Electronics World

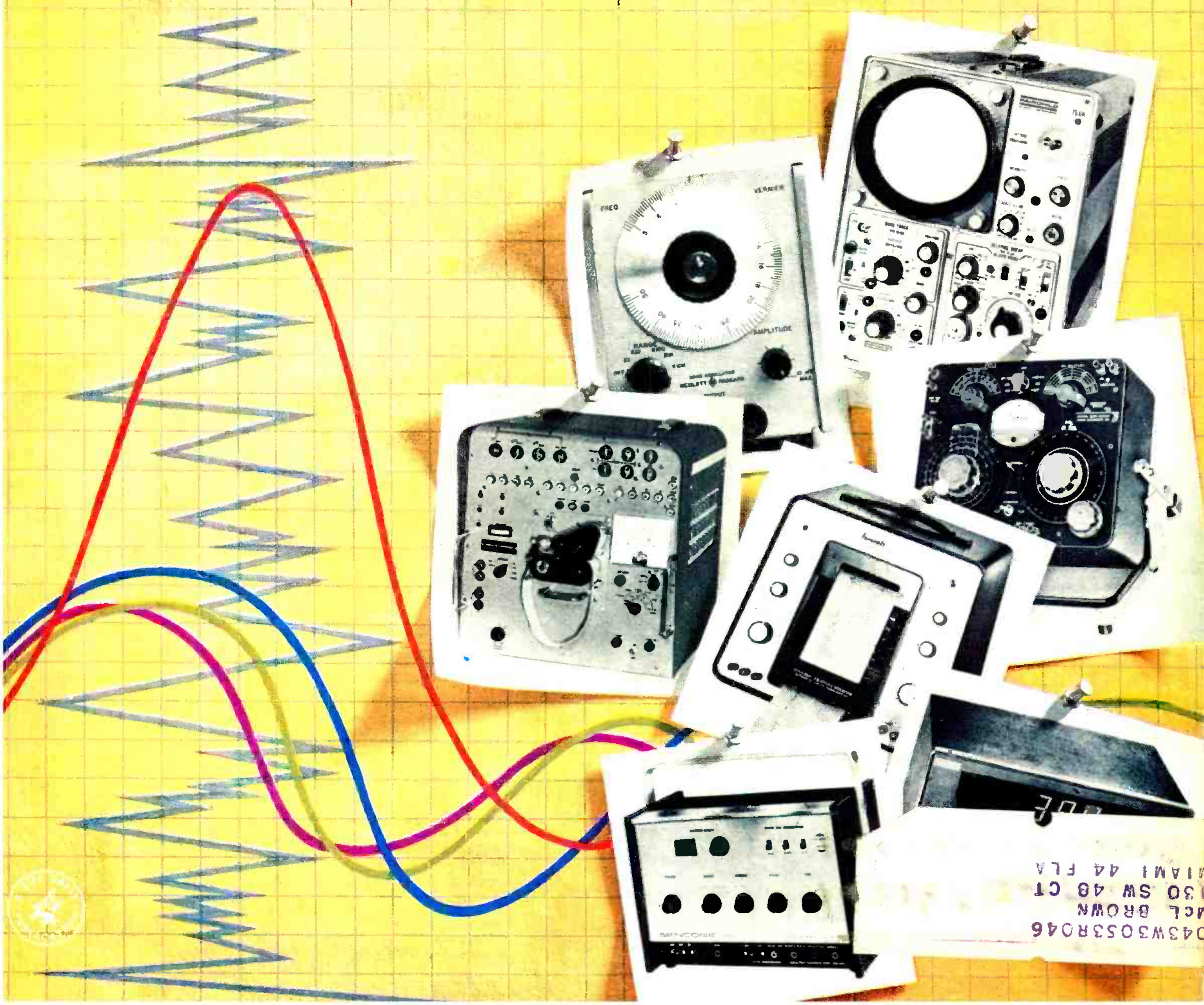
AUGUST, 1963
50 CENTS

SPECIAL TEST EQUIPMENT ISSUE

DIRECT-READING INSTRUMENTS
SIGNAL-GENERATING EQUIPMENT
CATHODE-RAY OSCILLOSCOPES

THE INSTRUMENT CALIBRATION & REPAIR TECHNICIAN • DETECTION OF NUCLEAR RADIATION BY SEMICONDUCTORS • CALIBRATING TEST EQUIPMENT • ACCURATE AUDIO FREQUENCY MEASUREMENT • 1963 DIRECTORY OF TEST EQUIPMENT KITS

bonus insert: Color Codes Chart



First All Channel UHF Booster—Blonder-Tongue U-BOOST

The fabulous new Blonder-Tongue U-Boost adds up to 15 miles to the UHF reception range. Homes formerly out of the range of UHF can now receive sharp, clear reception. The U-Boost will also clean up and improve fuzzy TV pictures in weak UHF signal areas, making them sharp and clear.

The U-Boost (gain 10 db) triples the antenna signal voltage. Teamed up with any UHF converter, or added to an all-channel receiver, the U-Boost improves reception on any UHF channel 14 to 83. Just a turn of the dial pinpoints the desired channel and brings it in sharp and clear. The TV picture quality is always excellent with the U-Boost, since it amplifies the signals before conversion, delivering the best signal-to-noise ratio.

Installation of the U-Boost is easy. It has an AC convenience receptacle; patented 300 ohm stripless terminals make it a cinch to connect twin lead without stripping or splicing.

The modern U-Boost styling matches the new Blonder-Tongue UHF converters. **U-Boost,** List **$39.95**

BLONDER-TONGUE UHF CONVERTERS, PERFORMANCE-PROVED 2,000,000 TIMES

Blonder-Tongue 99-S — all-channel UHF converter for prime signal areas List **$27.95**

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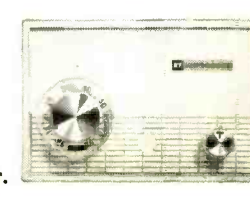

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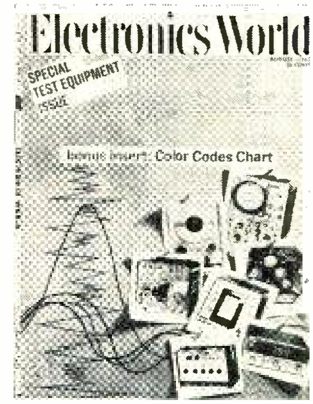
Electronics World CONTENTS

AUGUST 1963 / VOL. 70 NO. 2

MONTHLY FEATURES



THIS MONTH'S COVER symbolizes the important role played by test equipment on the service bench, on the production line, and in our laboratories. Special articles in this Test Equipment Issue survey the entire field with coverage of direct-reading instruments, signal-generating devices, cathode-ray oscilloscopes, and test-equipment kits. Other articles on the calibration of test equipment and role of technicians responsible for checking and repair are also included. For a description of the specific pieces of equipment shown on our cover, see the Cover Story on page 27.

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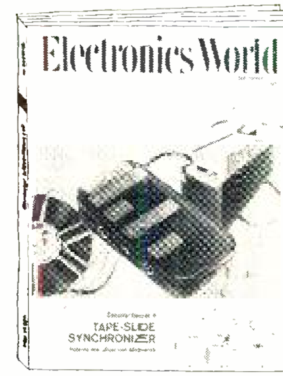

ELECTRONIC ANESTHESIA
Although the technique is far from perfected, interesting research and development work is underway as this survey indicates.

THIN LOUDSPEAKER SYSTEMS
The various methods being used to make hi-fi speakers and their enclosures as shallow as possible are evaluated and described in George Augspurger's article. Available commercial thin loudspeaker units are illustrated.

LOW-PASS AUDIO FILTERS FOR INCREASED "TALK-POWER"
The addition of this simple, low-cost device to the amateur phone transmitter will improve performance to a great extent. The unit is easy to build from standard, readily available electronic parts.

ELECTRONICS FIELD ENGINEERS AROUND THE WORLD
These specialists—in great demand—are trained to do the "impossible" in keeping military, government, and industrial equipment in top working condition at locations ranging from the arctic regions to dense jungle areas—wherever electronics equipment must be installed and kept in reliable operation.

TAPE-SLIDE SYNCHRONIZER
A silicon-controlled switch is the "heart" of this compact device designed for the photography fan who wants to record a commentary on his slide on tape and then synchronize the picture with his talk.

FREQUENCY MULTIPLICATION AND DIVISION
A survey of the techniques and circuits commonly found in such diverse units as frequency standards, counters, digital clocks, multiplex adapters, transmitters, and electronic organs. Practical applications are also covered.

TRANSISTORS IN HI-FI: PANACEA OR PANDEMONIUM?
Three top engineers from H. H. Scott discuss the conceptions and misconceptions prevalent in the industry regarding the role of transistors in high-fidelity audio equipment. This is the first article of a two-part series discussing this subject in depth.

All these and many more interesting and informative articles will be yours in the SEPTEMBER issue of ELECTRONICS WORLD . . . on sale Aug. 15th.

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Is It a "Coaching Service"?

The weakness of the "coaching service" or "Q & A" method employed by some schools and individuals is that it presumes the student already has a knowledge of basic electronics.

The Grantham course is presented from the viewpoint that you have no prior knowledge of the subject; nothing is taken for granted where your training is concerned. We "begin at the beginning" and progress in a logical, step-by-step manner from one point to another, with the necessary math taught as an integral part of the course. Every subject is covered simply and in detail; the emphasis is on making the subject easy to understand.

With each lesson you receive an FCC-type test so that you can discover after each lesson just which points you do not understand and clear them up as you go along. In addition to the lesson tests, ten comprehensive Review Exams are given throughout the course.

Is the School Accredited?

Grantham School of Electronics is accredited by the Accrediting Commission of the National Home Study Council.

Is It a "Memory Course"?

Grantham School has never endorsed the "memory" or "learn by rote" approach to preparing for FCC license exams. This approach may have worked in the early days of broadcasting, to the extent that a man could get his license that way; but, Heaven help the employer who expected this man to be able to demonstrate abilities implied by possession of the license!

Fortunately for all concerned, it is no longer possible for a man to pass FCC exams by spilling out memorized information which is essentially meaningless to him. Advances in the field of electronics—and the desire of the FCC to have the license really mean something — have caused upgrading of the exams to the point where only the man who is able to *understand* and *reason* electronics can acquire the 1st class FCC license.

Learn to thoroughly understand basic electronics from the school whose graduates are successfully employed by virtually every major electronics firm in the United States. Why not join them through Grantham training?

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For the record

WM. A. STOCKLIN, EDITOR

SPECIAL ISSUE

EVERY issue of ELECTRONICS WORLD, in its own way, presents interesting challenges to our staff, but since the electronics industry is so vast, it is not too difficult to find some theme that is outstanding and of special interest to most readers.

"Special Issues," however, present unusual challenges. Although we do not run too many, those we do must not only be better than any we have published previously, but they must be superior to any "Special Issue" published by others in our field.

We have seen many such issues that were simply directories or catalogues of equipment, while others have been so narrow in scope that only a limited number of professional readers would find them of value.

After months devoted to surveys and evaluation of the test-equipment industry, our present theme evolved—a "Special Test Equipment Issue" that would be broad in scope, covering every type of equipment, and written by experts employed by leading companies in a particular test-equipment field.

Many of our readers will ask, "Why such broad coverage?" Because there are many electronics technicians as well as engineers who daily use test techniques and equipment that are outdated and who have little or no desire to embrace modern practices. These individuals, unless they change, will find themselves on a road that will dead-end their careers.

Times have changed—even within the past few years. It seems like only yesterday when technicians in the consumer-product area considered a fraction of a volt, ohm, or milliampere the limit of their measurements. With the introduction of transistors and other semiconductors, they can no longer be vague. Many circuits call for a more exact evaluation of operating characteristics to insure top performance. The old philosophy "if it works the consumer will be happy" is obsolete. Today the consumer expects his radio and TV sets to perform as they were intended. Hi-fi equipment, particularly since the advent of FM multiplex, demands not only new test equipment unfamiliar to many technicians, but a degree of servicing competence far beyond that previously required. The alignment and adjustment of Citizens Band equipment is certainly critical and, again, must be done more accurately than is the case with conventional consumer products. Obviously, new equipment and new techniques are needed.

The old-time radar technician, who once measured time in microseconds, felt that it was impossible to go beyond this point. Today some of these same men are working with semiconductor computer circuits that can go through a complete cycle of operation in a few thousandths of a microsecond (a few nanoseconds).

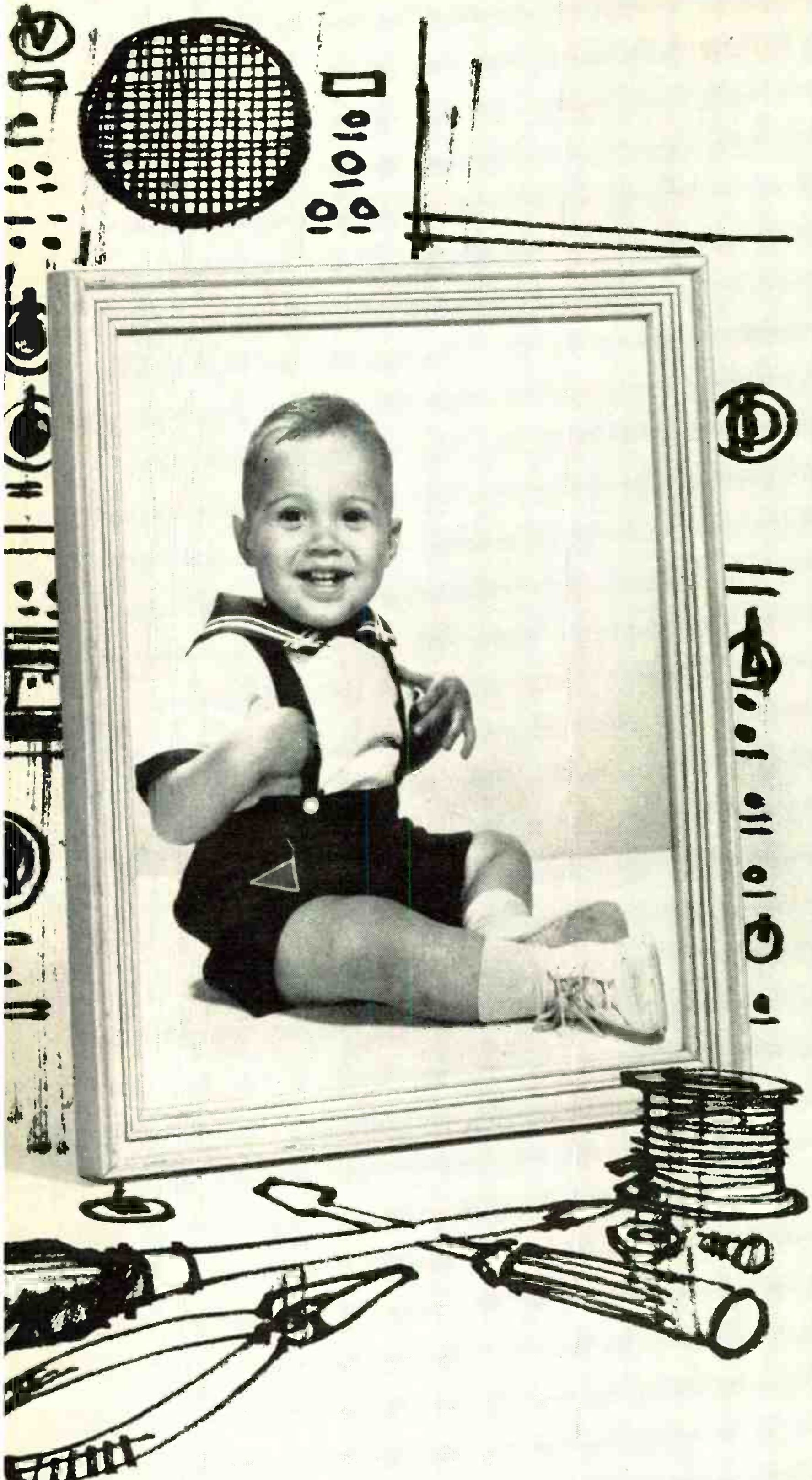
Even within the past few years, measurements have been refined and some new and strange words have been creeping into our vocabulary. For example: The old expression "micromicro" has been replaced by "pico." "Femto," "atto," "giga," and "tera" are fairly new prefixes for units of measurement, so new that not many technicians and engineers have become familiar with them. "Femto," abbreviated *f*, is 10^{-15}. For example, one femtoampere (an amount of current that is actually measurable today) would appear in decimal form as .000000000000001 amp. "Atto," abbreviated *a*, is 10^{-18}. This prefix is for a quantity that is a thousand times smaller than a "femto" unit.

As numbers keep getting larger and larger, we need new prefixes to simplify our language. For example, as we go higher and higher in frequency, the next logical step above *mega*cycle would be use of the term *kilomega*cycle. Today the unhandy prefix *kilomega* has been replaced by "giga" (10^9, abbreviated *G*).

As we go still higher up into the frequency spectrum, instead of using the term *megamega*cycle, the prefix "tera" (10^{12}, abbreviated *T*) will be used.

