 13,000 Hz. The playback response at 7½ ips, with the *Ampex* 31321-04 alignment tape, was ±1.5 dB from 50 to 15,000 Hz.

The wow and flutter at 7½ ips were, respectively, 0.02% and 0.09%, well below the rated 0.2%. The tape speeds were slightly fast—by about 30 seconds in 30 minutes. In fast-forward, 1200 feet of tape was handled in 55 seconds, while rewind required 80 seconds. The signal-to-noise ratio was 44 dB at both speeds. The noise was all in the form of a soft hiss—no hum was detectable.

The mechanical and electrical operation was flawless. At 7½ ips, we were unable to detect any audible differences between the incoming and outgoing signals. At 3¾ ips, a slight increase in hiss level could be heard, but the frequency response was adequate for full-fidelity recording of most FM broadcasts.

We did not have dynamic microphones designed for a 3000-ohm load impedance on hand for our tests. However, we were pleasantly surprised to find that a 50,000-ohm high-impedance dynamic microphone performed very well with the unit. The echo and sound-on-sound effects were obtained without undue complexity and with excellent quality (many recorders introduce excessive distortion when making sound-on-sound recordings).

We do have two minor criticisms of the operation of the recorder. The first is the need for three operations when going from playback to recording: setting the function switch, the monitor switch, and the record safety button. This sequence becomes virtually automatic when one has been using the recorder for a while, but we did, on occasion, find ourselves forgetting to change the monitor switch and wondering why the meters did not indicate a recording level.

The second difficulty was in placing the tape in the correct path over the heads. Even with the hinged head cover lifted, the tape does not fall very easily into place and requires a little dexterity on the part of the operator.

Judged solely by its sonic performance, the "Knight-Kit" KG-415 is easily the equal of most recorders selling for $400 to $700. It is surpassed in a few operating conveniences by only a few of the most expensive recorders. We know of nothing near its price which is comparable to it, from the standpoints of flatness of frequency response, operating flexibility, or speed uniformity. At $249.95, it offers a truly high-fidelity tape recorder at a reasonable price.

The same unit is now available factory-wired and tested as the Model KN-4450, for $299.50. Like the kit, it is an excellent value for the price. A portable carrying case ($29.95) or a handsome walnut enclosure ($19.95) can be had for either model. ▲

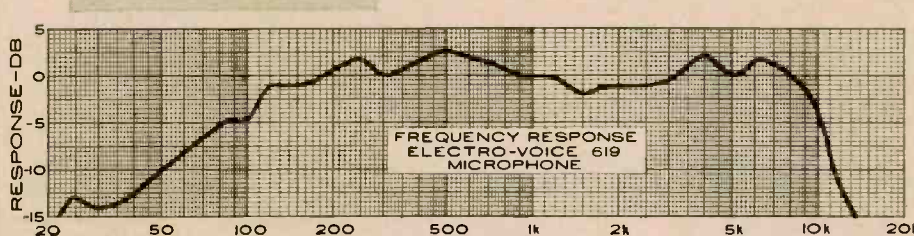
Electro-Voice Model 619 Microphone

For copy of manufacturer's brochure, circle No. 27 on Reader Service Card.

THE *Electro-Voice* Model 619 dynamic microphone is an omnidirectional type, with integral stand, intended for a variety of communications and paging applications. It is available in either low- or high-impedance models, having similar response characteristics.

The microphone has a non-metallic "Acoustalloy" diaphragm, resistant to the effects of humidity, salt air, and extreme temperatures. It is housed in attractive satin-finished case, permanently fastened to a die-cast zinc desk stand. The stand is contoured for comfortable hand-held operation and, with a total weight of about 2¼ pounds, the 619 is easy to use in either hand-held or table-mounted installations.

A plastic push-to-talk switch button



is located on the base of the microphone. It may be operated as a s.p.d.t. switch in the "Hi-Z" model, or as a s.p.s.t. (normally open) switch in the "Lo-Z" model. The switch may be locked in the "on" position by sliding it to one side. The microphone element is shorted in the "off" position of the switch. For hand-held operation, the switch may be relocated in the handle of the base, which is convenient for many push-to-talk applications.

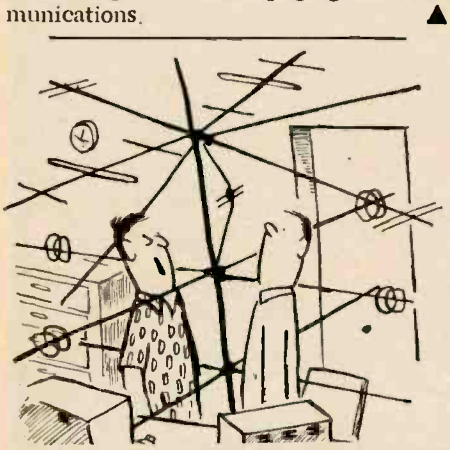
The integral shielded cable is 16 feet long in the low-impedance model and 6½ feet long in the high-impedance model.

We tested the Model 619 ("Lo-Z") by direct comparison with a calibrated wide-range capacitor microphone, using a loudspeaker as the sound source. The two microphones were located in the same position relative to the speaker and automatic response curves were made with each microphone. The difference between the two curves was plotted as the response of the *E-V* 619, since the other microphone was essentially flat in the frequency range of interest.

Our measurements confirmed the manufacturer's claim of 70 to 10,000 Hz response. The response was very smooth from about 110 to 10,000 Hz, within ±2.5 dB. It fell off gradually at lower frequencies, being down 6.5 dB at 70 Hz and 10 dB at 50 Hz. Above 10,000 Hz the response also fell off, −10 dB at 11,500 Hz.

The sound produced by using the microphone was very smooth and natural. The reduced bass response is highly desirable for a voice microphone, preventing the boomy sound which often characterizes close-talking microphones. We used the microphone in our amateur radio station, receiving uniformly complimentary reports on the quality. With the push-to-talk switch relocated to the handle, we found the balance of the microphone conducive to long hours of comfortable operating.

The *Electro-Voice* 619 sells for less than $30 and is admirably suited to any of its designated uses in paging and communications. ▲



"It's one of those spring-loaded jobs. I can't get it together again."

Receiver Noise Measurements

(Continued from page 24)

speaker, and with the potentiometer of the generator set to give some convenient reading on one of the lower ranges. The r.f. and mixer tuned circuits should then be "touched up" for lowest reading on the v.t.v.m. A signal generator should also be used to make sure that the circuits are not detuned to the point where sensitivity suffers greatly.

Fig. 1B is a schematic of a similar type of noise generator, but expressly designed for use with balanced inputs. For best results, both of these circuits should be constructed with the shortest possible leads and connected to the input of the receiver or converter being tested with short lengths of coaxial cable of the proper impedance.

Tube-Type Generators

Fig. 2A is a schematic of a noise generator designed for more accurate measurements of receiver noise. In this circuit the current through the diode-connected triode is measured and used to determine the noise figure. To use this generator, first turn on the receiver and, with the generator connected but turned off, adjust the receiver for some convenient reading on an audio v.t.v.m. connected to the audio output of the receiver. Now turn on the noise generator and, using the reading just taken as a reference, adjust the 100-ohm filament potentiometer until the v.t.v.m. indicates a 3 dB rise (about 40%) in output voltage. Do not touch any receiver controls. The diode current can now be read on the 0-10 mA meter. Once this reading is obtained, substitute it into the equation: $F = 20\ IR$, for noise figure directly, or $F_{dB} = 10\ \log_{10}\ 20IR$, for noise figure in decibels. In both cases, I is the diode current in amperes, and R the value of the resistance used in the generator output circuit (in ohms).

Fig. 2B shows the circuit of a noise generator that would be used for balanced inputs. All is as in the previous case except that the equations are now $F = 5IR$ and $F_{dB} = 10\ \log_{10}\ 5IR$. R is the total resistance across the output terminals $(R/2 + R/2)$.

Hence, by careful measurement of the noise figure and consequent adjustment of receivers, optimum performance can be obtained, and those weak signals which were previously "in the noise" can often be brought up to a readable level. In fact, on a commercial communications receiver which had been factory-aligned, an improvement of 2 dB was noticed after re-aligning the front-end with a diode noise generator like the one shown in Fig. 1A. Signals which could not previously be understood were now clearly readable. ▲

SCR AUTO BURGLAR ALARM

By EDWIN R. DeLOACH

A transistor-SCR circuit that actuates horn for 30 seconds when car door, hood, or trunk are opened.

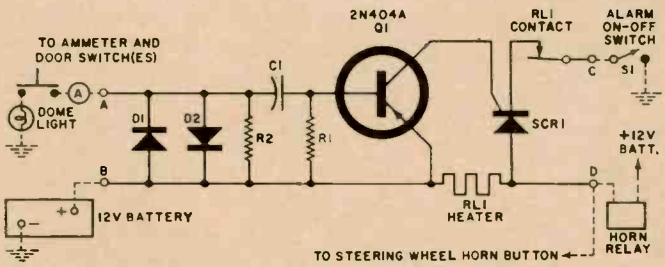
THIS circuit offers a new approach to a vehicle burglar alarm. It uses to advantage the already installed "sensors" found in most cars—the dome, trunk, and hood lights. Only four connections are required to install the circuit. The horn is the alarm and no battery power is drawn except when the circuit is triggered on. It is timed to cut off after a half minute to prevent discharging the battery. Then it will reset itself ready to be triggered on again if a second attempt is made to break into the car.

Note that this unit uses the dome, hood, or trunk lights as sensors. Your car must be equipped with these features or something to draw current from the battery otherwise the alarm would be without sensors and, of course, be inoperative. This was the author's problem at first—no hood light. Since such an installation was contemplated, the author purchased the type which operates off a mercury switch. Now, not only is there a hood light but also a burglar alarm sensor under the hood so if an attempt is made to tow the car away, this would tilt the switch and trigger the alarm. To make the alarm inoperative, the hood must be raised to get at the unit. This, of course, would trigger the alarm so it is practically impossible to disable it.

The operation is as follows. As a door light is switched on, current from the battery flows through the diode *D*1 to the light (Fig. 1). The voltage dropped across the diode is coupled through C1 into the base of the transistor. The transistor is switched on momentarily, applying current to the gate of the SCR. The SCR turns on, applying power to the horn relay and heater of the time-delay relay. When the time-delay relay breaks the circuit, the SCR switches to the "off" state as before. The circuit may be manually reset with the "on-off" switch. D2 passes current back into the battery when the battery is charging. R2 shunts small leakage current around D1.