Language usually advances along with advances in techniques. Some of the terms mentioned above, now finding their way into current technical literature, are one indication of the sophistication of today's test equipment. There should be no doubt that electronic circuits today require highly diversified test equipment that is faster, better, and more accurate than the equipment being tested. To continue progress in the electronics industry, not only must test equipment keep pace, but the engineers who design the equipment and the technicians who use it must keep pace as well. ▲

Planning his future is one thing... providing for it is another



Can you do it without more education in electronics?

You don't want to accept second-best for yourself and those who depend on you. But you may have to unless you get more education. In electronics, you must learn more to earn more. And, because electronics keeps changing, you must keep learning. Stop—and you soon won't be worth what you're earning now.

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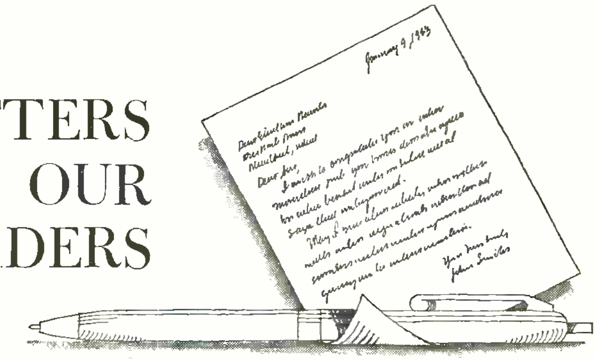
LETTERS FROM OUR READERS



TRANSISTOR IGNITION SYSTEMS

To the Editors:

Mr. Lynn's question (in the November, 1962 "Letters From Our Readers" section) concerning how the transistorized ignition system could improve overall engine performance when energy and secondary voltage considerations seem to favor the standard ignition system is well taken. Since Mr. Saatjian's reply did not do more than prove empirically the superiority of his system ("Transistorized Ignition System," August, 1962), I feel it may be of interest to Mr. Lynn and other readers to discuss why the system performs as it does.

The equation for energy storage in a coil (ignition coil, in this case), shows that as engine speed increases and point closure time decreases, the primary current and energy stored at break decrease. The larger the primary inductance, the more this current decreases with increasing engine speed. Furthermore, since the current in this relationship is a function of the second power as opposed to inductance which is a function of the first power, it is clear that it is more important to have a lower inductance and a high current at break than *vice versa*.

The foregoing being true, you may wonder why not merely increase the primary current by reducing the value of the ballast resistor in the standard ignition system? This is impractical because of the capabilities of the ignition points. For reasonable point life, the largest current that can be interrupted is about 5 or 6 amps and most modern systems push this limit closely. Currents higher than this will cause excessive arcing with resultant reduced contact life.

It may appear that simply substituting the transistor to carry the primary current with the points carrying only .6 or .7 amp would be sufficient improvement in the system. This is not true for we would still have the problem of voltage developed across the primary, which is a source of energy loss, not to mention the problem it presents to protect the transistor from destruction.

The problem of high primary induced voltage is licked by the special coil used in the transistorized system. The special coil has greater flux response and closer coupling between primary and secondary than the usual induction coil, thus allowing more energy transfer from the primary ampere turns to build flux and consequently greater voltage output. Since more energy is transferred to the secondary due to the close coupling, less energy is allowed to return to the primary by the collapsing flux, consequently the primary-induced voltage is less and the problem of protecting the transistor is reduced considerably.

Incidentally, I have built Mr. Saatjian's circuit and have found that it does everything he says it will do. My only problem is to find a place to put it in my "Corvair!"

Brian Hogan
Parts & Materials Engineering
AC Spark Plug Division
General Motors Corporation
Milwaukee, Wisconsin

° ° °

REGULATED POWER SUPPLIES

To the Editors:

We would like to applaud the excellent article "Regulated Transistorized Power Supplies" by John R. Collins in your March issue. The article is a pioneering step in acquainting your readership with a class of instruments formerly restricted to applications in the heavy military and industrial phases of electronics.

However, we would like to point out that an acknowledgment should have been made to our firm for the use of Fig. 5 on page 41.

Sidney Norinsky, Ad. Mgr.
Electronic Measurements Co., Inc.
Eatontown, New Jersey

° ° °

WRONG-WAY CHECK

To the Editors:

The use of magnetic numbers on checks may speed up banking considerably, but I am afraid that the check shown on your April cover won't get routed to the right bank.

If you look carefully, you will see that part of the bank's transit number shown in magnetic ink does not jibe with the transit number printed beside the date on the check.

Roger McElroy
Los Angeles, Calif.

Reader McElroy has sharp eyes. Our

NOW *EVERYONE* CAN QUICKLY

Set up and Service Color TV

1 PATTERN DISPLAY STANDARD
Shows correct pattern in window viewer for visual guide

2 PATTERN SELECTOR
Produces each pattern individually for quick, easy convergence

3 AUTOMATIC DECONVERGENCE
Simplifies static and dynamic convergence. No digging into set

4 COLOR SELECTOR
Produces each color one at a time for accurate color set-up

5 COLOR GUN KILLER
Automatically enables the technician to actuate any combination of the 3 guns

6 DEMODULATOR ALIGNMENT
Makes alignment extremely simple, without going into the color set

New! B&K Model 850 COLOR GENERATOR

Most Complete, Most Versatile, Portable Instrument for Use in the Home and in the Shop
Makes Color TV Set-up and Service Easier, Faster than ever!

Now every service technician can be ready to set-up and service color TV with amazing new ease and speed! New advanced design simplifies the entire operation, saves time and work in every installation. Eliminates difficult steps in digging into the color TV set. Gives you new confidence in handling color.

Produces Patterns, Burst, and Colors Individually—Provides dot pattern, crosshatch, vertical lines, horizontal lines, burst signal, and individual colors—one at a time—on the TV color set—for fastest, easiest check. Unique window-viewer on front of the instrument panel shows you each pattern and color as it should be—gives you an exclusive display standard to use as a sure guide for quick, visual comparison.

Provides Accurate, Individual Color Display—Produces Green, Cyan, Blue, B—Y, Q, Magenta, R—Y, Red, I, Yellow, and Burst—one at a time. All colors are crystal-controlled and are produced by a precision delay-line for maximum accuracy. Each color is individually switch-selected—no chance of error.

Provides Accurate NTSC-Type Signal—Color phase angles are maintained in accordance with NTSC specifications.

Makes Convergence and Linearity Adjustments Easy—Highly stable crystal-controlled system with vertical and horizontal sync pulses, assures the ultimate in line and dot stability.

Simplifies Demodulator Alignment—The type of color display produced by this instrument provides the ultimate in simplicity for precise demodulator alignment.

Provides Automatic Deconvergence—Eliminates the necessity for continual static convergence adjustments. The instrument automatically deconverges a white into a color dot trio without digging into the color set to misadjust the convergence magnets. It also deconverges a white horizontal or vertical line into red, green and blue parallel lines. This greatly simplifies dynamic convergence adjustments.

Provides Exclusive Color Gun Killer—Front-panel switch control makes it easy to disable any combination of the three color guns. Eliminates continuous adjustment of the background or screen controls, or connection of a shorting clip inside the receiver. The switch also selects the individual grids of the color tube and connects to a front-panel jack to simplify demodulator alignment.

Provides Switch-Selected R.F. Signals—Factory-tuned, for channels 3, 4, and 5—for open channel use in your area.

Model 850 also includes other features that make it invaluable for home and shop use. Net, **$199.95**

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artist used a blank check from one source and put his own number in magnetic ink at the bottom of the illustration. The first group of numbers in magnetic ink should actually have been: 0210-0012.—Editors.

° ° °

HIGH-PERFORMANCE IGNITION

To the Editors:

In my "High-Performance Transistor Ignition System" described in your June issue, I have made one minor change to compensate for a possible difference in the amplification of transistors *Q1* and *Q2*. If such a difference exists, I would suggest that a 5-ohm, 25-watt resistor be shunted across the present *R7*. Also, *RL2* is *P&B* type KA5DY.

M. R. MAYFIELD
Lancaster, Calif.

° ° °

MUSIC-SPEECH DISCRIMINATOR

To the Editors:

Some confusion has arisen regarding the relay used on my music-speech discriminator (April issue).

The relay is actually marked: *Allied Control Co., Inc.*, T-154-CC-CC, 1250 ohms, contacts 1 amp. 28 volts d.c. The coil is marked CL686-1250. This relay is definitely a 1250-ohm one, and I assume that it was designed for 24 volts d.c., but I do not know this for certain.

I was also under the impression that the relay was a low-cost stock item, but conceivably it was a special unit. The relay may be purchased from *Femco, Inc.*, Irwin, Pennsylvania, under the stock number RL2594.

The relay is used as the collector load of the Schmitt trigger. Any change of this value will shift the operating point of the circuit. Any reasonable 24-volt d.c. relay may be used, but the values of *R25*, *R26*, *R27*, and *R28* will have to be changed somewhat.

FRANK D. GROSS
Phoenix, Arizona

Also, in answer to many queries, the discriminator is not available in kit form nor is the author's unit available for sale or loan.—Editors.

° ° °

MICROPHONE VOLUME CONTROL

To the Editors:

We read with great interest your article in the April issue of ELECTRONICS WORLD entitled "Microphone Volume Control" by Art Trauffer. One reason for our interest is that Mr. Trauffer's mike volume control is very useful and can be used in many instances. A second reason is that *Switchcraft* has been manufacturing a similar volume control for many years, Part No. 329. However, since many of your readers might want to assemble such a control themselves, we would like to make a few suggestions.

One, for best results, use this type of volume control in a high-impedance circuit only; two, the female mike connector should be located off-center to facilitate mounting on microphones used with stands.

C. J. SCHULTZ
Switchcraft, Inc.
Chicago, Ill.

° ° °

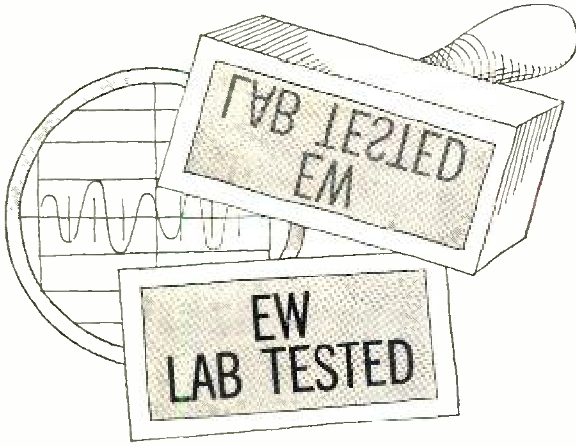
TECHNICAL WRITERS

To the Editors:

There was a typographical error in my article "Are You a Potential Electronics Technical Writer?" (May, 1963). The salary range given for trainees and junior writers on page 59 should have been from $65 to approximately $100 per week.

CYRUS GLICKSTEIN
Flushing, N. Y.

The article gives exactly the same salary range for trainees and junior writers as for intermediate writers. This, of course, is not correct.—Editors. ▲



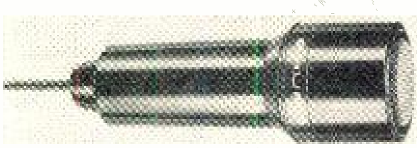
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Shure Model 560 Lavalier Microphone
Scott 350-B Stereo Tuner

Shure Model 560 Lavalier Microphone

For copy of manufacturer's brochure, circle No. 56 on coupon (page 19).

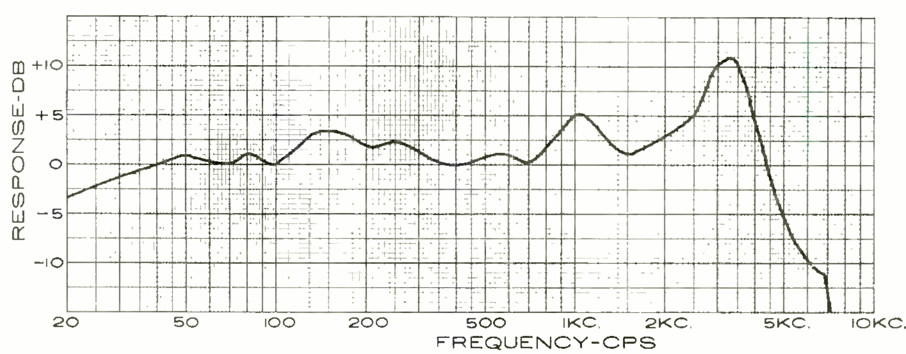


THE *Shure* Model 560 lavalier microphone is a dual-impedance dynamic unit designed for applications requiring a wearable microphone. Typical usage includes teaching, lecturing, or other activities where the speaker wishes to leave his hands free. The 560 is a compact, cylindrical microphone, finished in flat black and measuring less than 4" long and 1⅜" diameter. Weighing only 5 ounces, it comes with a lavalier cord and clip so the unit can be worn around the neck. It may also be hand-held or mounted on a stand with an accessory swivel adapter.

The microphone, as shipped, is connected for high-impedance operation. The load impedance should be at least 100,000 ohms. By changing its internal connections, it may be converted into a low-impedance microphone operating into a 150- to 250-ohm load. The unit is supplied with an integral 18-foot, two-conductor shielded cable.

The manufacturer's specifications rate the Model 560 as having a smooth, uniform response from 40 to 10,000 cps, with rising characteristics to 4500 cps. It is omnidirectional and has a rated voltage sensitivity of −57 db referred to 1 volt per microbar at 1000 cps, with a ±3 db tolerance. We measured its response by comparison with our calibrated laboratory microphone and found it to be in general agreement with the response curve in the microphone instruction sheet. At the lower frequencies, the measured response was better than the manufacturer's curve, while above 4500 cps it was lower. The response was ± 4 db from 20 to 2500 cps, rising to about +10 db at 3500 cps and falling to −10 db at about 6000 cps. The voltage sensitivity was −55 db referred to 1 volt per microbar at middle frequencies.

We used the microphone in a public-address application, and it performed very well. The sound quality was crisp, clean, and highly intelligible. Feedback problems which had existed with some other microphones were greatly reduced or eliminated with this unit. The Model 560 lavalier microphone is priced at $25.00. ▲



Scott 350-B Stereo Tuner

For copy of manufacturer's brochure, circle No. 57 on coupon (page 19).

THE *Scott* 350-B FM stereo tuner is similar to the FM portions of the Model 333 FM-AM tuner and Model 340 tuner-amplifier, which were described in previous EW Lab Tested Reports. For those who already have good stereo amplifiers, or do not need an AM tuner, the Model 350-B offers the same high quality FM performance as the other units.

The silver-plated, shielded front end uses a low-noise cascode r.f. amplifier and a triode-pentode oscillator/mixer. The wide-band ratio detector is preceded by two i.f. amplifiers and a limiter stage. The multiplex demodulator uses the switching-type circuits found in other *Scott* tuners and receivers. Noisy reception of stereo broadcasts can be improved, at the expense of separation, by the switchable sub-channel filter. Another filter circuit rolls off high-frequency response without affecting channel separation. The "Sonic Monitor" circuit provides a positive indication of a stereo broadcast. When a switch is moved from "Listen" to "Monitor," the

(*Continued on page 73*)

“Well worthy of the Fisher name, both in performance and in ease of construction...Beautifully packaged and ‘instructed’...Excellent specifications, and the performance equals or exceeds the specs.”

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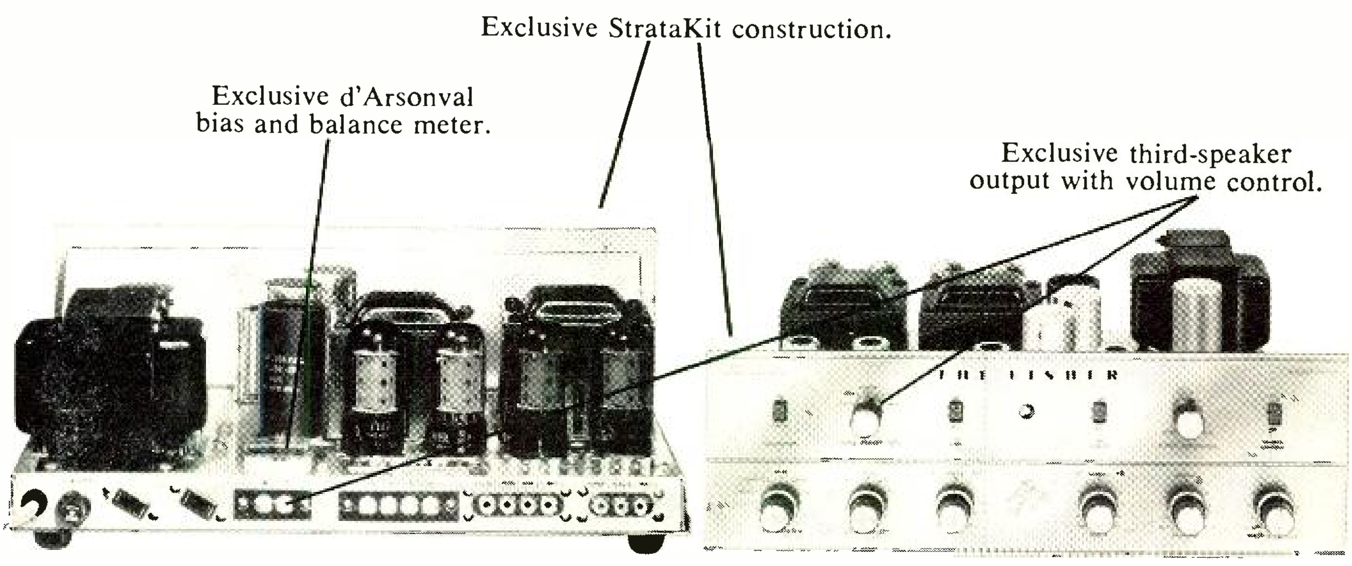

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Check these plus Sencore features: New, stick-proof D'Arsonval Meter will not burn out even with a shorted tube • Meter glows in dark for easy reading behind TV set. • New large Speedy Set-Up Tube Chart in cover, cuts set-up time • Rugged, all-steel carrying case and easy grip handle • Smallest complete tester made, less than one foot square. • The Mighty Mite will test every standard radio and TV tube that you encounter, nearly 2000 in all, including foreign, five star, auto radio tubes (without damage) plus the new GE Compactrons, RCA Nuvistors and Novars and Sylvania 10 pin tubes.

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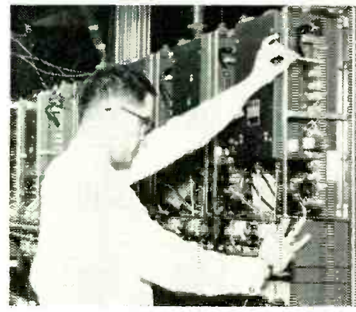

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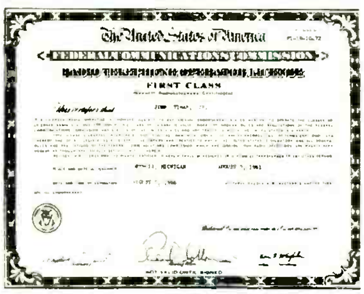

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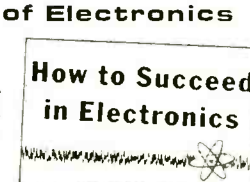

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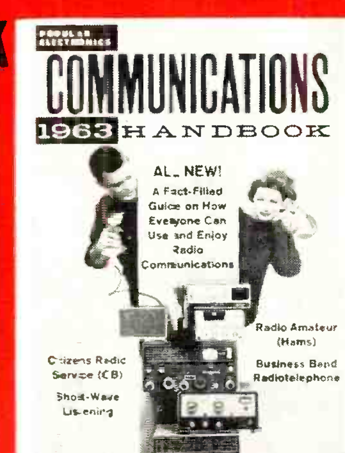

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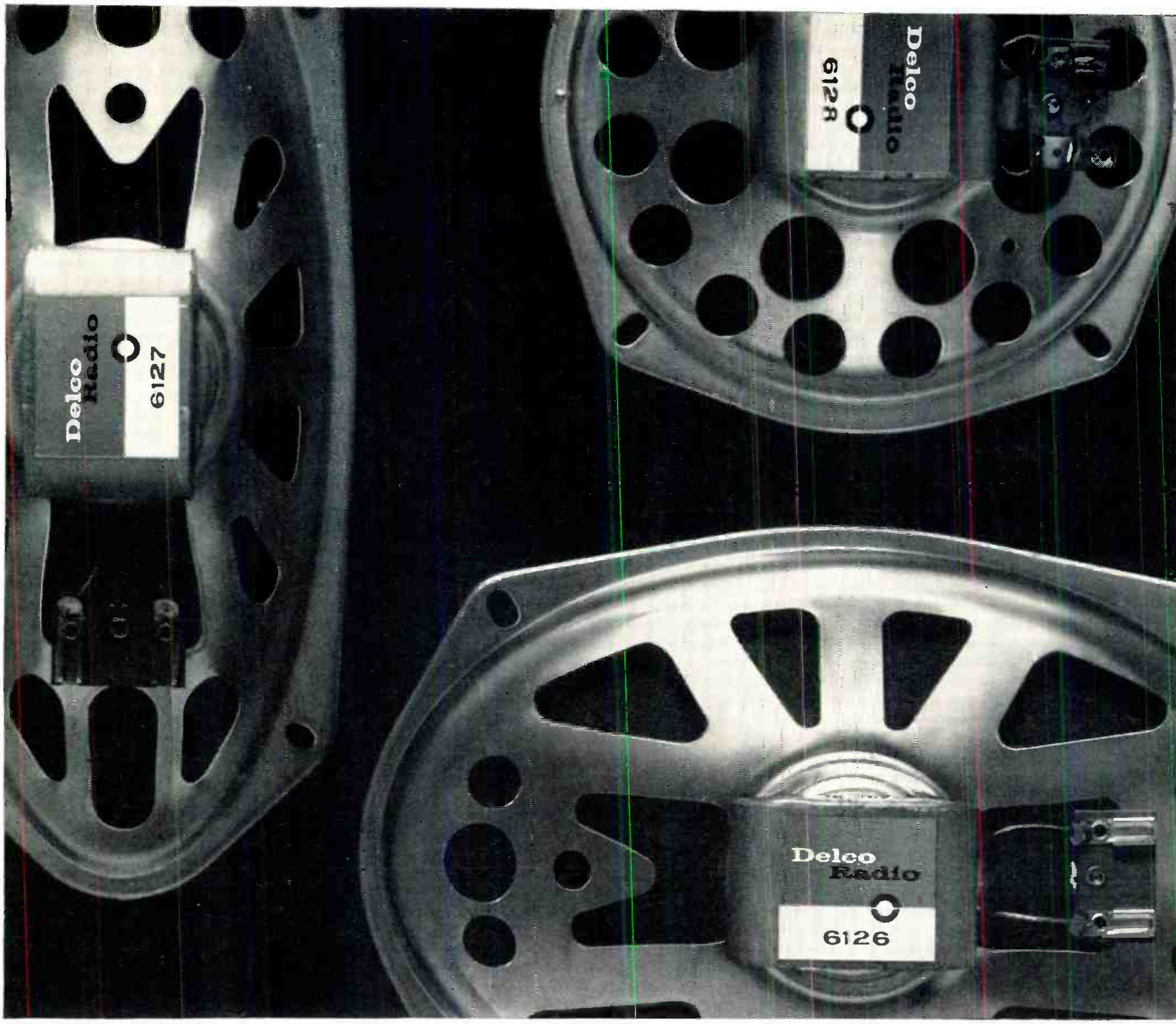

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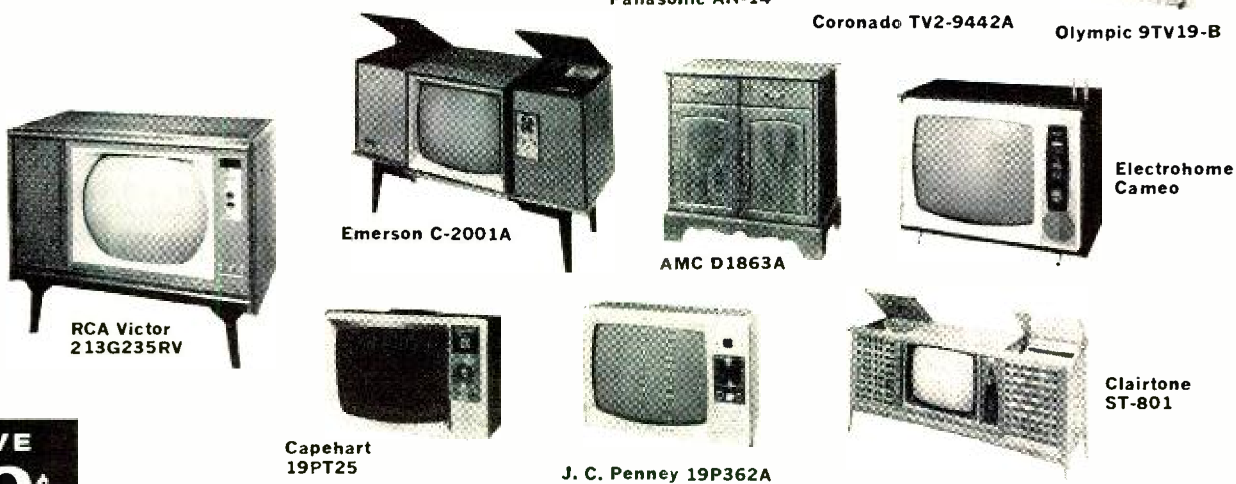

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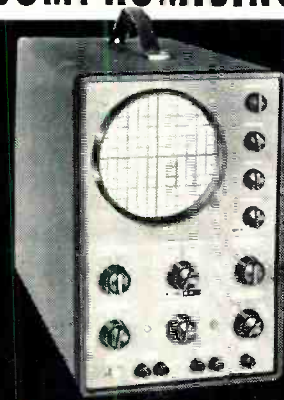

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*Formerly designated as #260.

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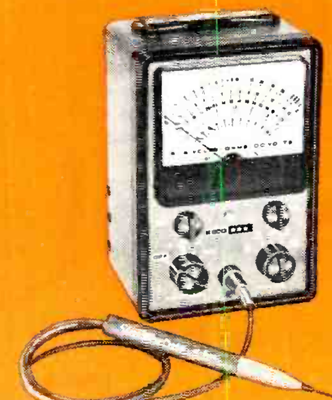

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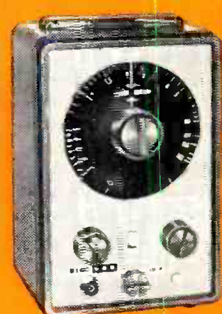

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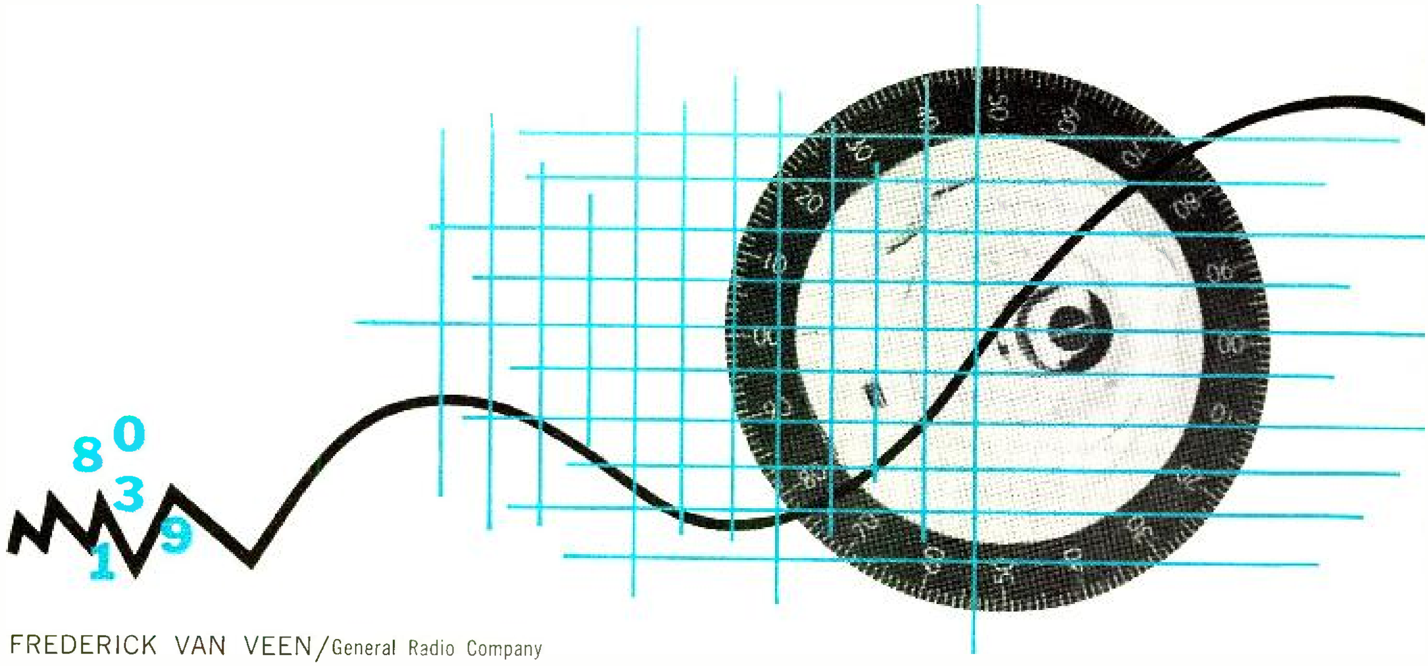
DIRECT-READING INSTRUMENTS



By FREDERICK VAN VEEN/General Radio Company

Significant developments in the past ten years, especially those that have advanced the art of measuring. New types of test instruments that measure frequency by counting, record quantities graphically, measure L, C, R, Z, voltage, and special microwave measuring devices.

[illegible] Lord Kelvin

THERE has been, over the past decade, a tremendous improvement in electronic measuring instruments. The rapid advances in precision, accuracy, and convenience of measurement have played a vital part in the electronics "boom" that has meant a 600% rise in sales dollars. Everything, in a sense, begins with measurements, and the limits of measurement are the limits of science.

The boom in electronic measuring instruments is a mixed blessing to the average technician. Ten years ago it was pretty easy to select a bridge or voltmeter for a specific job. Shopping was a matter of looking at a few catalogues and intercomparing some specifications. Then the measurement industry really expanded, manufacturers outdid one another in offering varieties of multipurpose instruments, and the catalogues bulged. The 1953 *IRE Directory* listed 69 manufacturers of bridges; the 1963 edition lists 140. Under "Graphic Recorders" the 1953 directory lists 47 companies, the current volume, 145. The 1963 edition lists no fewer than 224 companies making digital counters, a category not even included in the directory of a decade ago!

The hundreds of different instruments manufactured to measure frequency, impedance, resistance, inductance, capacitance, voltage, and current represent a wide choice of accuracies, features, and price. There is also, of course, the duplication inherent in our competitive system. No one article or series of articles can do justice to the overwhelming number of direct-reading instruments available today. The emphasis here will be on the more significant developments of the past ten years, and especially those that have advanced the state of the measurement art.

Mechanical and Convenience Improvements

The measuring instruments of 20 or 30 years ago were typically big, black, square, and heavy. This was simply the way people thought instruments *should* look; indestructible, reliable, conservative. But styles change and most of the black, square instruments went the way of black, square automobiles. Today's instruments enjoy the benefits of new materials, miniaturization, and much of what is sometimes called "human engineering" but which has always been a part of just good mechanical design.

Instrument cabinets now try to be all things to all people; some can be quickly adapted to relay-rack, bench, or portable use. Then there is the tiltable cabinet, with a captive cover that serves as an easel-type stand when the instrument is in use. Extensible front legs on many cabinets let the user look

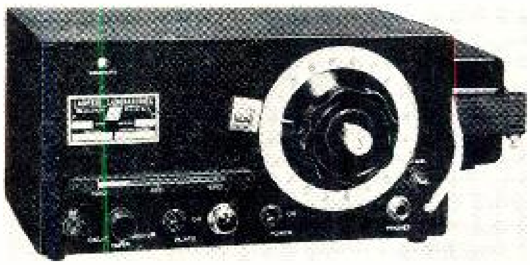
Probably the most important new type of instrument of the past decade is the frequency meter using digital counting techniques. This example, the General Radio 1151-A, is a general-purpose counter for laboratory or production-line use that can measure frequency accurately from a fraction of a cps up to 300 kc. The unit also measures the period of a cycle and frequency ratios. Price: $1195.

A

B

(A) Many direct-reading instruments are highly versatile since they may combine several functions within a single unit. Our example is in the audio field. The device shown, the Eico 902, combines an a.c. v.t.v.m. for accurate audio measurements, and generators and filter circuits for making both harmonic-distortion and intermodulation-distortion tests. Such measurements are read directly on the meter face. Distortion figures are within 5% of full scale and the voltage figures are ±4% of the full-scale reading. The price is $250, factory-wired.

(B) With the increasing use of semiconductor diodes in equipment have come specialized testers for checking these components. Many of these testers have been designed for practical laboratory use as well as for incoming diode stock inspection. One typical unit, the Seco 210, includes tests for zener diodes, silicon and germanium power and signal diodes, as well as selenium rectifiers. Various variable sources of power are incorporated in the circuit. Results are displayed on two meters. Price of unit: $154.95.



C

(C) Not all frequency meters are digital devices. Typical of the more common and, incidentally, less expensive type is the Lampkin 105-B shown. This instrument is a heterodyne-type frequency meter with a built-in crystal calibrator. It is used to measure transmitter frequencies anywhere in the range of 100 kc. to 175 mc. In addition, it will function as an accurate weak-signal generator for receiver alignment. Instrument meets FCC requirements for a frequency monitor in the mobile-radio service below 50 mc. With some additional equipment, the meter will also meet the FCC accuracy requirements for the newer split-channel frequencies. The price is $260.

at the front panel head-on whether he is sitting or standing at the bench. And cabinets of the larger manufacturers come in standard sizes, so that they can be stacked into a neat arrangement.