The alarm was built in a small aluminum box 3"x2½"x2". The photos show the approximate layout of parts. All parts are insulated from the chassis and the unit was wired on a printed-circuit board and potted. Of course the PC board and potting are not necessary, but the same wiring plan and rigid mounting are.

From the schematic you will notice the terminals are labeled "A" "B", "C" and "D." Mark the terminals on your unit to correspond. The alarm terminals "A" and "B" must be in series with the battery circuit to the ammeter and dome light.

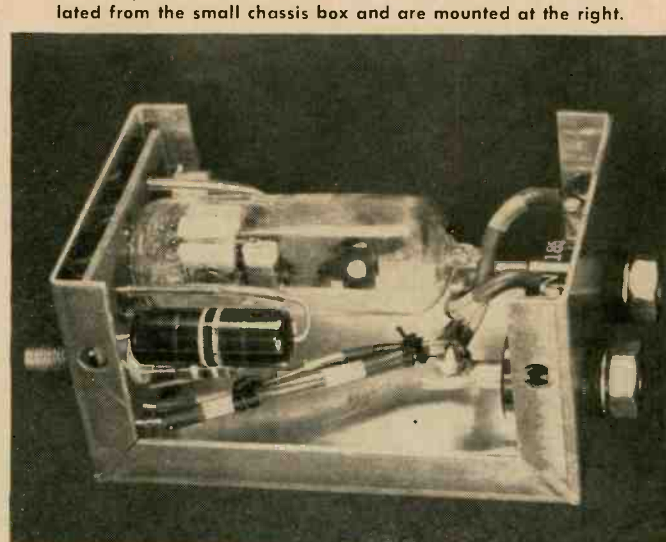


R1—1100 ohm, ¼ W res. ± 10%
R2—47 ohm, ¼ W. res. ± 10%
C1—0.1 μF paper capacitor
D1, D2—1N1184A silicon rectifier
RL1—Relay (Amperite 12C30T)
SCR1—Silicon controlled rectifier (IR 2N1600 or Westinghouse 207B)
S1—S.p.s.t switch (lock type, if preferred)
Q1—2N404A transistor
Note: For 6-volt automobile systems, change RL1 to 6C30T.

Fig. 1. Current drawn by dome light produces voltage that turns on transistor. This, in turn, switches on the SCR and operates horn. After 30 seconds, time-delay relay contacts open circuit and horn stops. Circuit can be retriggered. Alarm switch is off at all times except when driver leaves car.

All components except the two diodes are mounted on a small printed-circuit board which is then put in the circuit box.

The component board is at left and the two diodes are insulated from the small chassis box and are mounted at the right.



Connect the battery side of the circuit to the "B" terminal and the ammeter side of the circuit to the "A" terminal. If there is any doubt that you have found the right conductor, turn on a light (the door or dome light will do), then break or open the circuit. The light should extinguish.

Now connect terminal "D" to the horn-relay wire. This conductor runs from the horn relay to the steering wheel horn button switch. To check if you have the correct wire, quickly touch it to ground. The horn should blow. Next run a wire from terminal "C" to an "on-off" switch as shown. This may be a toggle switch in a concealed place or a lock switch on the fender or door.

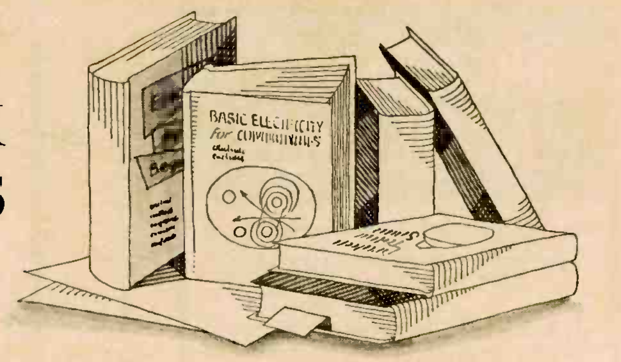
If the unit doesn't trigger upon opening the door but works fine upon closing the door, then you have mislabeled terminals "A" and "B." Reverse the wires to these terminals and the unit will operate correctly. If the unit does not operate at all, chances are your car has unusually high leakage currents. First, be sure that everything is off in the car—ignition switch, radio, lights, etc.—exactly the way you leave the car overnight. Then check to see that the alarm "on-off" switch is on and makes good continuity from terminal "C" to ground. Now, momentarily short a piece of wire across terminals "A" and "B." If this triggers the alarm, then you do have high leakage currents. Resistor *R2* (47 ohms) shunts these currents around the diode so there is no voltage dropped across the diode until, of course, the light or something is switched on. If this is the case, change the resistor to a lower value, say, 22 ohms.

This circuit can be used with any 12-volt system. If you have a 6-volt system, just change the relay from 12C30T to 6C30T. If you have an electric clock, its electric power must be supplied from terminal "B" on the battery side of the circuit. Failing to do so will result in the alarm actuating each time the clock rewinds.

Total cost of parts should be less than $20.00. This, you will have to admit, is a fair price for permanent insurance against theft, burglary, or vandalism. In addition, this device will warn of fire and flood. Electrical shorts resulting in or caused by fire and water would trigger the unit. One of the most unusual uses of all is that of acting as a "baby sitter." The author often leaves his kids in the car with instructions not to get out. With the alarm set, if they should open a door to get out or if someone attempted to take them out, the alarm sounds.

Editor's Note: This device is available in kit form for $18 or already assembled for $23 from General Electronics Sales & Service Co., *Box 52362, New Orleans, Louisiana 70150.* ▲

BOOK REVIEWS



"RCA TRANSISTOR MANUAL" compiled and published by Electronic Components and Devices, *Radio Corporation of America*, Harrison, N.J. 476 pages. Price $1.50. Soft cover.

This is a completely revised edition which will be useful to engineers, students, hams, hobbyists, and others technically interested in transistors, silicon rectifiers, silicon controlled rectifiers, varactor diodes, and tunnel diodes.

It contains extensive text material on semiconductor devices and, of special interest to those who work with transistors, an expanded data section with more extensive information on active transistors, up-to-date transistor selection charts, military-specification types, and mounting hardware than ever before.

Of particular note is the expanded circuit section with the operation of each circuit explained in considerable detail. Thus the builder not only constructs a piece of equipment but *learns* how and why the circuit works. In this section are more than 40 circuits with complete schematic and parts listing for each. A varied assortment of circuits is covered.

° ° °

"FUNDAMENTALS OF AUTOMATION AND REMOTE CONTROLS" by S. A. Ginzburg, I. Ya. Lekhtman, and V. S. Malov. Published by *Pergamon Press Inc.*, 44-01 21st Street, Long Island City, New York, 11101. 486 pages. Price $15.00.

This is the first English translation of the second edition of a Russian text which has been revised and up-dated to reflect recent developments in the field. The text now includes information on semiconductor and radioactive components and has been expanded with new material on ferromagnetic and electronic components.

The text has been slanted to the undergraduate engineer, as a reference source, and as a training aid in engineering firms. The treatment is somewhat mathematical. The authors have dealt only with the electrical components and systems and have omitted mechanical, hydraulic, and pneumatic systems used in automation.

At first the reader may encounter a little difficulty in converting the Russian method of designating various circuit components and parameters into American terminology, but after that is mastered, the text should offer no problems to those with the requisite technical background.

° ° °

"THIN FILM MICROELECTRONICS" edited by L. Holland. Published by *John Wiley & Sons, Inc.*, New York. 280 pages. Price $9.00.

This volume represents contributions by six experts (four English and two American) on thin-film technology—specifically as it applies to present-day electronics. The six chapters cover the properties of passive circuit elements, the properties of thin-film active elements, semiconductor integrated circuits, vacuum deposition apparatus and techniques, thin-film monitoring techniques, and the layout of microcircuits, masking, and etching techniques.

The text is written at the engineering level and the authors have assumed that their readers will have the requisite technical background. The book is well illustrated by photographs, micrographs, charts, graphs, line drawings, tables, and perspective drawings. An extensive bibliography accompanies each chapter making it easy for the engineering reader to continue his investigation.

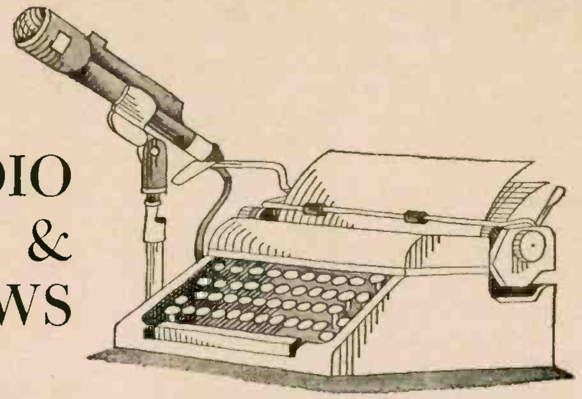
° ° °

"ANALYSIS AND DESIGN OF TRANSISTOR CIRCUITS" by Laurence G. Cowles. Published *D. Van Nostrand Company, Inc.*, Princeton, N.J. 304 pages. Price $9.75.

This is a thoroughly practical text written by and for electronics design engineers. By assuming that his reader is familiar with transistor electronics and is actually working with transistor circuits, the author has been able to eliminate much of the elementary material normally included in such texts. By treating the transistor as a circuit element with special emphasis on temperature effects and feedback, the text offers a new approach to circuit design.

The text is divided into 21 chapters and 10 appendices of value in working with the text. Diagrams, graphs, a listing of symbols, and individual chapter references for further reading are also included, thus enhancing the self-contained aspect of this excellent text. ▲

RADIO & TV NEWS



WITH the introduction of low-cost integrated circuits (see our June issue) into consumer-type equipment, more attention is now being focused on them. Because these solid-state devices have no moving parts to wear out, and because they do not employ physical phenomena that use up material, in theory they should last forever.

Engineers at the *Fairchild Semiconductor* labs have rigged up a set of 3626 digital IC's so that they can trigger each other into operation. Every so often the engineers "look in" on the pulsing circuit to see how the devices are doing. At the last count (Feb. 28, 1966), these IC's had been operating for a total of some 60,252,144 device-hours without a single failure. If this number looks large, it is. A single device would have to operate 24 hours a day for 6878 years to reach this figure.

One of the major roadblocks in the path of using IC's has been the unit price. Many companies are reducing the cost of these tiny circuits, with some digital types being reduced (by *Motorola*) as much as 70% in some cases to about 48% in others for an average price reduction of 57%. Although this price drop has been for digital IC's, as the demand for linear circuits goes up, the chances are that prices of these units will drop.

Laser Recorder

A new type of photographic recorder that uses a laser beam to generate images has produced its first pictures on film, according to scientists at *North American Aviation Autonetics Division*.