Readouts have improved tremendously. The meters are larger with scales designed for easy reading. And, too, there are now digits—neon digits, incandescent digits, projected digits, digits in windows, and more digits on printed tape.

Instruments are lower—the form factor apparently follows that of automobiles. The day of the three-inch-high instrument has arrived, apparently to save relay-rack space. Instruments used in the field have become more portable than ever, as they are transistorized. Also, some instruments with heavy power demands are starting to "go portable," thanks to the rechargeable nickel-cadmium battery.

There are so many convenience improvements in instruments that it is difficult to list them all. But one that deserves special note is the quality of instruction manuals. Another is the greater availability of manufacturers' sales and service engineers. Manuals and consulting services can be just as important as some of the instrument's technical specs.

Instrument Specifications

The buyer of an electronic instrument must be guided by the specifications published by the manufacturer, but the catalogue shopper who tries to select an instrument purely by published data had better be on his toes.

Not that the manufacturers aren't truthful. Dishonest specifications are fortunately a rarity in this business, because they punish their perpetrators too quickly. But every manufacturer wants to put his best foot forward and stress the specifications where he is strongest. Also, there are many honest differences of opinion among manufacturers on just how best to state something. Take, for instance, the problem of specifying the low limit of measurement on a v.t.v.m. Suppose the voltmeter has a low range with a full scale of 10 microvolts, and an accuracy of ± 10% of full scale. The voltmeter will certainly measure voltages below 10 microvolts, but a 1-microvolt reading might be wrong by 100%, and most people would not consider that a measurement. Another aspect of the same problem: a 3% voltmeter is generally more accurate than a 2% voltmeter if the 3% is 3% of indicated value and the 2% is 2% of full scale. The moral of all this is that you should not play the numbers game with instrument specifications, but should read words as well.

One of the best ways to approach laboratory instrument selection is to consult the manufacturer. Sales engineers who sell such electronic instruments are, by and large, extremely competent, helpful, and low-pressure. They will try to steer you to the right choice of instrument, even if it means steering you to another company. They offer a valuable consulting service for anyone with a measurement problem, and the wise shopper takes advantage of it.

But even knowing where to start is a problem. There is a bewilderingly large number of electronic measuring instruments made by several hundred different manufacturers to measure more than 200 different electrical and electronic parameters, separately and in combination, in many different frequency ranges, and to varying degrees of accuracy and precision. You may know exactly what you want to measure and the conditions of measurement, yet there is no quick way to narrow your selection to those instruments that qualify. Certain so-called "buyers' guides" try to classify instruments, but the task is too much for them. Several manufacturers publish excellent catalogues that bring order to their own houses. But the job of classifying all instruments in terms of well-defined standards remains.

A hopeful beginning is the recently published[1] program of IEEE Subcommittee 25.1 on Basic Standards and Calibration Methods. As a first step, this committee has designated three echelons of accuracy level. Echelon I is the highest calibration accuracy available within a country, Echelon II an intermediate level, typically that of the calibration laboratory of an instrument manufacturer, and Echelon III a level at which measuring instruments are calibrated before use by the ultimate consumer. For each echelon, various IEEE Technical Committees will report on the measurement accuracies available and needed. In its statement of objectives, the IEEE Committee says, "An appraisal of the present status of electrical measurements points up mainly the limited availability of complete, reliable technical information." All who make, buy, or use electronic instruments will wish this particular committee Godspeed in its work.

Measurement of Frequency

Today's most popular frequency-measuring instrument—the counter—scarcely existed ten years ago. Now that digital counting techniques are being widely applied to so many measurements, the frequency counter must be considered the most important new instrument of the past decade. The modern frequency counter represents a unique melding of borrowed technologies: the flip-flop circuit from atomic research, pulse techniques from radar, binary switching logic from computers. The counter became a practical instrument with the development of a method of converting binary information to decimal, new digital indicators, and improved switching devices.

The principles of counters are well known, and are here worth only passing mention: Successive cycles of the frequency to be measured are passed through a "gate" and counted, the total being indicated by a digital display. The counting time, or the time that the gate is open, is determined by a reference crystal oscillator, usually built into the counter. If the gate is set to remain open for one second, the digit display is direct-reading in cycles per second. The unit of time is established by a crystal oscillator—usually called the "time base"—and the accuracy of this time base determines, more than any other single factor, the accuracy of frequency measurement.

If one is interested chiefly in accuracy, then the significant specification is the accuracy and stability of the time-base oscillator. The possible error corresponding to time-base inaccuracy must be added to the plus-or-minus one-count error inherent in all counters. Other errors can be caused by noise[2], but these are harder to evaluate.

Frequency ranges of counters vary widely, but the upper limit for direct-reading counters is presently about 50 mc. Heterodyne converters extend this range up to 1000 mc. with no sacrifice in accuracy, and transfer techniques are used from 1000 mc. to above 10,000 mc.

One of the most valuable features a counter can offer is versatility—the ability to rearrange its components for different types of measurements. Thus many firms advertise "universal" counters. This usually means that the instrument can measure not only frequency, but also period, time interval, and frequency ratio as well.

To measure period, the functions of the "unknown" and time-base signals are interchanged, so that successive cycles of the unknown frequency open and close the gate, while "clock" pulses from the time base are counted. As a result, the digits displayed indicate the number of time units (*e.g.*, 10-μsec. units if the time base is a 100-kc. oscillator) passed during one cycle of the unknown frequency. At frequencies much lower than that of the time base, a period measurement will yield greater precision, due to the higher count used.

A time-interval measurement also counts "clock" pulses from the time base, but here the gate is opened by one signal and closed by another. In frequency-ratio measurement, one signal is used to open and close the gate, while the other is counted.

A consideration of increasing importance is the adaptability of the counter to accessory instruments. If you require permanent records of measurements, you will need either a data printer or the combination of digital-to-analog converter and analog recorder. Whether a particular counter will operate with a certain printer or D/A converter depends on the type of coding used, input and output voltage levels, and other considerations. Failure to check these in advance can easily lead to a pair of incompatible instruments.

Digital counters are by no means the only way to measure frequency, and it is unlikely that they will ever take over completely. For some applications, in fact, digits are a real nuisance. Suppose, for example, that you are trying to adjust a variable-frequency oscillator to exactly 12,230 kc., while monitoring the output frequency on a counter. You trim one way and then the other, as the digits dance tantalizingly around (but not on) the desired frequency. How you would long, at this point, for a heterodyne instrument with which your ears could guide you quickly to zero beat! It is a good idea to remember that any good variable-frequency reference, such as a signal generator, can be used with mixer and detector to measure frequency.

At frequencies up to about 1.5 mc., there are lab analog instruments available. One, using an interpolation technique with most of the frequency suppressed onto a switch setting, offers an over-all accuracy of ± 0.2% from 3 cps to 1.5 mc. And instruments for coarse frequency measurements—wavemeters and grid-dip meters—still enjoy a brisk market.

There is every reason to expect further substantial improvements in frequency measurements. Accuracy is, as mentioned, largely a function of the accuracy or stability of the frequency reference. Thus, it is possible to increase the accuracy of any counter by the use of a highly accurate frequency standard as the time base.

Measurement of Capacitance & Inductance

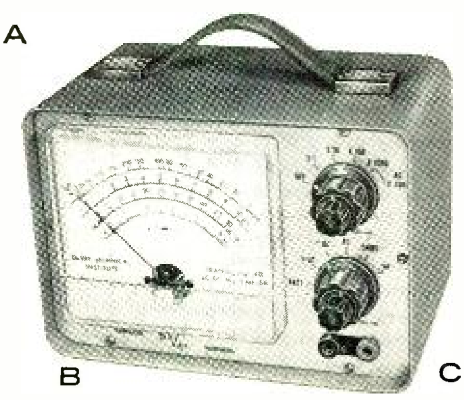
Capacitance and inductance measurements involve similar techniques and limitations. The basic instrument for precision

(A) Graphic recorders are widely used in industry where a written chart showing one or more variable functions is required. The recorder shown, a Moseley 2D-4, draws rectangular coordinate curves from two related sources of d.c. electrical information on standard graph paper. Writing area is 10 x 15 inches. High-gain solid-state servo amplifiers drive the two motors that are coupled to balance pots and recording pen. Ten calibrated input ranges from 0.5 mv./div. to 10 v./div. may be selected from the front panel of the recorder. The liquid-ink pen has a maximum writing speed of 15 inches per second. Price is $1490.

(B) Even vacuum-tube voltmeters have become transistorized. DeVry transistorized meter combines advantages of a v.t.v.m. with those of a sensitive microammeter for service-bench use. Instrument is completely portable, operating on four flashlight batteries. It has usual a.c., d.c., and resistance ranges, along with four d.c. current ranges from 50 μa. to 50 ma. full-scale. D.c. input impedance is 10 meg on most ranges. The price of the voltmeter is $89.50 ready-wired or $64.50 in kit form.

(C) Graphic recorders need not be large and bulky as shown by the Amprobe ATM-2. This is actually two most-frequently used recorders in a single compact carrying case. One of the units is an expanded-range a.c. voltmeter and the other is a high-current a.c. ammeter. Roll of 2½" wide pressure-sensitive paper, traveling at 12" per hour carries the record of voltage and current. With the paper removed, pointer position is visible on a calibrated scale so that unit can be used as an indicating meter. Price of the 2-recorder unit and case is $181.20.

A



B

C

measurements is the *bridge*—an instrument that permits the adjustment of a calibrated known until a state of electrical balance exists between it and the unknown. Here, as in frequency measurements, the major burden is on the accuracy of the "calibrated known," or standard. But even the best standard is of little practical use in measurements unless its accuracy can be somehow extended over a wide range of values. One significant advance in bridges over the past few years is the transformer ratio-arm bridge, a device for extending the usefulness of a single standard over a range from 1/1000 to 1000 times its value or better, with no sacrifice in accuracy. Although the transformer bridge was originally conceived over 30 years ago, its principles have only recently been exploited in commercial instruments. The most accurate capacitance bridges available use ratio arms to achieve direct-reading accuracy of 0.01% over a wide range of capacitance.

Capacitance standards can be made more accurate than inductance standards. The capacitance bridges just mentioned use ± 0.005% standard capacitors, for example, whereas the best standard inductors are ± 0.1% units. Inductance bridges therefore use capacitors, rather than inductors, as standard reactances. The most accurate inductance bridges available offer ± 0.1% direct-reading accuracy.

The ultimate accuracy of most precision bridges is, incidentally, well beyond the direct-reading accuracy. A high degree of resolution, that is, a readout of five, six, or more significant figures, can be used for ultraprecise intercomparisons. One of the 0.1% capacitance bridges, for example, permits intercomparison of capacitors to within one part per million.

Capacitors and inductors can be measured in terms of either series or parallel equivalent circuits, and many bridges therefore offer switch selection of C_s, C_p, L_s, and L_p. The difference between L_s and L_p and between C_s and C_p is less than 1% for inductors with "Q's" over 10 and for capacitors whose dissipation factor is less than 0.1.

Resistance Measurements

The instruments most often used to measure resistance are the ohmmeters included with many voltmeters. The accuracy of such an ohmmeter is limited to 5 or 10%, partly because of trying to squeeze an infinite range into a finite scale.

The resistance bridge is easily able to achieve 0.1% accuracy up to 10 megohms or so. Measurements of very high resistance are made by megohm bridges, which supply the required high voltages. One megohm bridge will measure resistances up to 10^{15} ohms, with 1% accuracy up to 10^{13}.

Resistance limit bridges are direct-reading in percent deviation rather than in ohms. Such bridges are used by production-line personnel to determine quickly whether a component is within specified tolerance.

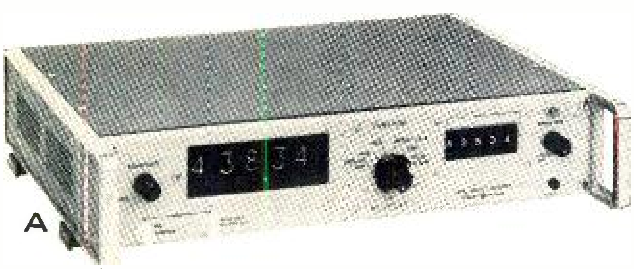
The exceptional accuracy of frequency standards has been applied to the measurement and standardization of other quantities. The ohm has thus been defined in terms of frequency and length, and standard resistors can now be specified in terms of a few parts per million. Standard resistors are used in series and parallel combinations, linear voltage dividers, and conventional bridges to extend their usefulness over a wide-range of measurement. Present state-of-the-art for general-purpose, wide-range resistance bridges seems to be the same as for capacitance: ±0.01%.

The most popular bridges are those that measure resistance, capacitance, and inductance—the so-called "universal" bridges. This popularity is easy to understand when, in this day of four- and five-figure prices, less than $500 can buy a self-contained, battery-operated, portable, five-bridges-in-one instrument that measures *C*, *R*, and *L* to ±1%, and also measures dissipation factor and "*Q*."

Voltage Measurement

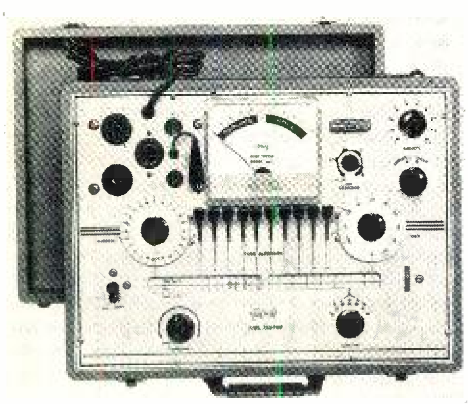
The digital revolution came to voltmeters less than ten years ago, and digital voltmeters are now produced by many manufacturers. The extra precision afforded by digital readout is of especial advantage in d.c. measurements, where the attainable accuracy warrants such fine resolution. Digital voltmeters are considerably more expensive than the usual analog meters of comparable ranges and quality, and this relation is likely to continue. Another relation that seems basic is that between the accuracies attainable in a.c. and d.c. measurements. While d.c. voltage can be measured to about ±0.002%, the best a.c. measurements are at least an order of magnitude less accurate. The a.c. voltage is usually measured in terms of a d.c. equivalent, and the translation from one to the other has to cost accuracy.

The scales on almost all a.c. voltmeters are calibrated in terms of r.m.s. voltage. However, until a year or two ago,



A

(A) Another example of an electronic counter is the Hewlett-Packard 5214L. This instrument totalizes and measures frequency and period. In addition, it can directly display readings in practical units, such as gallons/sec. or ft./min. from appropriate transducers. Two sets of decades are used: one to register the signal being counted; the other may be preset to any number from 1 to 100,000 to control a gate circuit that may be used to operate other equipment. Unit can be used to monitor automated processes, and for production testing and for laboratory applications. The price of the electronic counter is $1475.



B

(B) There is still much equipment in use that employs vacuum tubes. To check the performance of these tubes on the service bench requires an easy-to-use, flexible tube tester, such as the Triplett 3414 shown. This unit checks for shorts, leakage, and plate conductance. A self-contained roll chart supplies test setup data. Sockets are provided for octal, loctal, and miniature tube types. The price of the tester is $109.50.

C

(C) An example of direct-reading, accurate capacitance bridge that can measure very small capacitance values is the Boonton Electronics 75B shown. The instrument was originally designed for use in measuring the temperature coefficient of small "zero temperature coefficient" ceramic capacitors. It is also used for capacitance measurements of semiconductors at millivolt levels. Lowest range of the bridge is the extremely small value of only 0.1 pf. full-scale. Values as high as 1000 pf. can be measured with this particular capacitance bridge. Price: $1375.

most voltmeters actually responded to either peak or average value, with the scale conversion in terms of r.m.s. voltage assuming sine-wave input. Now "true-r.m.s." voltmeters have begun to appear in quantity. The most common type of true-r.m.s. voltmeter measures a.c. voltage in terms of its heating effect on a thermocouple. This effect is compared with the heating effect produced by a reference voltage. Other true-r.m.s. meters use dynamometers and rectifiers whose non-linearities synthesize r.m.s. response. True-r.m.s. response cannot be maintained by these means for all input waveforms, and the specification "maximum crest factor," that is, the maximum ratio of peak to r.m.s. voltage for which the voltmeter is reliable, is especially significant in pulse work.

The peak- and average-responding voltmeters are highly refined from years of development, and will probably continue to enjoy considerable popularity based on their price advantage.

Most peak instruments rectify the input voltage and then amplify the d.c. Their chief advantage is good high-frequency response. Also, since they include a d.c. amplifier, they can be made to measure both a.c. and d.c. voltage quite easily. A disadvantage at low voltages is that the a.c. output no longer bears a linear relation to the a.c. input.

The typical average-responding voltmeter first amplifies the input signal, then rectifies it. A wide-band amplifier, stabilized by negative feedback, is generally used. Although its high-frequency limit is well below that of the peak-responding voltmeter, it can measure much smaller voltages.

At very high frequencies, broadband amplifiers are difficult to design. At low voltage levels, rectifiers assume complicated characteristics. Therefore, the measurement of high-frequency, low-level voltages poses a special problem. One method of solving it is to accept the complex rectifier behavior and compensate for it on the meter scale. Another is to use a matched pair of semiconductor rectifiers, one to rectify the input voltage, the other to rectify a low-frequency reference voltage, and to compare the d.c. outputs. Commercial instruments of both types are available.