The light beam from a helium-neon laser, focused to a spot 0.0004 inch in diameter, "writes" lines on a fine-grained, high-resolution photographic film. The closely spaced lines form an image on the film in a manner similar to a TV-type picture. Only one ten-thousandth of a watt of light power is necessary to form the pictures. The device is capable of recording all the image detail of a normal television picture on one-tenth square inch of film.

Included in the device is a laser flying-spot scanner, believed to be the first of its kind that "reads" previously developed photographs and generates electrical signals as it scans the film line by line.

These signals are fed into a light modulator which acts as a high-speed valve to vary the intensity of the recording laser beam.

Studies performed at *Autonetics* show that, with modification, the device could read out and record information from 20 TV stations simultaneously.

Educasting

A new approach to education by radio called "Educasting" has been tested over a pair of New York City FM stations and is now FCC-approved as a subsidiary communications service on two Pennsylvania FM stations.

The source of the program is a four-track teaching tape, supplying signals to a four-channel subcarrier generator that, in turn, multiplex-modulates the FM transmitter.

The special receivers, manufactured by *Sylvania*, are equipped with four push-buttons that can select any of the four subcarrier channels.

The program material is presented in a step-by-step logical sequence. After each step the student is asked to respond to what he has heard. He can choose from four possible responses, each having a separate push-button. If the student selects the correct answer, he receives reinforcement of the concept. If he selects the wrong answer, he is given an explanation of why he was incorrect.

Ceramic CRT

Outside of a momentary excursion into the area of metal CRT's for use in some TV sets of several years ago, CRT's have always been made from glass. To meet the problem of operating under high stresses and severe vibration conditions that may damage conventional glass types, an English company is now fabricating a CRT whose outer shell is made from ceramic (alumina). The electron gun is brazed onto the ceramic and a glass faceplate is used. If necessary, the faceplate can be made from sapphire, a translucent form of alumina. At present, only 2-inch tubes are in production, but the company expects to market a 5-inch version soon. ▲

Calibration chart is taped to side of the 3" x 4" x 5" case. The output frequency of this particular unit is about 750 Hz.

Audio Calibrator for Transistor Amplifiers

By RYDER WILSON

Two-transistor circuit provides accurately calibrated signal, from 0.5 to 100 mV at low impedance, for checking gain and distortion of sensitive transistor amplifiers.

SENSITIVE transistor amplifiers are being used more and more in every type of electronic equipment from pocket radios to high-fidelity amplifiers, to portable TV sets. Finding a suitable test signal for these circuits is frequently a problem for the electronics technician. Few commercially available audio oscillators can produce stable, accurate, low-level signals that are completely free from noise.

Here is a simple, easily constructed oscillator that can be used to measure the gain and distortion of sensitive amplifiers and one which also provides a signal for checking speakers, earphones, or anything that responds to an audio signal.

Q1 is connected as a phase-shift oscillator. The *RC* network consisting of *R1-C1*, *R2-C2*, and *R3-C3*, determines the frequency and provides the regenerative feedback necessary to sustain oscillation. The frequency may be raised by decreasing the size of *C1*, *C2*, and *C3* or lowered by increasing the value of these capacitors. *R5* provides degenerative feedback to improve the stability and waveform of the oscillator. It should be adjusted with a scope across the output terminals to make sure that a good sine wave is obtained; otherwise the oscillator will be useless for distortion tests. *R4* controls the base bias of *Q1* and may also be critical. Select a value which insures oscillation every time the unit is turned on.

The output of *Q1* is transformer-coupled to the emitter-follower stage, *Q2*, which provides a low output impedance. *R6* is a calibrating pot used to set the voltage level at the output. *R8* and *R9* are precision 1% resistors, switch-selected to give the two voltage ranges. *R10*, a wirewound pot, is used for fine adjustment of the output voltage.

The completed unit, shown in the photo, is housed in a 3" x 4" x 5" metal utility box, finished off with decals and clear plastic spray. The 5-way binding posts used for the output terminals can be seen on the right, with the "off-on" toggle switch located on the left. The range selector slide switch is placed just below the dial scale. The two small batteries are mounted at the bottom of the case in a battery holder. *R6*, the calibration pot, is available for adjustment when the back cover is removed.

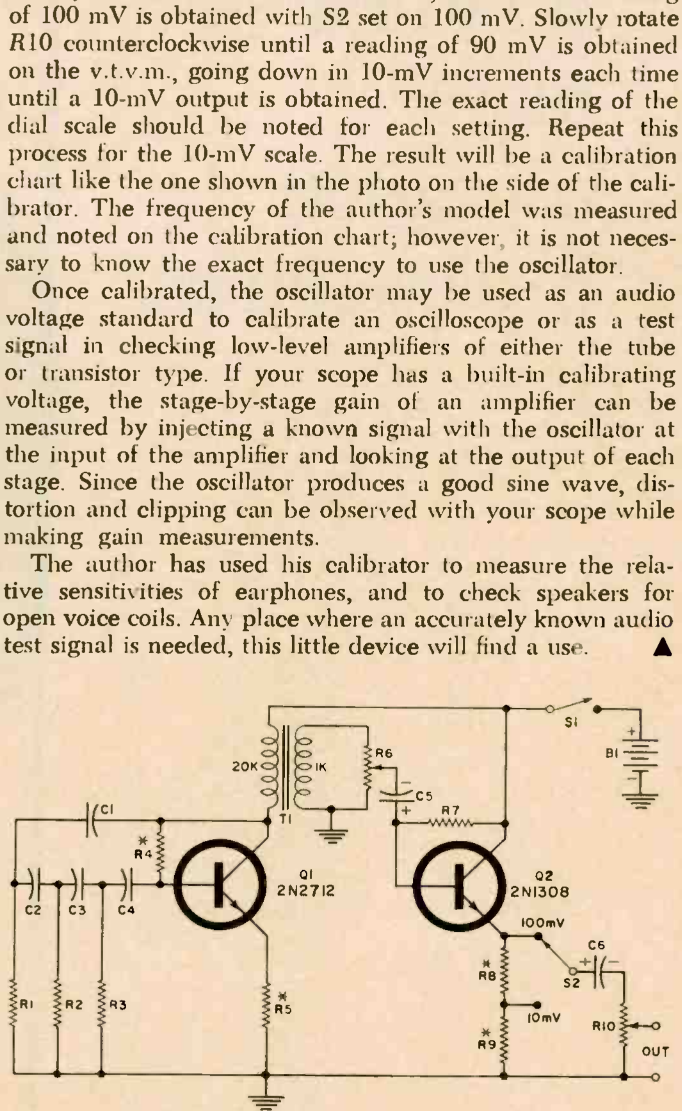
Most of the components were wired on a perforated circuit board using flea clips for terminals. The board was then mounted on a pot mounting bracket so that the output control, *R10*, holds the circuit board to the front panel. Parts layout is not critical since there is plenty of room.

Calibration

To get the most out of this instrument, it should be calibrated as accurately as possible. For this purpose, a *Ballantine* Model 300 a.c. v.t.v.m. was used. With the v.t.v.m. connected to the output terminals of the audio calibrator, the unit is turned on with the back cover removed so that the calibration pot, *R6*, is accessible. With the v.t.v.m. set on its 100-mV scale, rotate *R10* fully clockwise until it reads exactly 100 on the dial scale. Then adjust *R6* until a reading of 100 mV is obtained with S2 set on 100 mV. Slowly rotate *R10* counterclockwise until a reading of 90 mV is obtained on the v.t.v.m., going down in 10-mV increments each time until a 10-mV output is obtained. The exact reading of the dial scale should be noted for each setting. Repeat this process for the 10-mV scale. The result will be a calibration chart like the one shown in the photo on the side of the calibrator. The frequency of the author's model was measured and noted on the calibration chart; however, it is not necessary to know the exact frequency to use the oscillator.

Once calibrated, the oscillator may be used as an audio voltage standard to calibrate an oscilloscope or as a test signal in checking low-level amplifiers of either the tube or transistor type. If your scope has a built-in calibrating voltage, the stage-by-stage gain of an amplifier can be measured by injecting a known signal with the oscillator at the input of the amplifier and looking at the output of each stage. Since the oscillator produces a good sine wave, distortion and clipping can be observed with your scope while making gain measurements.

The author has used his calibrator to measure the relative sensitivities of earphones, and to check speakers for open voice coils. Any place where an accurately known audio test signal is needed, this little device will find a use. ▲



R1, R2, R3—2200 ohm, ¼ W res. ±5%
R4—270,000 ohm, ¼ W res.
R5—180 ohm, ¼ W res.
R6—100,000 ohm subminiature ¼ W pot
R7—220,000 ohm, ¼ W res.
R8—900 ohm, ½ W res. ±1%
R9—100 ohm, ½ W res. ±1%
R10—1000 ohm linear-taper, wirewound pot
C1, C2, C3, C4—0.04 μF, 200 V paper capacitor
C5—10 μF, 6 V elec. capacitor
C6—50 μF, 6 V elec. capacitor
S1—S.p.s.t. toggle sw.
S2—S.p.d.t. slide sw.
T1—Transistor interstage trans. 20,000/1000 ohms
B1—3 V battery (two 1.5-volt "AAA" cells in series)
Q1—2N2712 transistor
Q2—2N1308 transistor
* See text

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Radiation Measurements

(*Continued from page* 21)

several other radiation-detection devices which have been used or are in development. One of these is the cadmium sulfide (*CdS*) cell, commonly employed as an infrared light detector. The resistivity of *CdS* changes with the rate at which energy is received by the detector. The *CdS* detector is quite sensitive and is normally shielded to prevent saturation.

Photographic film and spark chambers may be used to record the path of charged particles. These techniques require viewing (with a TV camera) or, in the case of film, recovery of the experiment package.

The spark chamber is a series of fine wires, with high voltages maintained between them, encased in a gas-filled chamber. An incident particle ionizes the gas which, in turn, permits sparks to bridge between adjacent wires. The trail of sparks thus charts the track of the charged particle.

In addition to the detector methods described above, magnetic or electric fields are sometimes employed to separate charged particles. The principle is similar to the magnetic or electrostatic deflection schemes used in cathode-ray tubes. Charged particles are deflected by the field, the amount of deflection depending upon the energy of the particles and the strength of field the particles pass through.

Amplifiers

While many of the amplifiers used in radiation measurements may be of rather conventional broadband design, the charge amplifier deserves special mention.