The measurement of very small d.c. voltages is best accomplished by an electrometer. Some electrometers convert the small d.c. voltage to an a.c. voltage that is amplified and metered, while others use direct-coupled amplifiers. A good electrometer can measure d.c. voltages down to a few microvolts or less and currents to below 100 femtoamperes (a femtoampere is equivalent to 10^{-15} ampere).

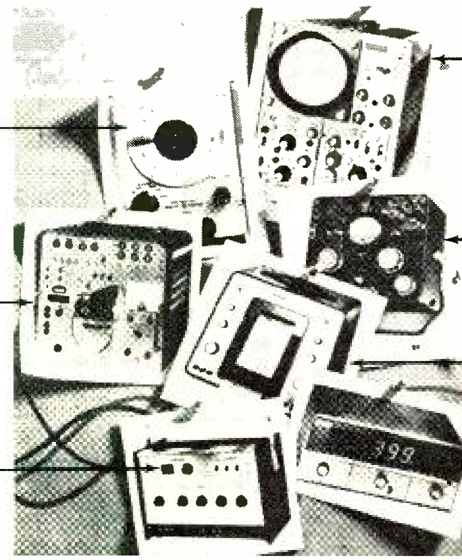
Wave Analyzers & Graphic Recorders

Many voltmeters travel under other names, because they are only indirectly concerned with mere measurement of voltage. An example is the frequency-selective voltmeter known as a wave analyzer. Operating ahead of the voltmeter in a wave analyzer is a filter that passes only a certain frequency band. The bandwidth is a constant number of cycles in some analyzers, a constant percentage of center frequency in others. The constant-cps bandwidth is generally more useful except at very low frequencies or where a logarithmic plot is required. Optimum bandwidth depends on how much detail you need. Very narrow bandwidths give more data but require more time for analysis. Wider bandwidths offer greater convenience at the cost of some detail. A wave analyzer with switch selection of two or three bandwidths lets you have your cake and eat it, too.

Of course, the chief application for wave analyzers is waveform measurement, and thus the oscilloscope and graphic recorder are important accessories.

The combination of a wave analyzer and an oscilloscope or recorder is known as a spectrum analyzer. Spectrum analyzers are available from very low frequencies to at least 100,000 mc. Most use automatic frequency sweeping to give continuous oscilloscope display. The modern spectrum analyzer combines the features (*Continued on page 72*)

ON OUR COVER



THE group of electronic test instruments on our cover this month indicates, in a small way, the tremendous variety of equipment being used in laboratories and on service benches.

For example, the portable audio oscillator at **(A)**, the **Hewlett-Packard 204B**, is designed for reliable audio work in the laboratory or field. It is fully transistorized and battery-operated with a balanced, isolated 600-ohm output. The frequency range of 5 cps to 560 kc. means that the oscillator can be used for generating signals outside of the audio range as well. Price: $315.

The field of automatic testing is represented by the **Lavoie "Robotester" LA-303**, shown at **(B)**. This is an automatic, tape-programmed measuring instrument that can select any 2 of 250 circuit points and then automatically measure resistance, d.c. or a.c. voltage, insulation resistance, and impedance. Between 60 and 100 tests per minute indicate wiring or assembly failures by flashing-light indicators. Price of the basic unit is $5600.

Representing the TV-servicing field is the **Sencore CA122** color-circuit analyzer **(C)**. This instrument generates all the test patterns (color bars, dots, cross-hatch) and signals for checking and adjusting the circuits in a color-TV receiver from antenna to tri-color picture tube. There are 10 crystal-controlled gated color bars of the RCA type. Signals are available in both r.f. and i.f. ranges; there are also video, sync, and audio signals for checking these portions of the TV set. Price: $187.50.

One of the most useful and versatile pieces of test equipment is the cathode-ray oscilloscope, represented on our cover by the **Fairchild-DuMont 766H (D)**. This is a bench and portable lab scope with a bandwidth from d.c. to 25 mc. The unit uses silicon transistors and features a new high-brightness CRT. The high sensitivity of 5 mv./cm. is provided with a rise time of 15 nsec. Price is $545 without the plug-in preamps and time-base generator.

A universal, general-purpose impedance bridge, the **General Radio 1650-A**, is shown at **(E)**. This is a self-contained, battery-operated, portable instrument for the measurement of: inductance and "Q" of inductors; capacitance and dissipation factor of capacitors; and a.c. and d.c. resistance of resistors. The unit is actually five bridges in one, together with a transistorized 1-kc. oscillator and sensitive detector. This bridge has an accuracy of ±1% and is priced at $475.

Graphic recorders are widely used in industry when a written record is required of one or more variables. The instrument **(F)** is the **Brush Mark II** recorder. Two channels of analog plus two of coded event or time data may be directly written on the moving roll of chart paper. Four chart speeds are available and, at the slowest speed, over 25 hours of data can be recorded on a 300-foot chart roll. Available for either ink or electric writing, the recorder is priced at $1495.

Where high-speed, accurate voltage measurements are required, especially by non-skilled personnel, and where this measurement is to be available in digital form, the digital voltmeter is used. The **Dynascan 111** shown at **(G)** is an example of a simple, fairly inexpensive instrument of this type. This unit uses all solid-state circuitry except for a single nuvistor. There are four ranges: 1, 10, 100, and 1000 volts d.c. with either polarity at an input impedance of 11 meg on all ranges except for 1 meg on the lowest range. Accuracy is ±0.1%. Price: $399.50. ▲

the INSTRUMENT CALIBRATION and REPAIR

(Left) Teletypewriter is tested with specially built test console. (Right) Checking voltage and current calibration of standard meter.

A growing field for qualified electronics technicians and engineers in government, military, and industrial laboratories in this country and all around the world.

By GROVER C. GEDNEY & FRANCIS M. WINTERBURG / Federal Electric Corp., Service Associate of ITT

ASTRONAUT Walter Schirra's flight was held up for five days because one pressure transducer was out of tolerance by 1½ pounds. This error in a simple instrument made necessary a new countdown and the expenditure of many, many thousands of extra dollars.

Accuracy in this case was critical. It is just as critical—if not as dramatic—in countless instances every day. Military operations, industry, and laboratories around the world all require greater and greater degrees of accuracy. The instruments which provide this accuracy could not serve their purpose properly without accurate calibration.

Calibration is the comparison of one instrument with another which has a higher order of accuracy. The ultimate in standards in this country are at the National Bureau of Standards at Washington, D.C. and at Boulder, Colo.

The importance of calibration cannot be overstressed. Research and development, manufacturing, and the installation of complex systems in the field can only be successful if measurements are taken by instruments calibrated to give nearly identical readings during each of these stages. For example, one microvolt prescribed by the design engineer in the laboratory must be read and set to one microvolt by the test technician during field installation.

There are, broadly speaking, three categories of instruments: (1) *Test instruments* are used to test and set up systems or equipment in the lab, factory, or in the field, and are of medium to high accuracy. (2) *On-line instruments* are associated with processing plants and other facilities utilizing automated production techniques, and are usually of lower accuracy. (3) *Precision-measurement instruments* are more unique, due to their specialized applications. These are used in space capsules, missile ranges, built-in test consoles and the like, and require a high degree of accuracy.

All of these must be calibrated but not at the same intervals. Here are some typical calibration intervals.

Daily	Six-month Interval
WWV receiver	Potentiometers High-resistance ohmmeters Decade capacitors Decade resistors Shunts Slotted lines Standard cells Ratio transformers Voltage regulators
30-day Interval	
Digital voltmeter Digital radiometer Digital divider	
90-day Interval	**One- to two-year Interval (All NBS certified standards)**
Frequency meters Oscillators Oscilloscopes V.T.V.M.'s Generators Galvanometers Resistance bridges	Standard cells Standard resistors Standard capacitors Standard inductors Standard potentiometers

While test instrument calibration and repair are closely allied, they require different levels of technical competence.

Standards-lab technicians perform lengthy and very precise calibration of the highest level, usually with secondary standards certified by the National Bureau of Standards. They must be proficient in the theory of instruments and the mathematical calculations necessary to determine probability of error and long-term reliability. They usually work in a controlled environment where temperature fluctuates not more than a degree, where humidity is held at plus or minus 10%, and where dust particles are no larger than 10 microns. The work is exacting, requires considerable training and experience. Base salaries range from $6000 to $9500. Highly qualified standards-lab technicians are hard to find.

Test-equipment technicians are called upon to diagnose and repair the many types of faulty and inoperative instruments which are brought to them. Their work is rarely routine, and they must be capable of operating independently, with a minimum of supervision. If gifted with the ability to train others quickly, a test-equipment technician may soon be given the opportunity of assuming supervisory responsibilities. He must respect the mission of the standards lab and establish a confidence in the accuracies to which standard instruments are calibrated for his use.

This category of technician, too, is in relatively short supply and the pay scales are only slightly lower than for the standards-lab group—approximately $5000 to $8000 a year.

As in other branches of electronics, the opportunities for graduate engineers in this particular field of electronics are growing steadily. The demand for specialized training in this area has been great enough for George Washington University to establish a "Center for Measurement Science" which offers an engineering curriculum oriented to the measurement field. Called "metrologists," these engineers develop new measurement criteria and prepare measurement and calibration procedures which the technician may perform. They may be called upon to assist technicians in solving difficult instrument troubleshooting problems, or to determine the probable error of calibration in several instrument systems tied together. Salaries range from $6000 to $15,000 and more.

Background Requirements

Most of the instrumentation we are concerned with at *Federal Electric Corporation* is in the electrical-electronic field. To qualify for employment in one of our calibration and repair facilities, a man must be a high-school graduate; he must have had one or two years of electronic schooling in a trade service school or engineering college; and three years of experience, at least one of which was in the test instrument field.

Math is extremely important; the more the better. We look for people who have had college physics, college algebra, trigonometry, analytical geometry, statistics, and even calculus. Any math above the high-school level conditions a man's mind to think along technical lines.

With this background, we can train technicians for calibration work on the job. Let's take, for example, a position in our DEW Line Communications and Electronic Equipment Depot.

The man usually begins by working with a more experienced man on the repair and overhaul of meters, or in troubleshooting a piece of test equipment. He then begins to assist in the calibration of test equipment. We have a set of written procedures to follow that becomes routine with experience. After a month or two of this, he may be ready to become a member of the mobile calibration team. This is a group of five technicians who carry certified instruments from our headquarters in Paramus, N.J. to different areas of the DEW Line Early Warning System in the Arctic, where they calibrate the test equipment that keeps the giant communications and radar system operating at peak efficiency.

After months of mobile team experience, a technician may be qualified to begin work in the Standards Laboratory. He will assist the more experienced men, learn the procedures, and become proficient in the techniques of transfer calibration from NBS standards to our secondary standards.

In choosing a calibration technician for the Early Warning System, a man who is single and willing to travel is preferred to a married man. We do have married men working on the mobile teams and will hire them if well qualified, but the single man is given preference because of having fewer home responsibilities.

These mobile teams travel to Alaska, across Canada at the Arctic Circle, and into Greenland and may be gone for four months at a time. They return to the Communications and Electronic Equipment Depot for three or four weeks to recalibrate their standard instruments and then again return to the DEW Line.

There is adequate opportunity for the married man with a family in the fixed laboratories or facilities. Only on mobile teams staying away from a home base for a considerable period of time is the unmarried man preferred.

Opportunities for Technicians

The instrument calibration and repair field is growing and the supply of qualified men is completely inadequate. For example, there are only about 14,000 engineers and technicians who are members of the Instrument Society of America. The U.S. Air Force, to cite another example, has within the past five years: (1) installed a standards laboratory at Newark, Ohio; (2) built 19 area laboratories; and (3) added 149 precision measurement laboratories.

Within industry, the example of the *International Telephone and Telegraph Corporation* might be of interest. To assure the accuracy and reliability of its products, *ITT Federal Laboratories* established in 1956 one of the first large-scale standards laboratories to serve an industrial facility. For several years, the calibration and repair of test instruments have been important services of *Federal Electric Corporation.*

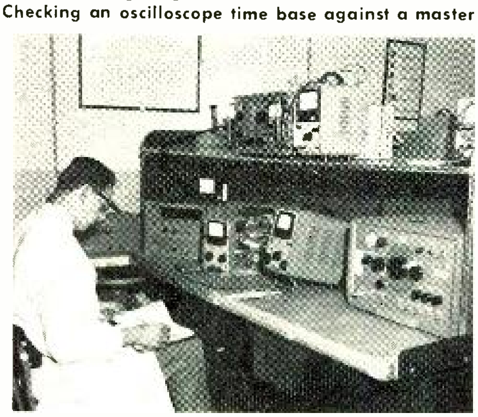
The instrument technician of today is not confined to the laboratory or factory. If he is well qualified, he enjoys an unprecedented demand for his services. ▲

ABOUT THE COMPANY

The Federal Electric Corp. operates instrumentation calibration centers in this country and overseas. At Paramus, N.J. there is the Communications and Electronic Equipment Depot established by the Air Force to repair and calibrate our Early Warning System instrumentation. There are 40 people employed there, including three traveling calibration teams made up of five technicians each. Some 20 are employed at an instrumentation center in Albuquerque, N.M. to serve Sandia Corporation, prime contractor for the Atomic Energy Commission, and other users in the Southwest.

The company also operates a standards laboratory at Chateauroux, France, serving the Air Force in Europe, Near and Middle East, and Africa. This group, consisting of 125 people, has technical teams and mobile calibration trailers for on-site checking and repair of electronic equipment. Over 400 are employed by the company in our Pacific Missile Range. These are responsible for the operation and maintenance of the Navy's range instrumentation facilities at Point Arguello and the missile launch facilities in California. Over 1500 pieces of precision measuring equipment are calibrated and repaired by this facility, which has its own 15-man standards laboratory.

(Left) Technician is shown calibrating a u.h.f. signal generator. (Center) Calibration of a vacuum-tube voltmeter against a standard. (Right) Checking an oscilloscope time base against a master frequency standard.



NAVAL OBSERVATORY TIME SIGNALS

By H. CHARLES WOOD

Description, use, and schedules for the "time ticks" that are broadcast on low, medium, and high frequencies.

Editor's Note: Although not as widely known and used as the National Bureau of Standards WWV and WWVH time signals, useful time signals are also broadcast by a number of Navy radio stations to ships around the world. This article discusses these time signals, tells how to interpret them, and gives the broadcast schedules of the stations involved.

JOHN HARRISON of Yorkshire, England is credited with developing the first practical shipboard clock (or chronometer) in 1735, and thus earned a handsome reward of £40,000 from the British Parliament. Prior to that date, accurate navigation on the high seas could not be achieved, because one of the major factors of celestial navigation is an accurate knowledge of time; an impossible feat in the days of the Ancient Mariner. This accounted for a seaman's reluctance to venture beyond the sight of land.

It wasn't long after Harrison's invention was made available to sea captains that new problems arose, the most important of which was the inability to predict the daily rate of error of the chronometers when the vessels were away from their home ports for a long period of time. This error is normally applied to the watch-time to determine the correct local time.

A small step forward was made in the 19th century when most of the major ports of the world were equipped with a "time ball" which was dropped from a conspicuous location in the harbor at noon. The sea captains in port would then set their chronometers accordingly. Unfortunately, however, not all port officials had the correct time. The problem of incorrect time, and the consequent error in a ship's position, continued throughout the 19th century, resulting in much loss of life and property, and was not solved until the invention of radio at the beginning of the 20th century.

Stations & Schedules

In 1904, U.S. Navy Radio Station NSS, newly established at Washington, D.C., began broadcasting time signals synchronized with the precision clocks at the Naval Observatory. This was the first significant advancement since Harrison perfected his invention nearly two centuries before, for now at last mariners all over the world could correct their chronometers with a signal of known accuracy.

Throughout the years, the U.S. system of radio time signals has been improved in accuracy and presentation, the power of the transmitters has been increased, new frequencies have been added, and new Naval radio stations have been built. Today, there is scarcely a spot on the planet that is not within range of at least one of the daily time signals.

Naval Observatory time signals are now being broadcast at numerous times throughout the day by five widely separated Navy radio stations: NSS Washington, D.C.; NBA Canal Zone; NPG San Francisco, California; NPM Honolulu; and NPN Guam. The hours of the transmissions and the frequencies of emission are listed in Table 1. At the top of each tabulation are the call letters, location of the station, and the frequency of transmission in kilocycles. The Greenwich Mean Time (GMT) of transmission is located in the left-hand column, followed by a conversion to the zone times maintained throughout the United States. Local time for any other location can be computed by applying the time zone number to the GMT. For example, Los Angeles, California is located in time zone +8. This means that 8 hours must be subtracted from GMT to obtain the local time of Los Angeles. Thus the 2400 hours midnight time signal will be heard in California at 1600 hours local time (4:00 p.m. for you landlubbers). It will be one hour later if your community is on daylight saving time. World time zone charts are available at U.S. Hydrographic Offices, nautical equipment stores, and most bookshops.

Now let's examine the time signal itself, as it is graphically displayed in Fig. 1. Essentially, (*Continued on page 82*)

STATION: NSS Washington, D. C.
Frequency in kc.: 121.95; 5870; 9425; 13,575; 17,050.4; 23,650

GMT =	Eastern Std. Time Zone +5	Central Std. Time Zone +6	Mount. Std. Time Zone +7	Pacific Std. Time Zone +8	Alaska-Honolulu Time Zone +10
0155 - 0200	2055 - 2100	1955 - 2000	1855 - 1900	1755 - 1800	1555 - 1600
0555 - 0600	0055 - 0100	2355 - 2400	2255 - 2300	2155 - 2200	1955 - 2000
0755 - 0800	0255 - 0300	0155 - 0200	0055 - 0100	2355 - 2400	2155 - 2200
1155 - 1200	0655 - 0700	0555 - 0600	0455 - 0500	0355 - 0400	0155 - 0200
1355 - 1400	0855 - 0900	0755 - 0800	0655 - 0700	0555 - 0600	0355 - 0400
1755 - 1800	1255 - 1300	1155 - 1200	1055 - 1100	0955 - 1000	0755 - 0800
1955 - 2000	1455 - 1500	1355 - 1400	1255 - 1300	1155 - 1200	0955 - 1000
2355 - 2400	1855 - 1900	1755 - 1800	1655 - 1700	1555 - 1600	1355 - 1400

STATION: NBA Balboa, Canal Zone
Frequency in kc.: 147.85; 5448.5; 11,080; 17,697.5

GMT =	Eastern Std. Time Zone +5	Central Std. Time Zone +6	Mount. Std. Time Zone +7	Pacific Std. Time Zone +8	Alaska-Honolulu Time Zone +10
0455 - 0500	2355 - 2400	2255 - 2300	2155 - 2200	2055 - 2100	1855 - 1900
0955 - 1000	0455 - 0500	0355 - 0400	0255 - 0300	0155 - 0200	2355 - 2400
1655 - 1700	1155 - 1200	1055 - 1100	0955 - 1000	0855 - 0900	0655 - 0700
2355 - 2400	1855 - 1900	1755 - 1800	1655 - 1700	1555 - 1600	1355 - 1400

STATION: NPG San Francisco, California
Frequency in kc.: 114.95; 4010; 6428.5; 9277.5; 12,966; 17,055.2; 22,635

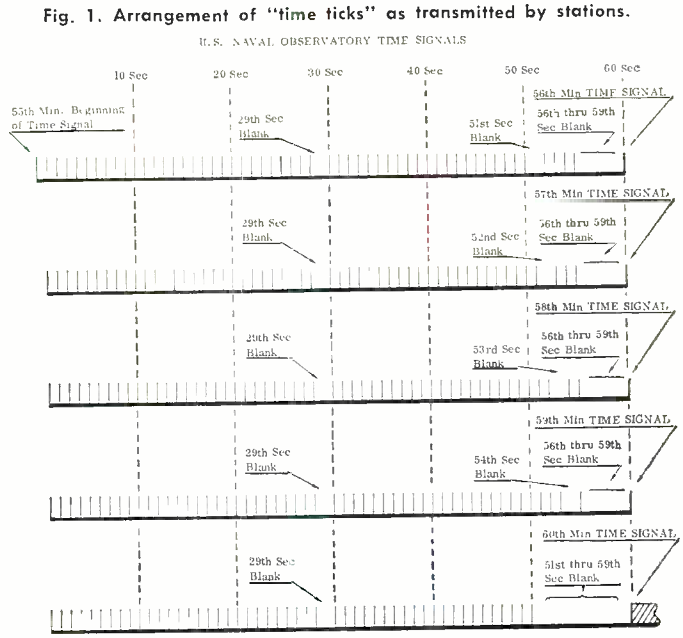
STATION: NPM Honolulu
Frequency in kc.: 131.05; 4525; 9050; 13,655; 17,122.4; 22,593

STATION: NPN Guam
Frequency in kc.: 484; 4955; 8150; 13,530; 17,530; 21,760

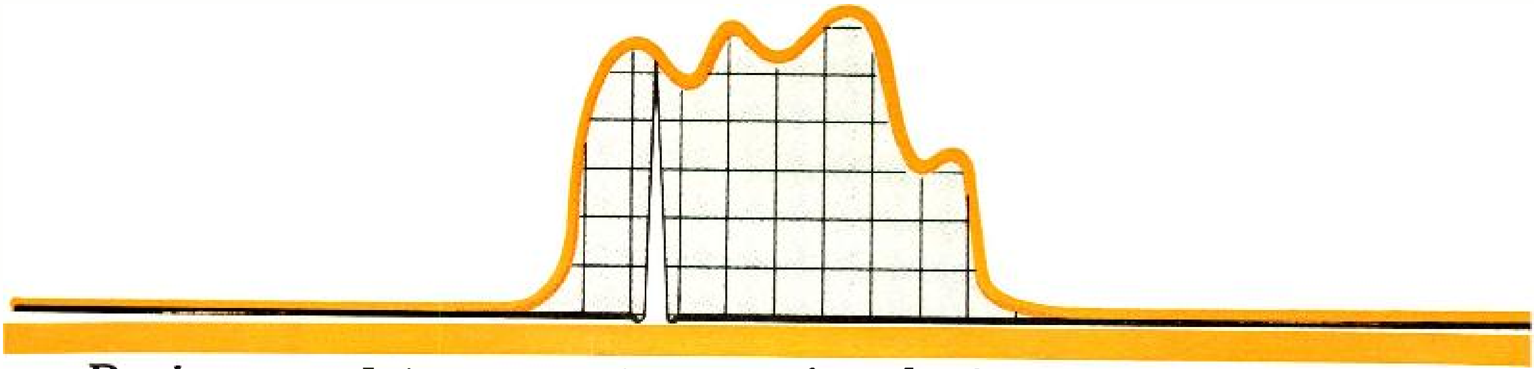
GMT =	Eastern Std. Time Zone +5	Central Std. Time Zone +6	Mount. Std. Time Zone +7	Pacific Std Time Zone +8	Alaska-Honolulu Time Zone +10
0555 - 0600	0055 - 0100	2355 - 2400	2255 - 2300	2155 - 2200	1955 - 2000
1155 - 1200	0655 - 0700	0555 - 0600	0455 - 0500	0355 - 0400	0155 - 0200
1755 - 1800	1255 - 1300	1155 - 1200	1055 - 1100	0955 - 1000	0755 - 0800
2355 - 2400	1855 - 1900	1755 - 1800	1655 - 1700	1555 - 1600	1355 - 1400

Table 1. Schedule of the U.S. Naval Observatory time signals.

Fig. 1. Arrangement of "time ticks" as transmitted by stations.



SIGNAL-GENERATING EQUIPMENT



Devices used to generate test signals from below the audio range up through microwaves. Performance, specifications, and effect of semiconductors on equipment design are covered.

By HOWARD L. ROBERTS / Hewlett-Packard Co.

SIGNAL-generating equipment comprises a wide variety of electronic instruments for generating test signals. This class of instruments includes everything from the human finger, placed on a grid connection, to complicated check-out equipment which automatically generates a number of frequencies, voltages, and other signals for quickly testing intricate missile systems.

The finger test may be all that you need if you merely want an indication of whether the equipment is working or not. But when you need to know *how well* the equipment works, then the appropriate piece of signal-generating equipment must be called upon to provide the answer.

If, for instance, you want to measure distortion in an audio amplifier, you need an oscillator that generates sine waves with far less distortion than you expect the amplifier to have. If you want to measure the rise time of a switching circuit, you ought to have a pulse generator that produces pulses with rise times faster than the switching circuit.

Types of Equipment

Signal-generating devices may be loosely grouped into two categories: special-purpose and general-purpose generators. Special-purpose generators are designed for specific kinds of tests and usually generate only those combinations of frequencies needed to test certain kinds of equipment. An example of this type is an FM stereo test generator. Special-purpose generators are best suited for making repetitive measurements since their built-in features make specific tests faster.

General-purpose equipment may not have many combinations of signals but usually can generate signals over broader ranges of frequency and amplitude. These generators find most use in the experimental and development laboratory, both professional and hobbyist, but are often used for specific tests as well. Presumably, any test performed by a special-purpose generator can be performed by an assortment of general-purpose equipment, but several instruments may be required to do the same job.

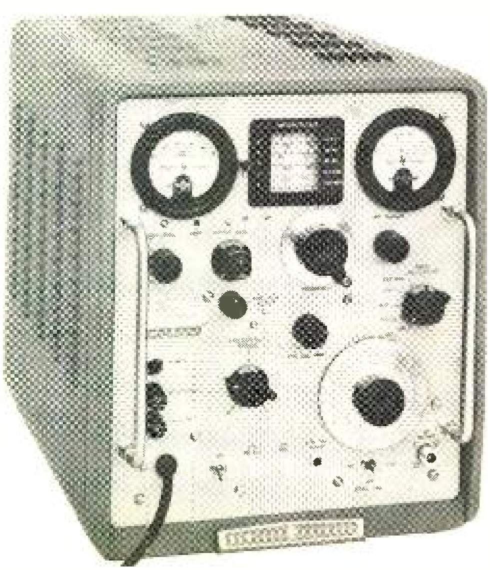
Since the basic design principles involved in general-purpose laboratory instruments are also used in special-purpose generators, we'll confine this discussion to general-purpose instruments.

Signal-generating equipment is often grouped according to the shape of the output signal waveform. Sine-wave generators form one important category since the sine wave is the most fundamental waveform. These instruments are widely used to test equipment performance at discrete frequencies.

Oscillators and Signal Generators

Among sine-wave generating equipment, a distinction is made between oscillators and signal generators. A signal generator is an oscillator that has accurately known amounts of output power as well as known frequencies. In many cases, this means simply that a signal generator has a meter to show the power generated by the output stage, and a precision attenuator for cutting down the indicated power by known amounts.

At audio frequencies it is a simple enough matter to read oscillator output with a lab voltmeter. For this reason, output meters are not included in the majority of audio oscillators. At r.f. frequencies, though, voltage measurements are more com-



When an accurate, stable v.h.f. signal source is required for receiver or v.h.f. amplifier measurements, then a standard signal generator is required. Our example is the Hewlett-Packard 608D. The instrument is especially suited for precise tests of narrow-band v.h.f. aircraft communications equipment. It has a calibrated output of 0.1 μv. to 0.5 v. throughout the 10 to 420-mc. band. Output frequency can be set to within a few kc. with built-in crystal calibrator. Price: $1300.

plex so that r.f. generators include a built-in output meter designed especially for each generator. (An r.f. generator without a meter is known as a "signal source.")

RC oscillators have dominated the audio and neighboring ranges for more than twenty years. This range extends from subsonic through ultrasonic and into the low-frequency r.f. ranges.

RC oscillators are so named because their frequency-determining networks consist only of resistance and capacitance —no inductance whatever. The reason for using an *RC* circuit is that if an *LC* circuit were used, the large inductors required for low-frequency oscillations would be much too cumbersome. The *RC* oscillator is much lighter, easier to build, and, as it turns out, a good source of distortion-free sine waves.

These oscillators generally use some form of amplitude limiting other than driving a tube to cut-off and/or saturation. The most common form of amplitude control is the use of a small incandescent lamp as a non-linear resistance in one of the feedback loops. The lamp's resistance changes, if the oscillation amplitude changes, readjusting the amount of feedback to counteract the change in amplitude. This type of limiting prevents the tubes (or transistors) from being driven beyond their linear operating regions and accounts for the low distortion output of these oscillators.

The oscillator circuit may also be followed by a tuned amplifier-filter ganged to the tuning dial so as to track the oscillator tuning. Filtering attenuates what little harmonic content there may be in the oscillator signal, resulting in hyper-pure sine-wave output. This type of instrument is most useful for making distortion measurements on other types of equipment.

Multivibrators with very long time constants are used in instruments for the very low frequencies, some of these operating as low as 0.001 cps (about 1 cycle per 15 minutes!). Multivibrators generate square waves, of course, but the square waves are changed to sine waves by wave-shaping networks. This is just opposite to the audio-range sine/square wave generators which start with sine waves and form these into square waves with clipping or triggering circuits.

Above 1 mc., the usual *RC* oscillator runs into certain problems. The tuning capacitors are in a range of values comparable to distributed circuit capacitance which makes tuning less precise. Phase-shift oscillators, a different form of the *RC* oscillator, swamp out the stray capacitances and can be used up to 10 mc. and beyond.

Beat-frequency oscillators are also used throughout the low-frequency region. These instruments use two r.f. oscillators, one generating a fixed frequency and the other being tunable. The outputs of these oscillators are mixed and the difference frequency is separated from the mixture by filter circuits.

The advantage of the beat-frequency oscillator is that very wide frequency ranges can be covered by a single sweep of the tuning dial, at the expense of tuning resolution however. The disadvantage is that the oscillators must be made many times more stable than the desired stability of the output signal because of the large step-down in frequency. High-quality beat-frequency oscillators made for laboratory applications do achieve the desired stability, however.

R.F. Signal Generators

The designation "r.f." is another all-embracing term, originally referring to signals that were destined to be radiated or detected as radio waves. As it turns out, radio signals are now propagated at frequencies even lower than 20 kc. (standard frequency broadcasts such as WWVL) and at super-high frequencies measured in thousands of megacycles (gigacycles). Our discussion here will be confined mainly to those radio-frequency generators which have lumped *LC* circuits, using coils and capacitors in the resonant circuit.

During the forty-odd years that these generators have been used, they have undergone considerable refinement. Factors which upset frequency stability have been designed out of the circuits. Manufacturers have learned how to wind coils tightly of low expansion wire on matched ceramic forms so that there is little change of inductance with a change in temperature. In high-quality generators, capacitors are made from rigid precision-machined plates, which are silver- or gold-plated for minimum resistance to r.f. surface currents (skin effect). In recent years negative feedback has been used in various ways to improve amplitude stability and modulation characteristics.

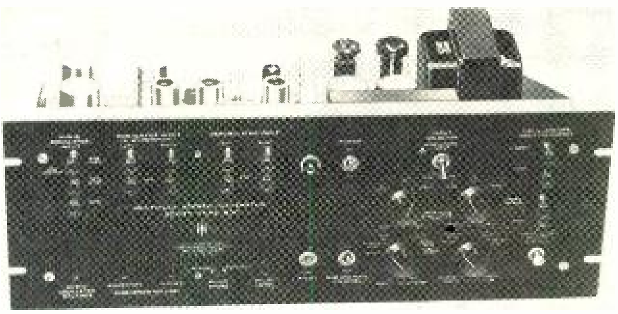
Even with all these refinements, a good r.f. signal generator still includes an accurate crystal-controlled frequency calibrator to enable precise setting of frequency. The calibrator frequency is usually a whole number, such as 1 mc., so that it is easy to spot the harmonics.

Such r.f. generators also include amplitude or frequency modulation capabilities. This enables the generator to supply signals which resemble the actual signals to be used by the equipment being tested.

When the response of a sharp cut-off filter or i.f. circuit is being measured, modulation may wobble the r.f. frequency across the circuit's cut-off point, broadening the apparent response curve. For this reason, most r.f. generators use the master oscillator-power amplifier (MOPA) configuration which isolates the oscillator from the output amplifier, per-

Designed mainly for servicing AM, FM, and TV receivers is the Hickok 288AX sweep and marker generator. The instrument has 8 bands of unmodulated or AM signal output from 35 kc. to 110 mc. as well as frequency-modulated output up to 160 mc. A built-in audio oscillator, tunable from 20 to 15,000 cps, is used for modulation or for audio tests. A crystal calibrator, with a choice of 100- or 1000-kc. signals, is also provided along with a 3-range decibel meter. Price of this unit: $315.

An example of a versatile pulse generator is the Fairchild-DuMont 404-B. This device can generate pulses suitable for use in signal-sampling techniques in conjunction with oscilloscopes. Another application is to trigger scope sweeps at the proper time to view the leading edges of very short transients. Pulses can be generated with widths continuously variable from 0.05 to 105 μsec., with various delays, and with repetition rates up to 250,000 p.p.s. Generator price: $760.



A multiplex stereo generator developed for design and production testing of FM multiplex adapters, tuners, and receivers is the Scott 830. The unit has also been used by FM broadcast stations to produce a composite stereo signal. When feeding a composite stereo signal into the front end of a tuner, the generator's output is used to modulate a laboratory-quality standard FM signal generator. The price of the unit: $600.

Intended mainly for the service technician working on FM multiplex equipment is the Fisher Model 300 multiplex signal generator. The instrument is also suitable for use in production testing. Incorporated are an audio oscillator and an r.f. generator, which is factory tuned to the approximate center of the standard FM broadcast band. An output-level indicator is also provided. Price of generator: $495.

mitting amplitude modulation of the amplifier without affecting the frequency of the oscillator.

The output impedance of r.f. generators deserves special comment. If the output cable and load impedances aren't the same, r.f. energy reflects from the load, giving rise to standing waves. If the generator itself is not matched to the output cable, then reflections are re-reflected, which alters the character of the standing wave and interferes with measurement accuracy. Most r.f. generators are matched to one of the 50, 75, or 300-ohm impedance levels commonly used but pads or baluns are required to match other impedances.