In solid-state *p-n* junction detectors, the charge Q generated by a particle of energy ε is simply $Q=\varepsilon e/K$ where e is the charge on an electron (1.6×10^{-19} coulombs) and K is a constant characteristic of the material. For silicon, K is 3.6 electron-volts; for germanium, K is 2.9. Thus, the energy of the incident particle is determined by measuring the charge (Q) which is generated in the detector. We know that $V=Q/C$, and if C for the detector were constant, a conventional voltage amplifier could be used. However, the capacitance of a junction is strongly dependent upon the bias voltage, so for maximum precision, only the charge signal is amplified. Such an amplifier, shown in Fig. 4B, has a very high open-loop gain, and the output voltage $V_o=Q/C_f$ where C_f is the feedback capacitor. This capacitor can be chosen for temperature and age stability (for example, a glass capacitor). Hence, the output voltage of the amplifier is proportional to the energy of the incident particle. Very stable low-noise amplifiers have been built using this principle. The continued improvements in field-effect transistors (FET's) also point the way to even better low-noise measurement circuits.

Calibration

Calibration of most radiation experiments is performed by using a radioactive source or "bug" of known radiation spectrum. The use of such sources for in-flight calibration is not always practical, however, so some other means is often required. A burst of pulses of known amplitude may be switched into the input stages, simulating the pulses generated by the detectors. Such calibration pulses may be programmed into the experiment or triggered by ground command. A means of in-flight calibration is essential for precise radiation measurements, particularly on spacecraft missions of long duration.

Some experiments may require calibration by particle-accelerating machines (accelerators) or nuclear reactors, depending upon the kind of particle spectrum needed.

Noise

As with most low-level electronic systems, the presence of noise makes the designer's job more difficult. Beyond the noise generated in electronic components and cross-modulation noise from other systems, background noise must be reduced as much as possible. Background noise refers to the presence of particles other than those being measured. Particles of sufficiently high energy may strike spacecraft materials close to the detectors and generate secondary particles which could be falsely recorded by the instruments. The use of shielding or absorbing materials to act as a "sponge" for unwanted particles is often required. Combinations of shielded and unshielded detectors can also be used. The shielded detector measures only background radiation, while the unshielded detector measures background radiation plus the desired data. The true radiation level may then be found by subtraction.

In addition to background noise, there is a lower limit of energy resolution imposed by the detector noise and circuit noise. Counting-rate limits are set by the response time of the system.

Systems

With reference to Fig. 3, a simple radiation-measuring experiment may be described. The detector output pulse is proportional to the energy of an incoming particle. The preamplifier and postamplifier raise the signal to a usable level. The amplifiers may also shape the pulse and should recover quickly when swamped by pulses of large amplitude and/or high count rate. The amplified signals are then supplied to differential discriminator circuits. These circuits propagate a pulse only when the pulse amplitude is within set limits. For example, a window may be set at 0.8 volt and 1.3 volts. A pulse less than 0.8 volt or greater than 1.3 volts will not pass through the circuit. Only pulses having an amplitude *between* the limits of 0.8 and 1.3 volts will be observed at the output. This output then corresponds to a section of the energy spectrum. The space scientist must apply statistical methods to complete the spectrum and must know the physical and geometrical properties of the detector. Pulses of a particular energy range are then counted in a series of flip-flops, or scalars, as they are called in radiation work. The scalars are read out by the telemetry at some time interval and then are reset to zero to start the next counting interval. Sorting of pulses by amplitude (and therefore energy of the particles) as described above is known as pulse-height analysis.

A great many varieties of radiation experiments have been flown in rockets, satellites, and deep-space probes. Photos of several experiment packages which make use of the detectors and circuits previously described appear in this article. The particular system is tailored to meet the requirements of the experiment, the region of space to be traversed, the power and weight limitations of the vehicle, the length of the mission, and the availability of telemetry channels. Other constraints may also limit the scope of the experiment. ▲

The Technical Representative

(*Continued from page* 41)

market and service a product designed and produced by *Magnavox* to make facsimile communications available to anybody with a telephone. This is a self-contained, desk-top transceiver that connects to any telephone simply by resting the handset in a special receptacle.

Farther into the future, tech reps can probably look forward to new types of output devices for electronic computers.

For this reason, employment standards are high. The average TR competes with about 50 other applicants for his job. He must be highly qualified in electronics, mechanics, and optics. Applicants are usually young men who have an associate's degree or diploma from a community college, training at a recognized technical institute, or advanced training and service in electronic-mechanical fields of the Armed Forces.

A Typical Day

A typical day for Levit begins at 8:30 a.m. when he reports on the job. If he has a service call to make, he goes directly to that. He then calls his office for his next assignment unless he has a full schedule ahead of him. If there are no real service calls, he drops in on the office of a customer to do preventive maintenance. This includes installation of any new components or parts in order to keep the machine up to date.

If he has no service calls and no scheduled preventive maintenance, the TR helps others, either on their calls or back in the office by making sure that all spare parts and equipment are in proper order. In a normal day, Levit averages between five and six service calls.

In slack periods when there are no service calls or when he has finished his work on a machine, Levit finds it worthwhile to talk with users of the company's equipment. He tells them of the latest models and suggests how such equipment could help in the user's own operation. The company has found that many solid leads for its salesmen come from such a casual approach.

The independence that the TR develops also gives him a good chance to make suggestions as to how to improve equipment. One tech rep, for example, developed a special switch that permits the testing of a copier's corotron current without actually turning the machine on. Another suggested a wiring modification for the LDX printer that materially reduced service calls. Levit himself is responsible for two modifications that were adopted by the company.

Xerox maintains a committee to evaluate new designs and ideas submitted from the field by its TR's. One of its goals is to lighten the load in the attaché case that the TR carries on the job. Part of the TR's job is to serve as sort of *ex officio* member of the committee. He must always be on the alert for new ways to improve his product and the way in which he performs his duties.

While the workday ends at 5:00 p.m. there are often in-house lectures and discussions on new developments, and training periods whenever new products are introduced. For many, there are also their night classes in nearby colleges and universities. Their goals are promotions and personal development.

Levit's office manager, Donald T. Forlenza, who is Manager of Service and Sales Administration, started as a TR himself after graduating from Staten Island Community College. He became a supervisor, then a Marketing Team Technical Manager, prior to his present position. His career could lead him to the position of Branch Manager, or "almost any position in any route you want to take."

The rewards for Stephen Levit have already been good and steady. An added bonus in his case is his wife of three years. He met her while working on one of the machines in her office. ▲

Convergence Circuits

(*Continued from page* 39)

convergence relatively simple. Again, the signal is taken from the flyback transformer through *C*4 and series coil *L*2. The signal is divided by center-tapped coil *L*3, and one portion is applied to the red horizontal convergence coils while the opposite polarity goes to the green horizontal convergence coils. Both convergence coils return to ground through the center-tapped secondary of *T*1.

Because the magnetic fields generated by the red and green convergence coils must be "in step," the windings on one of the two coils are reversed to compensate for the opposite polarity of the signals. One advantage of using currents of opposite polarity in the convergence circuits is that a minimum of interference can be expected. As in the case of the blue horizontal convergence signal, a resistor and diode (*R*4 and *D*2 for red and *R*5 and *D*3 for green) limit the positive peaks and the possibility of ringing in each coil. Of the four controls in this circuit, two control *both* the red and green convergence. Variable inductor *L*2 affects both the red and green current and determines the convergence at the right side of the screen, while *R*6, which is part of the common return to ground, determines the convergence at the left side of the screen for both red and green. Both *L*3 and *R*6 control the current going to either set of coils, with *R*7 determining the convergence between the red and green electron beams at the left of the screen, and *L*3 controlling the convergence between red and green at the right of the screen.

It is apparent from this description that coils *L*2 and *L*3 have their greatest effect at the right of the screen while the resistors have their greatest effect at the left of the screen. This was also observed for the blue horizontal convergence circuit in which the resistor had its greatest effect at the left and the coil at the right of the screen. The reason for this is that in a circuit with a series inductance and shunt *RC*, variation of the coil will have its greatest effect on the phase shift in one direction, while the *RC* portion will have its greatest effect on the phase shift in the opposite direction. By distorting the current waveforms of Fig. 3, the results of this phase shift can be clearly seen. Whether these directions are left or right depends, of course, upon the polarity of the winding and on the location of the U-shaped pole pieces over the neck of the picture tube. In the actual circuit, center-tapped transformer *T*1 provides a small amount of feedback, or bucking signal, to the low end of the red and green signals. Adjustment of *T*1 also affects this bucking signal and therefore, to a very small extent, the red and green convergence. This electrical interaction, however, helps to overcome some of the magnetic interaction which is inevitable among the three convergence fields in the neck of the picture tube.

Vertical Convergence

As shown in Fig. 4, dynamic vertical convergence signals are obtained from the cathode of the vertical output amplifier through *C*1 and are applied to the blue convergence circuit through *R*1. Components *R*2, *C*1, and *C*2 determine the correct current waveshape. The upper center-tapped secondary winding on the vertical output transformer is the ground return for the convergence signal, and the amount and polarity of any feedback is determined by *R*3 which controls the blue convergence at the top of the picture. Potentiometer *R*4 controls the blue convergence at the bottom of the picture. Both *R*5 and diode *D*1 perform the same functions as the similar circuit in the horizontal convergence sections; they limit peaks and prevent ringing.

The red/green vertical convergence has four controls. The red/green convergence signal is obtained, as with the blue convergence signal, through *C*1 and *R*1 and is supplied to the red and green convergence coils. Both *R*6 and *R*7 affect the convergence at the bottom of the screen, while *R*6 and *R*8 both affect the red/green convergence at the top of the screen. Similar to the arrangement of the horizontal red/green convergence, *R*6 and *R*8 have their primary effect on both red and green beams, while *R*1 and *R*7 tend to differentiate between the two.

The vertical convergence circuits are much simpler than the horizontal ones. One reason for this is that the aspect ratio of the screen means that there is less vertical deflection than horizontal and therefore less correction is needed. Another reason is the lower frequency of the vertical sweep signal which makes it somewhat easier to shape and control.

Most 1966 color-TV models, including *Admiral, Philco, Motorola, Sylvania,* and *Zenith,* use a very similar approach in their convergence systems. The few existing differences are minor and do not affect convergence circuit operation as described in this article. ▲

MARINER IV STILL ALIVE

THE Mariner IV, which took close-up pictures of Mars last year, has been contacted at a distance of 197.5 million miles. Among the information gleaned was that all systems are operating normally, the solar panel is at full strength, and all temperatures and voltages are normal. NASA hopes to command more exercises in 1967. During its life, Mariner has travelled 750 million miles. ▲

NEW PRODUCTS & LITERATURE

Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • HAM • COMMUNICATIONS

TWO-CHANNEL SAMPLING RECORDER

A two-channel sampling recorder with a sampling rate of 3 kHz per channel is now offered as the Type 1520-A. The new unit achieves its high speed through a bank of 101 fixed styli which, when energized, produce plots on electrosensitive chart paper.

The maximum recordable frequency is determined by the sampling rate and the paper speed

which can be set as fast as 10 inches per second. A vertical rise time as short as 300 μsec can be determined from the chart.

Calibrated voltage ranges are 1 V to 500 V (linear) and 20 to 50 dB (log) full-scale. The recorder prints its own coordinates as well as voltage and time scales. Over-all accuracy of the recorder is the same as its accuracy: ±1%. General Radio

Circle No. 126 on Reader Service Card

PRECISION DECADE BOXES

Two new "Resist-O-Stat" decade boxes are now being marketed as the Models RDS 67A and RDS 67B. These units feature accuracies of 0.01% and 0.025%, respectively. Allowance for zero resistance is not required. These six-decade units have a decade-ohms-per-step range from 100 ohms to 10 megohms.

Utilizing positive in-line readout, these numeric dial decade resistors permit rapid selection of resistance settings accurate to 0.01%. They are used in test, checkout, and ground-support equipment.

Stability is 25 ppm per year, switch life is better than 100,000 operations, temperature coefficient is 5 ppm per °C, redundant switching, and weight is 5¼ lbs. General Resistance

Circle No. 127 on Reader Service Card

REGULATED POWER SUPPLIES

A new series of highly regulated, continuously variable power supplies, suitable for both laboratory use or for rack mounting, is being offered as the H Series.

All thirteen models in the new series are free from overshoot; are short-circuit-proof; and are supplied with large, accurate meters; front and rear terminals; and coarse and fine controls. All units include 0.01% line and load regulation.

Ratings from 0-20 to 0-100 d.c. volts at from 2 to 100 amperes are included in the line. Bulletin

108A giving complete specifications is available on request. Deltron

Circle No. 128 on Reader Service Card

WIREWOUND POWER RESISTORS

The development of a new dielectric material has made possible a new series of power resistors wound on a solid aluminum core. The new dielectric is a high-temperature, high-emissivity insulation which withstands continuous operation at 350°C, intermittent temperatures in excess of 500°C, and BCM high-voltage tests between leads and core without flashover—under high temperature and high altitude conditions.

The new resistors require only a fifth the volume of a resistor with beryllium oxide core and 1/18th the volume of a resistor with aluminum oxide core—with the same power rating.

Complete specifications on this new series of resistors are contained in Data Sheet R366 which will be supplied on request. Ultronix

Circle No. 129 on Reader Service Card

"N"-TYPE COAX CONNECTORS

A new Type "N" coaxial connector, electrically identical in both field-serviceable and crimp versions, enables design engineers to use the field-serviceable type for prototype equipment and for field replacement and the crimp unit for production.

Impedance of the connectors is 50 ohms; voltage rating is 1000 V r.m.s.; and specified frequency range extends up to 10 GHz. Maximum v.s.w.r. is 1.12:1, exceeding the MIL-C-39012 "N" specification. Cable retention exceeds the specification requirement of 75 pounds. Operating temperature is 200°C maximum.

The connectors are available in a number of

configurations, details of which will be supplied on request. Amphenol

Circle No. 130 on Reader Service Card

FLAT-CONSTRUCTION FILTER

The FLH-600 flat-construction low-pass filter is especially suited for 400-Hz applications. Designed, manufactured, and tested to complete MIL-F-18327B specification, the new unit has a source and load of 10,000 ohms. It is within 1 dB from d.c. to 450 Hz, 3 dB ± 1 dB at 600 Hz, and then sharply attenuates to at least 40 dB at frequencies above 800 Hz.

The filter is housed in a case measuring 2" square by ½" high. It weighs 2.5 ounces. UTC

Circle No. 131 on Reader Service Card

DUAL-WAVEFORM GENERATOR

The new Model 636 provides a complete source of sine- and square-wave signals from 20 to 200,000 Hz for a wide range of audio and video testing, servicing, and experimental work. The instrument is designed with one scale-frequency dial to simplify readings for both sine- and square-wave outputs, and a dual-function control.

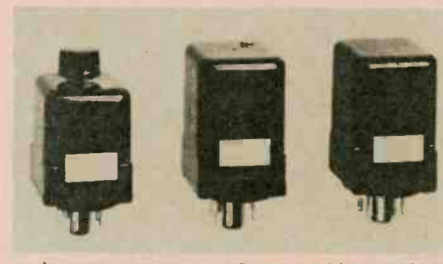
Other features include negligible distortion and high stability of sine-wave output; a Schmitt trigger multivibrator and buffer to provide isolated optimum waveform square-wave output; negligible square-wave tilt and fast risetime at all square-wave frequencies; and extensive shielding for minimum radiation pickup.

The instrument measures 8¼" x 11¼" x 7" and weighs 15 pounds. Precise Electronics

Circle No. 1 on Reader Service Card

SOLID-STATE TIMER

A new solid-state timer which can be combined with the firm's advanced-design line of wide application relays has been announced. The time range is from 100 msec to 300 seconds, with reset time less than 20 msec, repeatability of ±2%,



and temperature range from −40°C to +85°C.

The units are mounted on standard 8- and 11-pin octal plugs, enclosed in a hermetically sealed rectangular dust cover, and offered as knob adjustable, screwdriver adjustable, and fixed time or remote resistor adjustable models. Cornell-Dubilier

Circle No. 132 on Reader Service Card

LOW-COST WIRE TIE

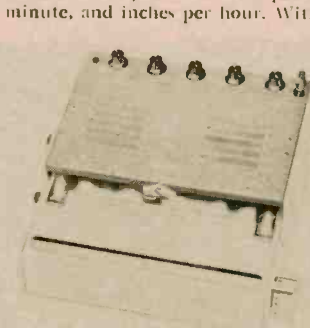
A new low-cost plastic wire tie has been introduced as the "Purse-Lock." Suited to the job of bundling several loose wires in a wide variety of applications where a number of electrical wires run along the same path, the new unit consists of a plastic tie which is looped around the wires and the spherical ends then twisted to snap the tie into a locking position.

The wire tie is being offered in a variety of sizes to accommodate wire bundles from 0.200 to 0.499 inch in diameter. Other sizes are available on custom order. Fastex

Circle No. 133 on Reader Service Card

SERVO-CHART RECORDER

The Model EUW-20M servo-chart recorder features 21 switch-selected chart speeds. In its internal mode of operation, the available chart speeds range from 0.5 inch per hour to 12 inches per minute with selection of any desired speed made by means of a single knob. The 21-position switch is calibrated with five rate scales—seconds per inch, minutes per inch, hours per inch, inches per minute, and inches per hour. With the mode



switch in the external position, the unit may be operated from an external source of sine waves, square waves, or pulses. The sine-wave frequency or pulse repetition rate and the position of the selector switch determines the chart speed in this mode.

The recorder is offered with or without the 21-speed drive feature. The 21-speed drive accessory is available separately for installation in earlier models. Full specifications on the EUW-20M are available on request. Heath

Circle No. 2 on Reader Service Card

VIDEO TAPE RECORDER

A new video tape recorder featuring instant play, ease of operation, and a new long-life recording head has been put on the market as the Wollensak VTR-150. The unit has been designed primarily for educational, industrial, and military markets.

The unit will be offered in two package concepts: as a recording and playback device or installed in a mobile console. Tape for the unit is priced at $39.95 per 2400-foot roll which will yield one hour of recording time.

The unit contains all-transistor, solid-state circuitry which, coupled with a two-motor driver, produces an almost instantaneous runup time of 8 seconds. Recording and playback speed is 7½ ips. The VTR-150 uses ½" video tape and will record and replay up to one hour on a 7" reel. Maximum reel size is 8".

The VTR-150 will not be available on the commercial market until later in the year but information regarding the recorder is available on request. 3M

Circle No. 3 on Reader Service Card

PRECISION A.C. POTS

A new line of precision a.c. potentiometers is now being marketed as the Series 7 "Vernistats." These high-accuracy, 20-turn units in size 11 offer very low output impedance. For example, Model 7B1 provides an output impedance of 20 ohms and an absolute linearity of ±0.01 percent. Extended slope is 180° at each end.

These new pots meet applicable requirements of MIL-E-005272, MIL-R-12934, and others. They are designed to be used in servo and control systems such as missile guidance systems, automatic checkout equipment, navigation systems, simulators, computers, and specialized industrial equipment.

Electrical and mechanical specifications on this new Series-7 line will be supplied on request. Perkin-Elmer

Circle No. 134 on Reader Service Card

ENCAPSULATED TRANSISTORS

A new line of microminiature, high-performance, plastic-encapsulated transistors is now available at what are believed to be the lowest prices for their type. Included in this new silicon "microtab" line is a high-gain, low-noise amplifier which is designed for use in hearing aids, instrumentation, hybrid circuits, linear and analog circuits, miniature operational amplifiers, and any other application where small size is important.

These amplifiers, designated Types D26E-1 through E-7, are similar to conventional 2N930 or 2N2484 types. Betas range from 40 to 300. The high-frequency amplifier, D26G-1, is similar to the 2N918. It has a beta at 100 MHz of greater than six.

The amplifiers are color coded for type number and lead configuration. Package size is 0.07" x 0.07" x 0.085". General Electric

Circle No. 135 on Reader Service Card

MAGNETIC-REED ROTARY SWITCHES

A complete line of magnetic-reed rotary switches, consisting of eight models, is currently available. They are available with either Form A or Form C contacts, or in combination of both, and have isolated contacts, making it possible for each stack to handle up to 12 individual circuits.