Because of standing waves, the r.f. voltage at the generator may be different from the load voltage. For this reason, an output voltmeter is a reliable indicator of signal strength only when the load is matched to the generator.

The attenuators of r.f. generators require careful design to account for distributed capacitance and inductance. These devices are frequency-sensitive unless components are positioned carefully. Furthermore, the impedance of the attenuator must be matched to the output cable at all settings.

U.H.F. and Higher Frequencies

Above 300 mc. the inductance and capacitance of tuned circuits become so small that it is difficult to treat them as discrete circuit elements. At these higher frequencies, resonant cavities of one sort or another are generally used as the resonating elements.

Gridded tubes for u.h.f. frequencies have rather odd shapes so that all elements make contact at the right place when installed in a cavity. Above 1000 mc., klystrons are most often used as oscillators.

Microwave signal generators use a single power oscillator for the r.f. channel, avoiding the cost and complexity of a power output stage. Because of this, modulation is usually restricted to pulses and square waves. Modulating waveforms turn the power oscillator completely off and on, making the transition between off and on states as fast as possible to minimize frequency pulling or FM as the klystron voltage changes. On the other hand, it is relatively easy to frequency-modulate a klystron over a range of a few megacycles by applying a saw-tooth voltage to the klystron repeller.

The attenuators of these generators also avoid the use of lumped circuit elements, the waveguide-beyond-cut-off type being favored. This attenuator uses a pickup loop which slides in and out of a length of waveguide that opens into the resonant cavity. The waveguide dimensions are smaller than those required to carry an electromagnetic wave at the frequency of the oscillator but the cavity's magnetic field leaks into the waveguide. The further the loop is from the cavity end, the weaker the field is and, what is more, the field strength drops off in a predictable manner so that these attenuators are inherently accurate.

Sweep Generators

Sweep generators are indispensable for anyone concerned with circuit response throughout a band of frequencies. A straightforward way of obtaining a sweep frequency is to add a motor drive to the oscillator tuning dial. This approach is widely used at audio and low frequencies, where electronic techniques for changing frequency fail to achieve the necessary wide (in terms of number of octaves) bandwidth. The beat-frequency oscillator shines here as a means of getting wide sweeps.

Motor drives are also used at radio frequencies but vibrating capacitors often serve to vary the oscillator frequency. At microwave frequencies, the voltage-tuned backward-wave oscillator (b.w.o.) can easily sweep through an octave band of frequencies simply by modulating the helix voltage.

Motor-driven sweeps, unless carefully designed, cause mechanical vibrations which induce microphonics that generate spurious oscillations. Motor-driven sweeps are also limited in speed. Electronic sweeps, which vary the oscillator tank circuit's resonant frequency either with a reactance tube, a voltage-variable capacitor, or a saturable reactor, are used wherever possible.

Many service-shop sweep generators have a fixed sweep rate of 60 cps, taken right from the power line. This simplifies circuitry and also makes synchronization of related oscilloscopes easier.

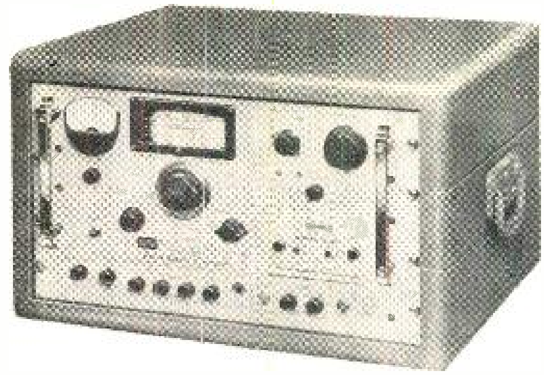
Circuit response is usually displayed on an oscilloscope. The sweep rate should be fast enough to obtain a flickerless display. Slow sweep rates are required for pen recorders which may trace with more detail than a scope does.

Pulse and Square-Wave Generators

Pulse and square-wave generators produce signals of an "off-on" nature by switching between two d.c. levels. These generators are used to check systems which operate in a pulsed mode, such as radar modulators, oscilloscope triggering circuits, computer circuits, and teletypewriter systems. These generators are also used for transient response testing of linear systems.

The shape of the input pulse or square wave has to be neatly rectangular if anything is to be learned from the shape of the output pulse. Rounding of the pulse corners, or overshoot, wiggles, and sag of the pulse top, are the symptoms of system performance so should not be present on the

In order to take quantitative r.f. frequency response measurements, a sweep-frequency generator is used. The response curve, traced on a scope, is usually marked with a marker generator. Incorporating both functions in a laboratory instrument is the General Radio 1025-A. The unit covers 0.7 to 230 mc. plus two bandspread ranges (400-500 kc., 10.4-11 mc.) for i.f. curves. The accurate marker pip is continuously adjustable in frequency and amplitude. Price: $3250.



Another example of sweep-frequency generator is the Jerrold Model 900-B. This instrument, which has been designed for laboratory or production use, generates sweep signals with center frequencies from 500 kc. up to 1200 mc. in the u.h.f. range. Sweep widths vary from a narrow 10 kc. to a wide 400 mc. for the higher frequencies. The unit also has built-in crystal-controlled harmonic markers and provision for external variable marker signal generator. Price of unit: $1980.

input pulse that is produced by the pulse generator employed.

A square-wave generator is really a pulse generator having equal "on" and "off" times. "On" time duration therefore varies with frequency. Pulse generators have one control for frequency, or pulse repetition rate, and a separate control for "on" time duration, or pulse width. "On" time is usually much shorter than "off" time so that pulse generators are often used to drive r.f. oscillators or other circuits where high power is needed during the pulse but where average power should be kept low.

These generators usually use some form of multivibrator circuitry for wave generation with clipping circuits and other devices for "squaring up" the waveform. An exception is the mercury-wetted relay which, unlike ordinary relays that have a certain amount of contact bounce, latch on for good when contact is made. Generators using these relays are able to generate high power pulses with turn-on times (rise times) measured in fractions of a nanosecond (10^{-9} second) but their use is limited because of relatively slow repetition rates.

Noise Generators

Measuring signal-to-noise ratios in receivers with sine waves or other coherent signals is complicated because of theoretical considerations involving bandwidth and noise power per cycle bandwidth. This difficulty is circumvented by using broadband noise from a suitable generator as the test signal. A comparison of receiver noise output without signal input to noise output with a known amount of noise power at the input, provides a measure of receiver performance.

Noise generators are also used as a source of broadband signals. Since "white" noise is an equal mixture of all frequencies, a test using a noise voltage as the input is a test which covers the complete range of a system all at once. This is a good one to use for spotting any resonances in audio systems or in acoustic measurements.

Broadband noise sources require careful design; otherwise, resonances may prevent an equal-energy distribution for all frequencies. Noise sources include hot resistors, gas tubes, and temperature-limited diodes (these are diodes operated with low filament voltages and with plate voltages high enough to maximize shot noise in the diode current).

Impact of Semiconductors

Transistors are used in signal generating equipment where their low power drain and low heat can contribute to a lightweight, battery-powered design. As the cost of transistor circuitry becomes more competitive with vacuum tubes, we can expect to see more use made of transistors in test equipment.

Low-capacitance semiconductor diodes can be used at much higher frequencies than thermionic diodes and are used as harmonic generators to double the frequency of microwave generators. They do this by partial rectification which distorts the r.f. wave, creating harmonic frequencies.

Tunnel diodes find application as low-level, low-impedance r.f. generators and as fast-rise pulse generators. One available pulse generator uses a simple tunnel diode circuit to generate pulses with rise times of less than 0.1 nanosecond. Pulse amplitude, though, is less than half a volt.

The step-recovery or snap-off diode represents a recent discovery which is being designed into fast-pulse generators. Any semiconductor diode stores a charge, when forward-biased, which flows as reverse current for a brief interval when a reverse bias is suddenly applied. The step-recovery diode is designed so that this stored charge is used up abruptly, making the transition from short-circuit (charge carriers flowing) to high impedance (no charge carriers) in less than a nanosecond. This device is used in a new pulse generator as a pulse sharpener to square up the output pulses.

Still another kind of diode is revolutionizing the modulator in microwave generators. This device, known as a *p-i-n* diode because of the intrinsic (no impurities or doping) silicon layer sandwiched between the *p* and *n* layers, also exploits charge carrier flow. At microwave frequencies, a half-cycle does not last long enough for the charge carriers to be swept out, so that current flows through the diode in alternate directions in response to the r.f. voltage waveforms. The diode appears resistive, however, and the apparent resistance is changed by varying the diode bias.

A voltage-controlled attenuator is made by placing *p-i-n* diodes across a transmission line so that they bypass or absorb some of the r.f. energy, the amount that is bypassed being controlled by the diode bias. The oscillator can then operate continuously and modulation is achieved by absorbing various amounts of r.f. energy without causing reflections on the transmission line

With these diodes, it is now possible to amplitude-modulate a klystron output with sine waves, or any kind of complex wave for that matter. What is more, the microwave power can be turned on and off more quickly with these attenuators than power can be built up or damped out in high-"*Q*" cavities.

Equipment Accuracy

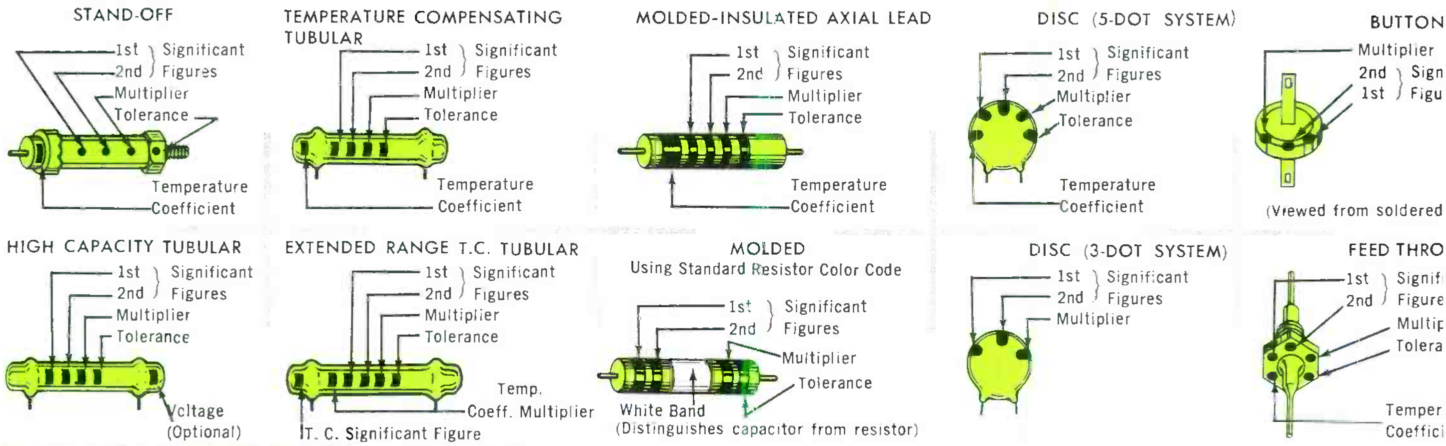
A quality r.f. signal generator built during the past ten or fifteen years can be expected to have about a 1% or 2% accuracy in frequency setting. (*Continued on page* 80)

DECIBEL TABLE

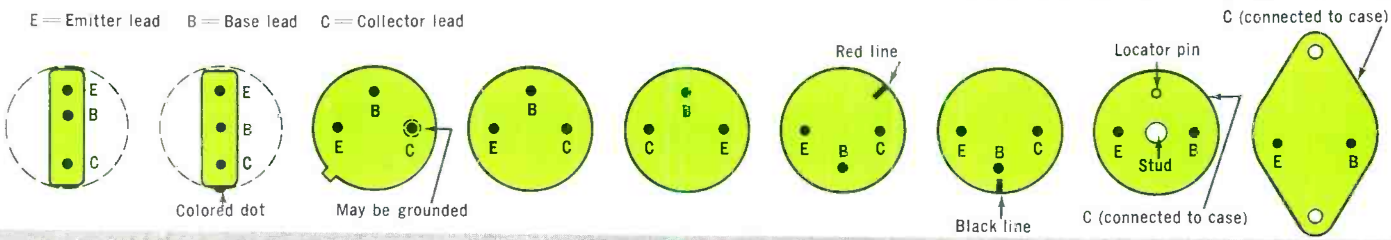
Voltage Ratio (Equal Impedance)	Power Ratio	← − db + →	Voltage Ratio (Equal Impedance)	Power Ratio
1.000	1.000	0	1.000	1.000
0.989	0.977	0.1	1.012	1.023
0.977	0.955	0.2	1.023	1.047
0.966	0.933	0.3	1.035	1.072
0.955	0.912	0.4	1.047	1.096
0.944	0.891	0.5	1.059	1.122
0.933	0.871	0.6	1.072	1.148
0.923	0.851	0.7	1.084	1.175
0.912	0.832	0.8	1.096	1.202
0.902	0.813	0.9	1.109	1.230
0.891	0.794	1.0	1.122	1.259
0.841	0.708	1.5	1.189	1.413
0.794	0.631	2.0	1.259	1.585
0.750	0.562	2.5	1.334	1.778
0.708	0.501	3.0	1.413	1.995
0.668	0.447	3.5	1.496	2.239
0.631	0.398	4.0	1.585	2.512
0.596	0.355	4.5	1.679	2.818
0.562	0.316	5.0	1.778	3.162
0.531	0.282	5.5	1.884	3.548
0.501	0.251	6.0	1.995	3.981
0.473	0.224	6.5	2.113	4.467
0.447	0.200	7.0	2.239	5.012
0.422	0.178	7.5	2.371	5.623
0.398	0.159	8.0	2.512	6.310
0.376	0.141	8.5	2.661	7.079
0.355	0.126	9.0	2.818	7.943
0.335	0.112	9.5	2.985	8.913
0.316	0.100	10	3.162	10.00
0.282	0.0794	11	3.55	12.6
0.251	0.0631	12	3.98	15.9
0.224	0.0501	13	4.47	20.0
0.200	0.0398	14	5.01	25.1
0.178	0.0316	15	5.62	31.6
0.159	0.0251	16	6.31	39.8
0.141	0.0200	17	7.08	50.1
0.126	0.0159	18	7.94	63.1
0.112	0.0126	19	8.91	79.4
0.100	0.0100	20	10.00	100.0
$3.16\text{x}10^{-2}$	10^{-3}	30	$3.16\text{x}10$	10^{3}
10^{-2}	10^{-4}	40	10^{2}	10^{4}
$3.16\text{x}10^{-3}$	10^{-5}	50	$3.16\text{x}10^{2}$	10^{5}
10^{-3}	10^{-6}	60	10^{3}	10^{6}
$3.16\text{x}10^{-4}$	10^{-7}	70	$3.16\text{x}10^{3}$	10^{7}
10^{-4}	10^{-8}	80	10^{4}	10^{8}
$3.16\text{x}10^{-5}$	10^{-9}	90	$3.16\text{x}10^{4}$	10^{9}
10^{-5}	10^{-10}	100	10^{5}	10^{10}
$3.16\text{x}10^{-6}$	10^{-11}	110	$3.16\text{x}10^{5}$	10^{11}
10^{-6}	10^{-12}	120	10^{6}	10^{12}

COLOR CODES CHA

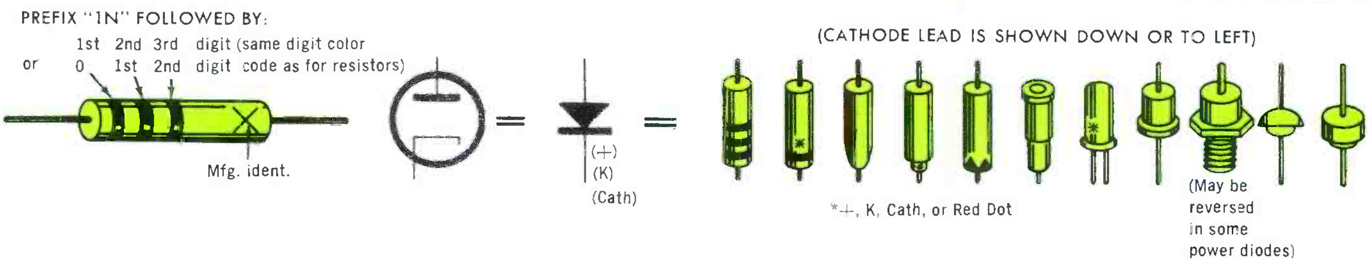
CERAMIC CAPACITORS



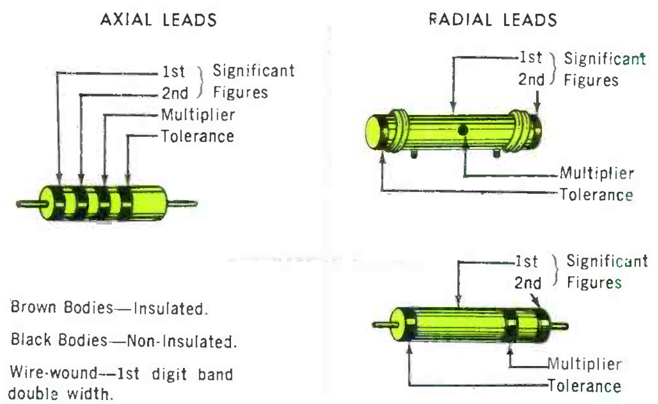
TRANSISTOR BASES



SEMICONDUCTOR DIODES



RESISTORS



Brown Bodies—Insulated.