The units are light in weight—as little as 3 ounces for a 12-position switch—and have an improved ball and sprocket detenting mechanism and no sliding contacts, which greatly reduces operating force and eliminates contact wear. Rhodium contacts hermetically sealed in pure nitrogen make these units suitable for use in hazardous locations, dry-circuit applications, and assures reliable operation with low contact resistance under all environmental conditions. Hart

Circle No. 136 on Reader Service Card

METAL-FILM TRIMMERS

A new line of low-ohm, metal-film trimmers which provide the temperature coefficients and noise characteristics of wirewounds is now available. The new units are housed in humidity-vibration-shock-proof cases while a silicon "O" ring shuts out dust and humidity. A precious metal contact assures low contact resistance. Resistances available in the new line range from 50 to 100,000 ohms. Amphenol

Circle No. 137 on Reader Service Card

U.H.F./V.H.F./FM ANTENNA

A log-periodic antenna designed especially for urban use has been introduced as the LPV-VU5. The new "Metro-Color" antenna is designed for v.h.f./u.h.f. black-and-white or color and FM or FM-stereo. This single-downlead log-periodic unit is 45 inches long and has three driven V dipoles to cover both v.h.f. bands. Three active dipoles plus three directors provide the stepped up gain needed for u.h.f. Frequency response is flat within ±½ dB on any channel. A sharp forward lobe in the polar pattern assures unidirectional pickup and high front-to-back ratio on all the designated channels. JFD

Circle No. 4 on Reader Service Card

NEW CABINET LINE

Designed to accommodate various sizes of electronics systems, the new "Classic" cabinet line is being offered in 15 different sizes to house standard 19" panels. The finish is vinyl textured charcoal gray or sand. Doors are available as auxiliary items. The cabinets have welded frames of aluminum extrusions while patterned aluminum panels complete the enclosures. Bud

Circle No. 5 on Reader Service Card

EXACT-REPLACEMENT TV PEC's

Ten new exact-replacement PEC's for television receivers are now available for use in retrace suppression, sound i.f., and sync circuitry. Nos. PC-491, PC-492, PC-493, and PC-494 are three-terminal retrace suppression networks consisting of two resistors and two capacitors of various values and manner of combination.

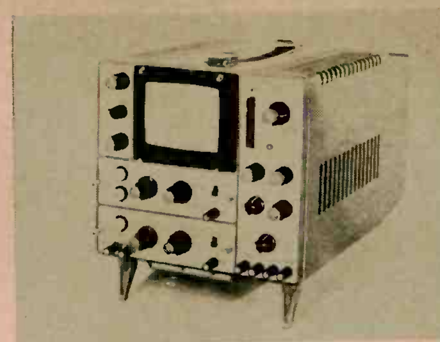
PC-495 is a four-terminal sound i.f. network consisting of three resistors and two capacitors. PC-496 through PC-500 are two- to five-terminal networks for sync coupling and take-off. Centralab

Circle No. 6 on Reader Service Card

DUAL-BEAM SCOPE

The high-performance, dual-beam oscilloscope, D53, is a laboratory-type instrument designed for wide-band, multiple-trace applications including differential measurements and high-d.c.-sensitivity applications.

The main frame contains the CRT, power supplies, and the delays; the time base and horizontal amplification are provided by a plug-in module; vertical amplifiers are available in six models for use with the D53.



Full specifications on this 25-MHz range scope will be forwarded on request. Data Instruments

Circle No. 138 on Reader Service Card

BROADBAND MEASURING SET

A general-purpose voltmeter featuring ruggedness, compactness, and a frequency response of 50 Hz to 800 MHz is now being offered as the Type 74832. This all-transistor level-measuring set is a portable, general-purpose 75-ohm-input voltmeter. It is housed in a strong diecast metal case, making the unit suitable for field use. It combines small size, light weight, and long operation from its internal dry cells.

Three r.m.s. measuring ranges are provided: 0-60 and 0-600 millivolts and 0-3 volts. The scale on the 60-mV range is also graduated from −10 to 0 dB. The response is flat within 0.3 dB between 1 and 30 MHz and 0.6 dB between 30 and 500 MHz.

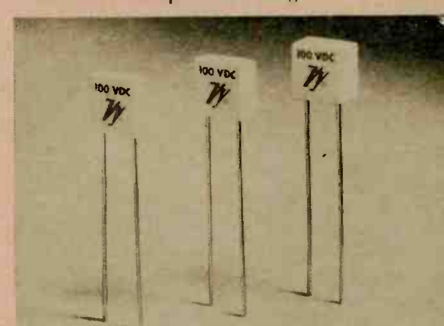
The instrument measures 7⅜" x 5¾" x 3" and weighs 4 pounds. ITT Industrial

Circle No. 139 on Reader Service Card

PORCELAIN CAPACITOR LINE

A new line of radial porcelain capacitors with a 0 ± 25 ppm/°C temperature coefficient as standard, 0.200" lead spacing, and voltage ratings up to 200 V d.c. is now on the market. These new monolithic capacitors have a high volumetric efficiency in a small case size and incorporate new electrode and terminal designs.

The new line is available in 13 standard values within the capacitance range of 5.1 to 1000 pF. They have low dissipation factors of 0.001 (@ 25°C) and 0.002 (@ 125°C) and operate within the temperature range of −55°C to +125°C without voltage derating. Based on extensive life tests, they are rated at 200 V d.c. from −55°C to +85°C; 100 V d.c. from −55°C to +125°C; and 50 V d.c. from −55°C to 150°C. Vitramon



Circle No. 140 on Reader Service Card

SINGLE-SCALE CIRCULAR SLIDE RULE

A radical new slide rule, created by John Tyler, professor emeritus of mathematics at the U.S. Naval Academy, uses only a single numbered scale for calculations in trigonometry, geometry, multiplication, division, and log functions.

One advantage of the new design is the elimination of multiple sets of numbered scales. The new rule presents a clean and uncluttered face with a single, easy-to-read, spiraled scale carrying all numbers necessary to perform the computations of the older type rule.

The new rule has a transparent cursor arm and a rotating disc mounting on a flat plastic base, 8½" square. The spiral-shaped C scale is the only working scale and is imprinted on the rotatable disc. All other scales found on the conventional rule are replaced by curved hairline indexes which are inscribed on the base. Weems & Plath

Circle No. 7 on Reader Service Card

PRECISION ROTARY SWITCH

The Model SW200 precision rotary switch can be supplied with various conducting angle switch segments and tolerances held within ±1°. Conducting current is 100 mA and the conducting material, nominal zero resistance, is precious metal.

The case is machined anodized aluminum, with a one-piece diallyl phthalate molded interior and external terminal board. This technique provides a complete insulating envelope inside the housing and eliminates all possible leakage paths. The unit is supplied as a sleeve-bearing panel mount, ball-bearing servo mount, or with a coupling device wherein it can be coupled to precision pots. Samarius

Circle No. 141 on Reader Service Card

25" IMPLOSION-PROTECTED TUBE

A new 25-inch, 110-degree black-and-white TV picture tube recently introduced features its own integral implosion protection system. It features a viewing area of over 327 square inches, has special tinted glass that improves picture contrast, four integral mounting brackets, as well as the implosion protection system. This latter is

composed of a metal rim band and a steel tension strap. The metal rim band, suitably curved to fit snugly around the periphery of the tube face, is epoxy bonded to the glass. A steel tension strap is then prestressed tightly over the rim band and mechanically clinched in place to maintain a residual tension in the system. Westinghouse

Circle No. 142 on Reader Service Card

MULTI-PURPOSE PROBE

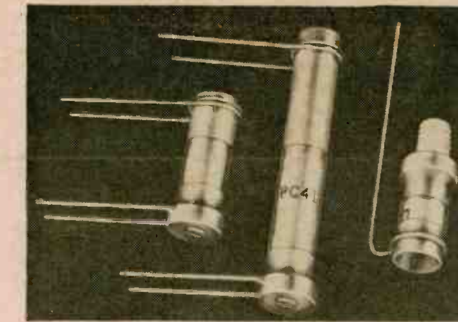
A multi-purpose probe, the Model MP-1, can function as a d.c. probe, a.c./ohms probe. r.f. probe, and a low-capacitance probe. The new four-in-one design saves the cost of four probes and eliminates the need for switching probes during servicing. The unit will extend the operating range of a v.t.v.m., scope, or signal tracer.

As a d.c. probe, the MP-1 provides isolation for all d.c. measurements. As an a.c./ohms probe, it can be used for all low-impedance, low-frequency voltages and waveforms. As an r.f. probe it is a demodulator for checking r.f. voltages, waveforms, and signals in TV-radio r.f. and i.f. stages. As a low-capacitance probe, it can be used for high-impedance sync circuits where regular probes would overload the circuit. Mercury

Circle No. 8 on Reader Service Card

NEW TRIMMER CAPACITORS

A new series of miniature trimmer capacitors, to meet styles PC40 and PC41 of MIL-C-14409, is now on the market. Ten models of these new higher capacitance trimmers are available, five each in panel-mount and printed-circuit styles. Models are available with both H and J characteristics and capacitance ranges meet values



specified in MIL-C-14409 for all values from 0.8 to 4.5 pF and 1.0 to 30 pF.

Quality factor is guaranteed at 650 maximum. d.c. working voltage is 750 volts. LRC Electronics

Circle No. 143 on Reader Service Card

TERMINAL/WIRE-WRAPPING TOOL

A new terminal design and a new wire-wrapping tool combine to reduce the wiring time on the firm's line of low-cost connectors. A stripped lead is quickly ready for soldering after being fed into the terminal hole and wrapped around the terminal with a single stroke of the tool.

The improved connector meets requirements for 14-milliohm contact resistance, 50-gram individual contact retention, 2000-volt breakdown, and 2-ampere current-carrying capacity. North Electric

Circle No. 144 on Reader Service Card

SUBMINIATURE TOGGLE SWITCH

The Model 7205 d.p.d.t. subminiature toggle switch features minimum life of 100,000 cycles, solid-coin-silver contacts and terminals, and molded phenolic bases. Bat-handle operating levers are standard, but color-coded plastic caps in many color choices are available on request.

Contact rating is 5 amperes resistance load at 117-volts a.c., insulation resistance is 1000 megohms minimum, dielectric strength is 1000 volts r.m.s. at sea level, and initial contact resistance is 20 milliohms at 2-4 volts d.c., 1 amp. Weight is 5.5 grams. C&K Components

Circle No. 145 on Reader Service Card

400-Hz SINE-WAVE INVERTER

A 110-volt, 400-Hz sine-wave inverter rated at 100 watts is now on the market. The unit operates from an input voltage of from 24 to 30 volts d.c. and the output is 110 volts r.m.s., adjustable ±5%. Output frequency is 400 Hz, with a tolerance of ±0.5%. Output power is rated at 100 VA at 50°C or 80 VA at 71°C. The waveshape is sinusoidal with 4% maximum harmonic distortion at full load. Input regulation (from 24-30 V d.c.) for frequency is ±0.3% and

for the output voltage it is ±0.5%. Load regulation for frequency is ±0.3% and for the output voltage it is ±2%.

The unit measures 4" x 5" x 2½" and weighs approximately 56 ounces. Arnold Magnetics

Circle No. 146 on Reader Service Card

A.C. VOLTMETERS

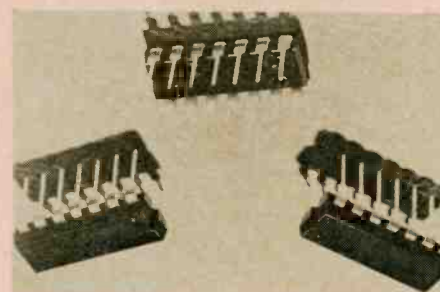
Two new models have been added to the 400 Series of a.c. voltmeters as the 400F and 400FL. Both have 100-μV full-scale ranges and 10-megohm input impedance. An a.c. output produces one volt r.m.s. for full-scale meter deflection, regardless of range and use; on the 100-μV range, the amplifier has 80-dB gain with less than 5 μV noise. Frequency range is 20 Hz to 4 MHz. Accuracy, in the range from 100 Hz to 1 MHz, is ±0.5% of full scale ±0.5% of reading for the 400F and 1% of reading for the 400FL. The Model 400F presents the linear voltage scale uppermost, while the Model 400FL presents a linear dB scale uppermost. Hewlett-Packard

Circle No. 147 on Reader Service Card

PLASTIC-PACKAGED INTEGRATEDS

A new line of resistor-transistor-logic circuits is now being offered in a solid, void-free, pressure-molded case providing a high degree of environmental protection. The lead arrangement is a dual in-line configuration with leads on 100-mil centers and with 300-mil spacing between parallel rows of leads. The circuits feature central power supply connections; specifically, the ground connection is on pin 4 and V_{CC} is on pin 11.

The new "Unibloc" packaged units are available in quad 2-input, triple 3-input, and dual



4-input gates as well as dual buffers and dual J-K flip-flops. The initial series has an operating temperature range of +15°C to +55°C. Motorola

Circle No. 148 on Reader Service Card

DRY-TRANSFER SYMBOLS

A line of dry-transfer alphabets and numerals and electronic symbols is now being offered in various sizes and in black or white type. Size ranges are 1/8", 1/4", 3/8", 1/2", 21/32", and 25/32". The electronic symbol sheets, 7" x 13", cover the entire gamut of electronic components for drafting of circuits. Russell Industries

Circle No. 149 on Reader Service Card

HI-FI—AUDIO PRODUCTS

AUTO REVERB SYSTEM

A deluxe car "Vibrasonic" sound system, designed to add reverberation to music for greater depth and realism has been put on the market as the Model KM201R. The new unit employs three transistors and can be added to any car radio where the car has a 12-volt negative ignition system and the radio has either an 8-10 or 40 ohm speaker.

The unit has a die-cast control housing which fits under and dash; one control knob with three positions for reverberation, regular listening without reverb, or front-speaker only; and a second knob which acts as a balance or fader control that permits speakers, front or back, to be adjusted to the listener's personal preference, with or without reverberation. Motorola

Circle No. 9 on Reader Service Card

SOLID-STATE TAPE/PHONO PREAMP

A new solid-state tape/phono preamplifier featuring an extremely low noise figure of 6 dB below inherent noise generated by unrecorded tape is now available as the Model ATP-24.

The unit is designed for use with conventional magnetic tape heads or phono cartridges. Proper equalization is provided for playback compensation of tapes recorded at 7½ and 15 ips. Also, by simply strapping a terminal on the board, proper equalization is obtained for the playback compensation of discs recorded using the RIAA curve.

In addition, the unit features compact size, controls for gain and high-frequency tape response, output impedance of less than 10%

of nominal load, 20 to 20,000-Hz power bandwidth, and high-sensitivity tape and phono input. Melcor

Circle No. 10 on Reader Service Card

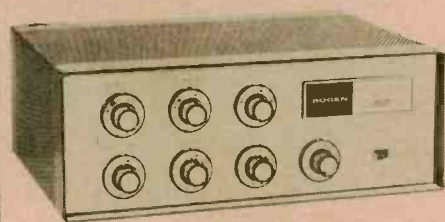
SOLID-STATE P.A. AMPLIFIERS

A new line of public-address amplifiers, the MTA series, includes six units featuring solid-state circuitry for ultra reliability yet at moderate cost.

The series, with a complete accessory line available, delivers 10 to 100 watts and features silicon transistors, low-impedance microphone inputs requiring no transformer, and built-in protection against short-circuited or open speaker lines.

Plug-in circuit boards provide high quality control and servicing ease. Chimney-type heat sinks and heat-sensing "thermoguards" permit safe and continuous operation up to 158° F.

Available accessories include manual phono



tops, carrying cases, plug-in transformers and magnetic cartridge module, rack panel kits, control guard locking plate, standby controllers, remote volume controllers, and a plug-in component for microphone precedence. Bogen

Circle No. 11 on Reader Service Card

12" COMPONENT LOUDSPEAKERS

Two new twelve-inch component loudspeakers, the MC12 and the MT12, have recently been added to the "Michigan" speaker line.

The MC12 features the "Radax" dual cone while the MT12 features the same dual cone but adds a ring diaphragm tweeter and annular horn for increased efficiency in the higher frequencies. The MT12 has a continuously variable level control for adjusting brilliance to suit varying personal tastes and environmental acoustics. Its frequency response is 40 to 14,000 Hz. The MT12 covers 40 to 18,000 Hz. Electro-Voice

Circle No. 12 on Reader Service Card

30-WATT P.A. DRIVER

A built-in transformer and watts/impedance selector switch are features of the new 30-watt public-address driver unit being marketed as the PD-30T. The weatherproof unit is designed to be used as a replacement driver on any industry-standard horn having 1⅜"-18 threads. Special corrosion-proofing and melamine enamel finish maintains weather protection.

The unit's screw-to-line terminals, cable strain-relief clamp, watt/impedance switch, and built-in transformer save installation time, costs of wiring, and speeds balancing of power levels in multiple speaker systems.

Power output is a continuous 30 watts, power equalized to frequencies above horn cut-off is 40 watts, and frequency response is 120 to 14,000 Hz. The sound level is 126 dB measured 4 feet on-axis with a DR-42 horn at 30 watts input. The unit is 4¾" in diameter and 4⅞" deep. Atlas Sound

Circle No. 13 on Reader Service Card

MICROPHONE MIXER

Four low-impedance microphones can be fed into the new microphone mixer currently being offered. Each channel has its own volume control and built-in preamplifier. A master output volume control and "on-off" switch are provided.

The unit will operate on either batteries (six 1.5-volt penlight type) or on 110-240-volt a.c., with automatic switching. Other features include an output jack for connection to a rever-

beration unit, separate "on-off" switch, a.c. power-indicating light, and a scratch-resistant vinyl case which measures 9" x 8" x 6". Weight is 5½ lbs. American Geloso

Circle No. 14 on Reader Service Card

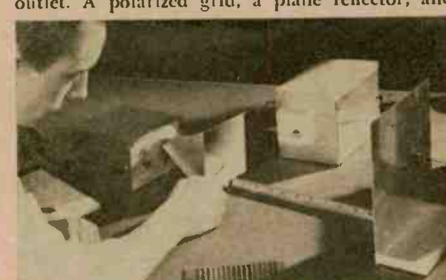
CB-HAM-COMMUNICATIONS

MICROWAVE OSCILLATOR KIT

The theory and behavior of microwaves can be demonstrated by means of the new Andrews microwave oscillator kit. Designed for use by teams of four students, the apparatus employs microwave frequencies to introduce students to the basic laws of light waves. Standing waves, interference in thin films, Young's experiment, Lloyd's mirror, polarization, and Doppler effects can be explored and measured in laboratory experiments.

A clean, polarized electromagnetic wave with a frequency of 6.6 GHz and a 4.6 cm wavelength is generated by a small 7486 triode. The tube's metal cap is employed to form an inexpensive grid-anode coaxial resonant cavity. This is positioned at the throat of a flared microwave antenna horn attached to a small, specially designed power supply.

The unit comes factory tuned and ready for use. It operates from a three-wire 117-volt, a.c. outlet. A polarized grid, a plane reflector, and



a plastic rule for measuring wavelengths are supplied, along with a copy of Dr. C. L. Andrews' book "Optics of the Electromagnetic Spectrum." Macalester Scientific

Circle No. 15 on Reader Service Card

FM ALERTING/MONITORING UNITS

Three new FM radio alerting and monitoring receivers, especially designed for use by fire departments, Civil Defense units, police departments, Industrial and Business Radio Services licensees, emergency crews, etc., are now on the market.

In use the alerting receiver remains on silent standby until activated by a tone signal transmitted from headquarters. The receiver, now operating at full sensitivity, produces a voice message advising the listener the exact nature of the alert and the action to be taken.

The three basic models are the "Polaris," a 24-transistor FM tone-voice alerting unit; the "Mercury," a 31-transistor monitor receiver; and the "Gemini" (photo), a 36-transistor combination tone alerting and monitoring receiver. They are available in the low (30-50 MHz) or high (150-174 MHz) bands with other frequencies available on special order. Viking Instruments

Circle No. 16 on Reader Service Card

450-MHz MOBILE RADIO

To provide effective and economical communications in the u.h.f. band, a new 450-MHz two-way FM mobile radio has been introduced as the "Dispatcher."

The unit features completely transistorized exciter, receiver, and power supply. The only tubes in the unit are three in the transmitter, which provides 15 watts r.f. power output.

The new 450-570-MHz unit has ultra-stable solid-state channel elements to maintain precise frequency control at wide operating temperatures—without using crystal heaters or ovens. A battery-saver circuit switches off the transmitter filaments when the vehicle ignition is turned off.

Five watts of audio output with less than 5 percent distortion is provided in the unit. This permits hearing calls even when the operator is away from his vehicle.

Complete technical specs on the "Dispatcher" are contained in Bulletin E-746 which will be forwarded on request. Motorola

Circle No. 17 on Reader Service Card

SSB/AM MOBILE UNIT

The CH25M has been specifically designed to meet the growing demand for both land and marine mobile SSB, has an output of 100 watts SSB or compatible AM—all in a package weighing less than 22 pounds and measuring 10¾" x 7" x 13¾".

The unit will mount under the dashboard of most vehicles, eliminating the necessity of a separate control head and connecting cables. Transistorization has reduced the current requirement to less than 0.16 ampere on receive, permitting constant monitoring without excessive battery drain. Plug-in power modules, either a universal 12, 24, 32 volt d.c. or a 115/230 volt a.c. unit, permit instant conversion from mobile to base-station use.

The CM25M is a six-channel unit with plug-in tuning coils to facilitate rapid change of operating frequency in the field. A matching antenna tuner, which may be installed on the back of the set or remote controlled up to 100 feet away, permits the unit to be used with a variety of antenna types without excessive signal loss. Kaar

Circle No. 18 on Reader Service Card

MANUFACTURERS' LITERATURE

AUDIO EQUIPMENT

A wide range of microphones and accessories for professional sound applications is presented in a new 34-page fully illustrated catalogue (No. 566). Wide-range, hand-held, and lavalier types of omnidirectional microphones are included, as well as stand- and boom-mounted cardioid and "Cardiline" devices.

Wall-mount and free-standing studio monitors are also covered, and a 4-page section on selecting the proper professional microphone is provided. Electro-Voice

Circle No. 19 on Reader Service Card

INSULATION RESISTANCE

A new 12-page pocket-size manual (P-16424) which discusses the fundamentals of insulation resistance testing is now available. The booklet shows test hook-ups for performing insulation resistance evaluations on wiring, meters, appliances, d.c. motors and generators, and a.c. motors with the Model 2000 "Meg-Chek" instrument. Associated Research

Circle No. 20 on Reader Service Card

BATTERY WALL CHART

Information on the chemistry and physical structure of advanced battery systems is presented on a new illustrated wall chart. Suitable for schools and colleges, the chart is printed in four colors and contains data on the performance, power, and applications of primary batteries. Mallory Battery

Circle No. 21 on Reader Service Card

EDUCATIONAL TV

The basic types of educational TV systems, including broadcasting stations, 2500-MHz instructional TV systems, inter-school cable, and conventional microwave link, are outlined and evaluated in a new 36-page reference: "1966 Schoolman's Guide to ETV Communications." Master antenna TV (MATV) and closed-circuit TV (CCTV) systems are also covered, along with financing information and sources of ETV advice and counsel. Jerrold

Circle No. 22 on Reader Service Card

COLOR-TV COMPACTRONS

A new 12-page guide to the selection of multifunction compactrons for color and black-and-white TV is now available. Approximately 150 devices are listed in the booklet, which contains easy-to-use charts giving condensed specifications.

Also included in bulletin ETD-4359 is a page of basing diagrams. General Electric

Circle No. 150 on Reader Service Card

BROADBAND ANTENNAS

A new 20-page illustrated booklet describing a complete line of stock and custom broadband antennas has been published. Included are log-periodic types, cavity-backed devices, conical spiral and helical units, horn antennas, and a variety of special-purpose antennas.

Information on antenna characteristics and terminology is also provided. American Electronic Laboratories

Circle No. 23 on Reader Service Card

SOUND COLUMNS

A new 10-page manual which describes and illustrates the advantages and applications of sound columns in p.a. systems has recently been published. Methods of installation and arrangement of sound-column speakers are fully explained.

In addition, the booklet contains a table of technical data and specifications. American Geloso

Circle No. 24 on Reader Service Card

PILOT LIGHT/SWITCH

Information on the new "Slidelite" unit which combines a pilot-light indicator with a switch in one compact, snap-in installation is contained in a new catalogue sheet (No. SL66).

The device is designed to operate with either neon or incandescent lamps, and a variety of lens colors is available. Messages, trademarks, or other legends may be stamped on the pilot-light lens. Leecraft

Circle No. 151 on Reader Service Card

WIRE DESIGN BOOKLET

Information on advantages and applications of precision wire forms and welded assemblies of wire, strip, and tubing is contained in a new 20-page handbook entitled "New Concepts in Wire Design."

The brochure includes a discussion of the types of steel wire as well as a table of steel wire sizes. In addition, a section on the elements of wire design lists design tips and describes various methods of forming and welding wire. Titchener

Circle No. 152 on Reader Service Card

TEST EQUIPMENT

A new 16-page brochure covering a complete line of test equipment has been published. Included in booklet No. 2072 are v.o.m.'s, v.t.v.m.'s, scopes, microtesters, and temperature indicators.

The company is also offering a catalogue which gives full specifications and applications data on its "Lab-Line" group of precision electrical measuring instruments. Simpson

Circle No. 25 on Reader Service Card

R.F. POWER MEASUREMENT

Absorption wattmeters, coaxial load resistors, directional wattmeters, and coaxial switches are among the instruments for r.f. power measurement that are listed in a new 4-page illustrated short-form catalog (SF-66).

In addition, the brochure describes related custom-built accessories such as coaxial filters and power monitors. Bird

Circle No. 153 on Reader Service Card

MEASURING EQUIPMENT

A comprehensive 50-page 1966-1967 index of electronic measuring instruments has been published. Covering a wide range of devices, including waveform and distortion analyzers, oscilloscopes, amplifiers, and attenuators, as well as equipment for measuring voltage, current, resistance, impedance, frequency, microwave noise figure, and temperature, the index is illustrated and contains complete specifications for all devices listed. Hewlett-Packard

Circle No. 154 on Reader Service Card

FREQUENCY STANDARD

Complete technical specifications for the Model JKTO-66 5-MHz laboratory frequency standard are contained in a new illustrated catalogue sheet. CTS Knights

Circle No. 155 on Reader Service Card

CATV FINANCING

The National Community Television Association (NCTA) has announced publication of the proceedings of its "CATV Financial Seminar" which was held in New York City in January, 1966.

Contained in the 172-page volume are the complete texts, charts, and illustrations of 16 papers on the financial aspects of CATV which were presented by prominent spokesmen from the industry itself, government, broadcasting, and allied fields.

Copies of the publication are available from the National Community Television Association, 535 Transportation Building, Washington, D.C. 20006 at $15.00 per copy.

CABLE INSTALLATION

A new cable installation handbook which provides guidelines for the construction of CATV transmission lines has been published. The manual includes tips on selection of materials and lists specifications for conforming to utility-company practices and the National Electrical Safety Code.

Two sections dealing with pole line and aerial construction are already contained in a soft-cover, loose-leaf binder, and a third section on buried cable construction is forthcoming.

The handbook is available from Ameco, 2949 West Osborn Road, Phoenix, Arizona 85017. List price is $5.00 including all future additions and revisions.

USING THE V.O.M.

Simpson Electric Company, 5200 West Kinzie Street, Chicago, Illinois 60644 is currently offering a 90-page paperback entitled "1001 Uses for the '260' Volt-Ohm-Milliammeter."

Fully illustrated, the book is a comprehensive compilation of all known test applications for the device and covers voltage, current, resistance, and power measurements, as well as receiver, transmitter, and industrial measurements and automotive tests.

The manual is available from electronic tributors for 75¢ or directly from the compa for $1.00 (to cover postage and handling). ▲

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3	.14	.22	.28	.40
15	—	.75	1.20	1.55
35	—	1.30	2.00	2.70

Amps	700 PIV	800 PIV	900 PIV	1000 PIV
.75*	.25	.32	.40	.55
3	.49	.58	.67	.78
15	1.70	1.85	2.25	2.50
35	3.15	3.60	4.50	4.80

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TRANSISTORIZED Products Importers catalog. $1.00. Intercontinental. CPO 1717, Tokyo, Japan.

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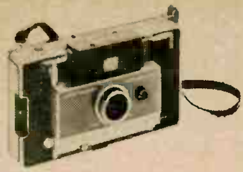

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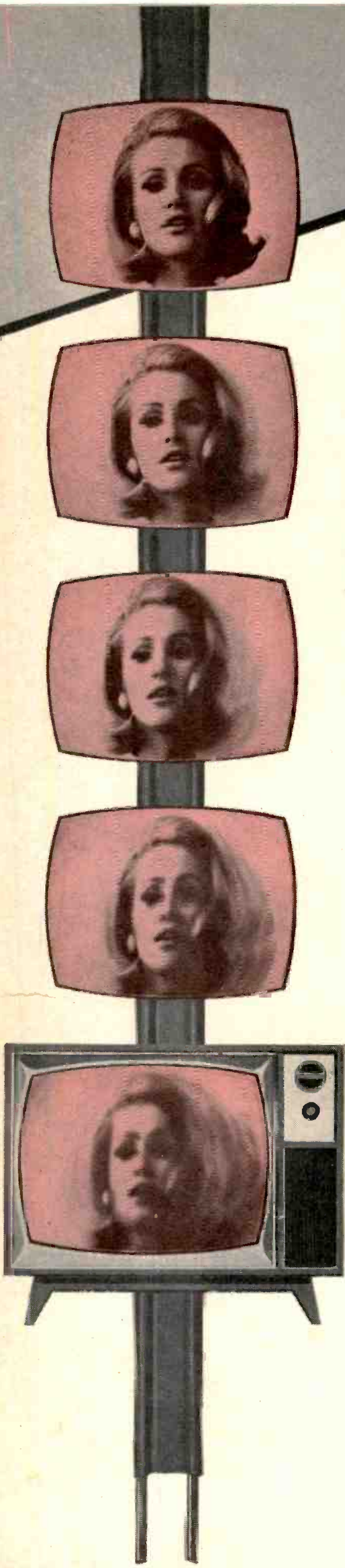

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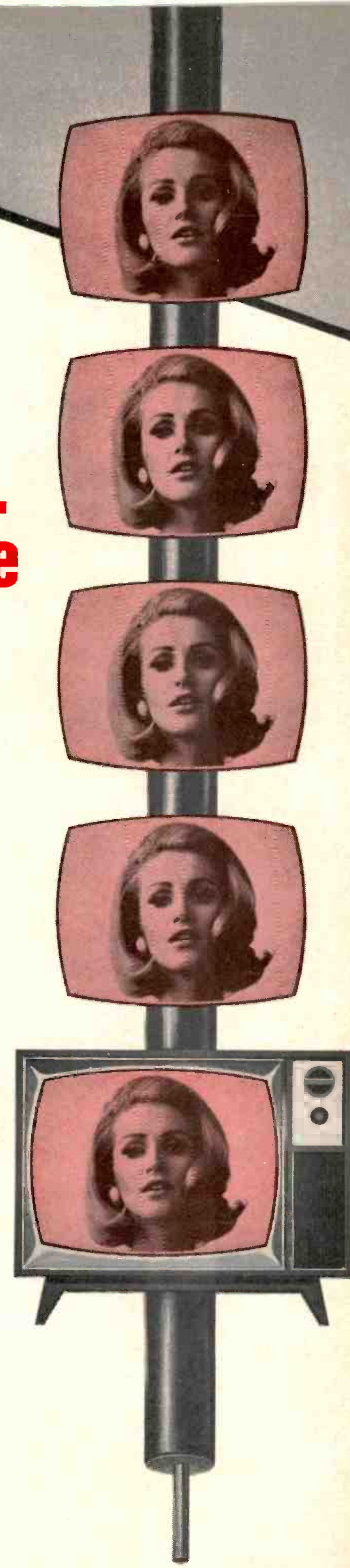

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