Black Bodies—Non-Insulated.

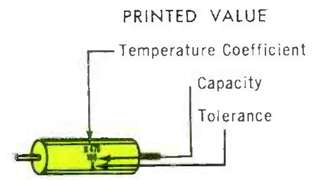
Wire-wound—1st digit band double width.

RESISTANCE IN OHMS

COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	±20%
BROWN	1	10	±1%
RED	2	100	±2%
ORANGE	3	1000	±3%*
YELLOW	4	10,000	GMV*
GREEN	5	100,000	±5% (EIA Alternate)
BLUE	6	1,000,000	±6%*
VIOLET	7	10,000,000	±12 1/2%*
GRAY	8	.01 (EIA Alternate)	±30%*
WHITE	9	.1 (EIA Alternate)	±10% (EIA Alternate)
GOLD		.1 (JAN and EIA Preferred)	±5% (JAN and EIA Pref.)
SILVER		.01 (JAN and EIA Preferred)	±10% (JAN and EIA Pref.)
NO COLOR			±20%

*GMV = guaranteed minimum value, or −0 + 100% tolerance.
±3%, 6%, 12 1/2%, and 30% are ASA 40, 20, 10, and 5 step tolerances.

Electronics World



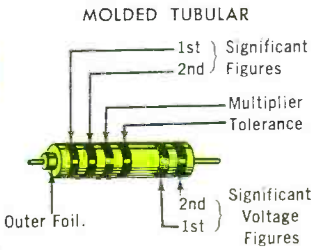
CAPACITY IN μμF.							
COLOR	DIGIT	MULTIPLIER	TOLERANCE 10 μμ FD. or less	TOLERANCE Over 10 μμ FD.	TEMPERATURE COEFFICIENT PPM/°C	EXTENDED RANGE TEMP. COEFF. Sig. Fig.	EXTENDED RANGE TEMP. COEFF. Multiplier
BLACK	0	1	±2.0 μμ FD.	±20%	0(NPO)	0.0	−1
BROWN	1	10	±0.1 μμ FD.	±1%	−33(N033)		−10
RED	2	100		±2%	−75(N075)	1.0	−100
ORANGE	3	1000		±2.5%	−150(N150)	1.5	−1000
YELLOW	4	10,000			−220(N220)	2.2	−10,000
GREEN	5		±0.5 μμ FD.	±5%	−330(N330)	3.3	+1
BLUE	6				−470(N470)	4.7	+10
VIOLET	7				−750(N750)	7.5	+100
GRAY	8	.01	±0.25 μμ FD.		+30(P030)		+1000
WHITE	9	.1	±1.0 μμ FD.	±10%	General Purpose		+10,000
SILVER					Bypass & Coupling		
GOLD					+100 (P100, JAN)		

Voltage ratings are standard 500 volts for some manufacturers, 1000 volts for other manufacturers.

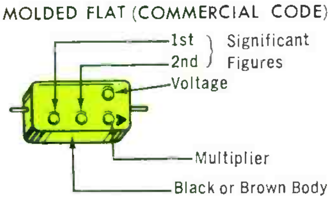
JAN LETTER	TOLERANCE 10 μμ F. or less	TOLERANCE Over 10 μμ F.
C	±0.25 μμ F.	
D	±0.5 μμ F.	
F	±1.0 μμ F.	±1%
G	±2.0 μμ F.	±2%
J		±5%
K		±10%
M		±20%

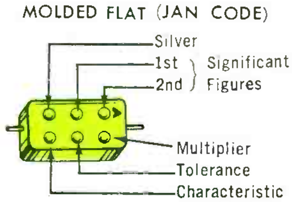
PAPER CAPACITORS

CAPACITY IN μμF.			
COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	20%
BROWN	1	10	
RED	2	100	
ORANGE	3	1000	
YELLOW	4	10,000	
GREEN	5	100,000	5%
BLUE	6	1,000,000	
VIOLET	7		
GRAY	8		
WHITE	9		10%
GOLD			5%
SILVER			10%
NO COLOR			20%



Add two zeros to voltage figures. One band indicates voltage ratings under 1000 volts.

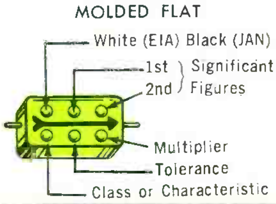


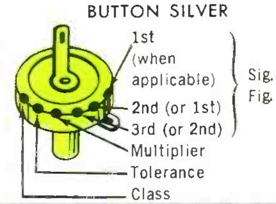


MICA CAPACITORS

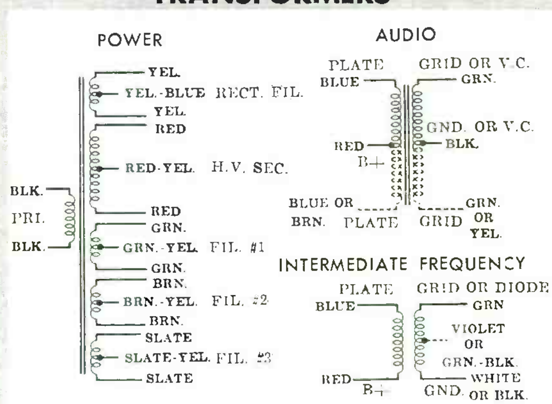
CAPACITY IN μμF.				
COLOR	DIGIT	MULTIPLIER	TOLERANCE*	CLASS OR CHARACTERISTIC**
BLACK	0	1	20%	A
BROWN	1	10	1%	B
RED	2	100	2%	C
ORANGE	3	1000	3%	D
YELLOW	4	10,000		E
GREEN	5		5% (EIA)	F(JAN)
BLUE	6			G(JAN)
VIOLET	7			
GRAY	8			I(EIA)
WHITE	9			J(EIA)
GOLD		.1	5% (JAN)	
SILVER		.01	10%	

*or ±1.0μμF , whichever is greater.
**Specifications of design involving Q factors, temperature coefficients, and production test requirements.
All axial lead mica capacitors have a voltage rating of 300, 500, or 1000 volts.





TRANSFORMERS



WIRING

COLOR	CIRCUITS
BLACK	GROUNDS
BROWN	FILAMENTS, HEATERS
RED	B-PLUS
ORANGE	SCREEN GRIDS
YELLOW	CATHODES
GREEN	CONTROL GRIDS
BLUE	PLATES
VIOLET	
GRAY	A.C. LINES
WHITE	OFF-GROUND RETURNS

METER RANGE-EXTENSION NOMOGRAM

The limited ranges of voltage- or current-reading panel meters can be extended quickly and without complicated calculations.

By A. L. TEUBNER

WHEN measurements are being made with limited-range panel meters, the situation often arises in which a voltage or current to be read exceeds the full-scale capability of the instrument. It is a relatively simple matter to extend the voltage range by adding an appropriate dropping resistor in series or to extend the current range by adding a shunt resistor, and then to multiply the reading by the appropriate factor. The calculation of the value of resistor to be added to provide the desired range extension and convenient multiplication factor is not so simple.

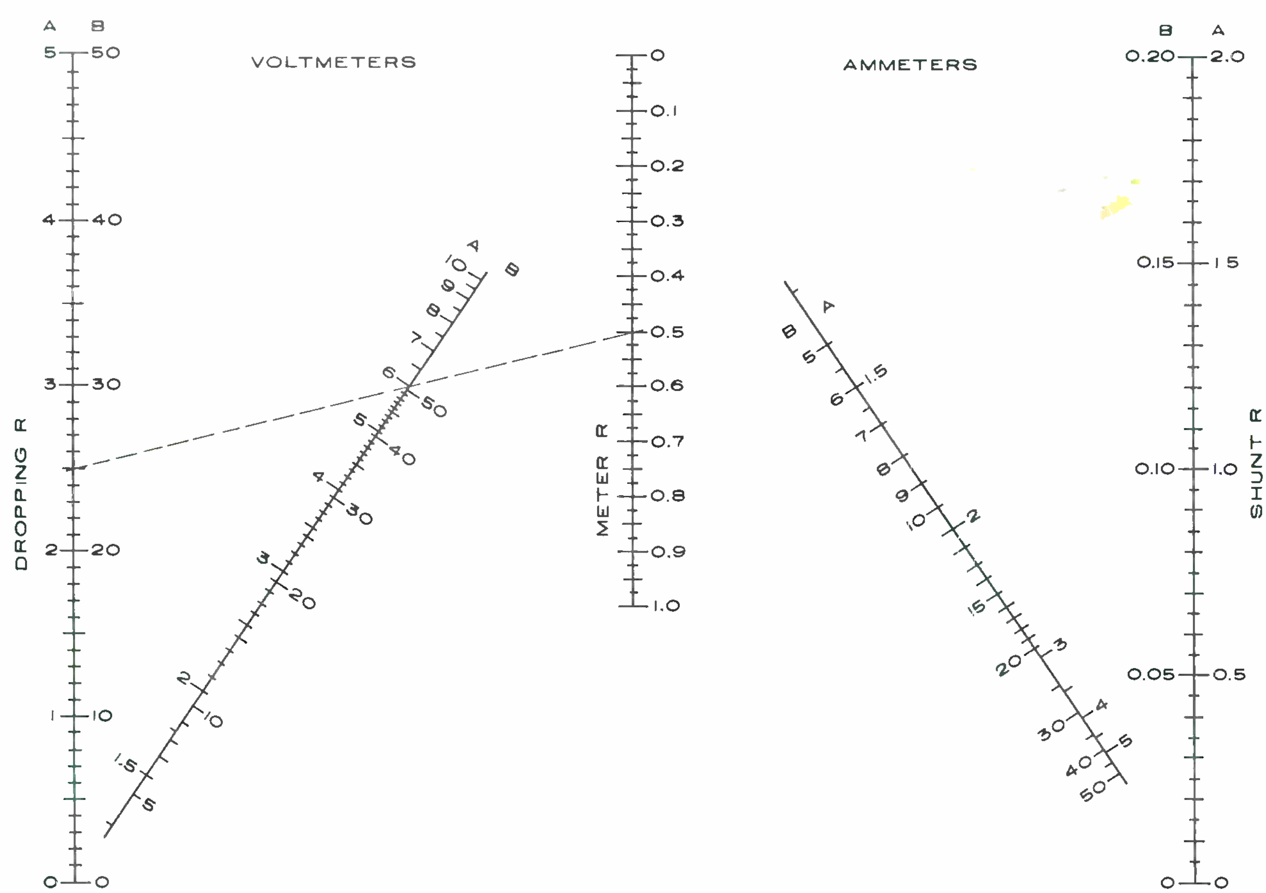
With the handy chart shown here, a meter can be extended to read up to 50 times its full-scale deflection. Depending on the instrument itself and what is known about it, it is possible to use the resistance of the movement alone or the over-all resistance presented by the meter to the external circuit. The chief precaution is that the user must keep track of the decimal point (or powers of ten).

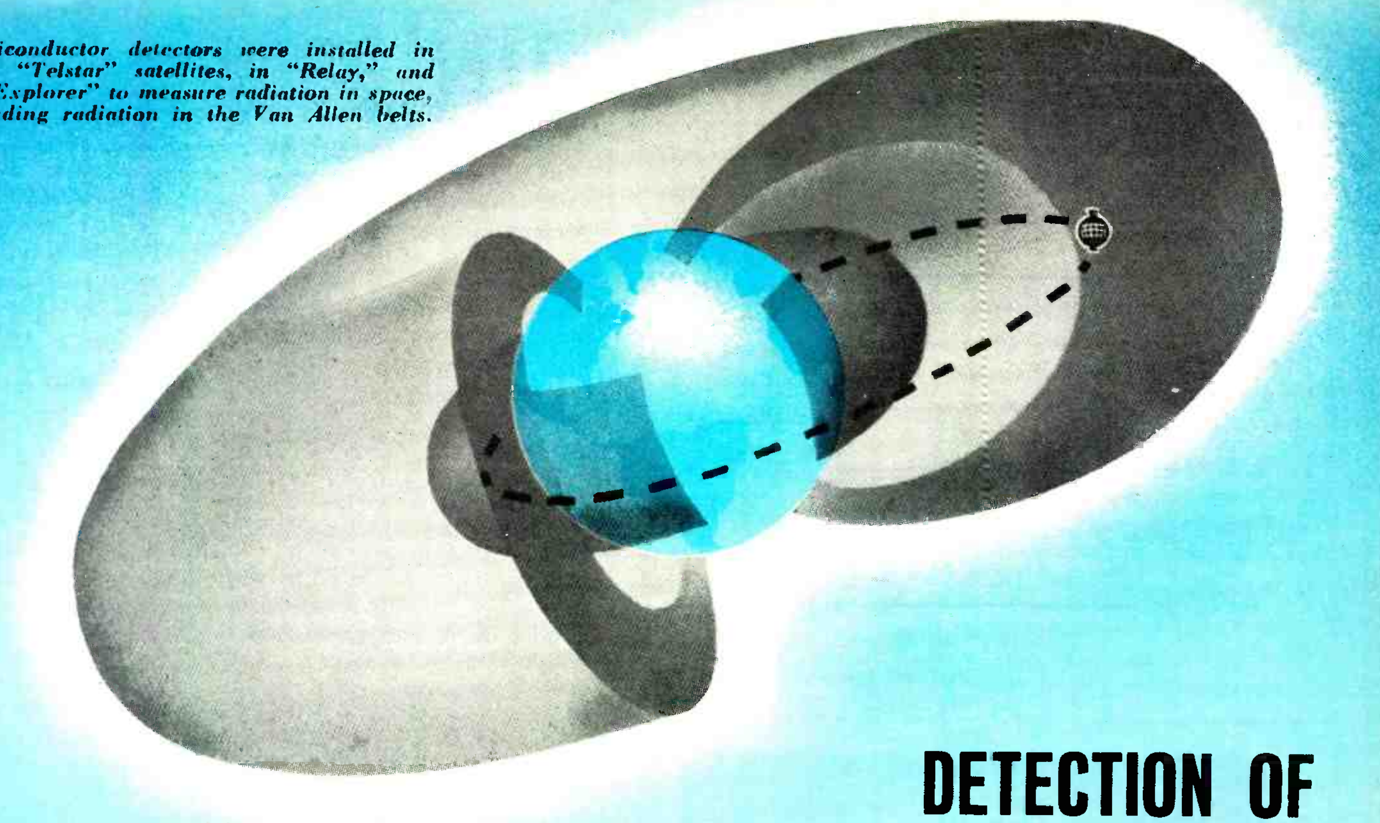
The center line is for meter resistance, whether an ammeter or voltmeter is involved. The diagonal scale on each side of the chart represents the factor by which the original range is to be multiplied. Each diagonal is doubly graduated, with the "A" scale running from 1.5 to 5 (or 10) and the "B" scale from 5 to 50. Scales for the voltage dropping resistor (left) and current shunt (right) are also doubly graduated. Always use an "A" scale with an "A" or a "B" with a "B." Value of the external shunt or dropping resistor will then be in the same units as meter resistance.

Use of the chart is best explained with an example, indicated with a broken line on the nomogram. Suppose you have a panel meter that reads 500 volts full scale and you want to read a potential known to be something over 2000 volts. The instrument is rated by the manufacturer at 1000 ohms per volt. Internal resistance is then 500,000 ohms, or .5 (in megohms) on the center scale. Increasing range by a factor of 6 will enable full-scale reading to 3000 volts.

Lay a straightedge from .5 on the center scale to 6 on the "A" side of the voltmeter diagonal. The line intersects the "A" side of the "dropping R" scale at 2.5 (still in megohms). A dropping resistor of this value in series with the meter will enable an on-scale reading, which is multiplied by 6 to determine the actual voltage. The procedure is similar, on the other side of the chart, for ammeter shunts.

The chart provides accuracy in the order of 5 per-cent, sufficient for most panel-meter applications. For greater precision you must pay the price in detailed calculation, precision components, and careful calculation. ▲





Semiconductor detectors were installed in both "Telstar" satellites, in "Relay," and in "Explorer" to measure radiation in space, including radiation in the Van Allen belts.

DETECTION OF NUCLEAR RADIATION BY SEMICONDUCTORS

By HAROLD S. RENNÉ

In order for radiation to be useful, we must be able to measure it easily, precisely, and inexpensively. Semiconductors, especially silicon, are now finding wide application in this important field.

GREAT strides have been made in the field of nuclear science in recent years. Evidence of these advances is all around us—new nuclear power plants, ships, submarines—and a continuing growth in the uses of radioactive isotopes. And nuclear radiation itself—*alpha, beta,* and *gamma* rays—is being employed in industry, medicine, and agriculture on an ever greater scale.

Food preservation by means of nuclear radiation is rapidly becoming a reality. The Army is embarking on an extensive program of testing irradiated bacon for palatability and preservation. The radiation protects the bacon from spoilage for long periods without refrigeration. And in Canada, much of the potato crop is irradiated to inhibit premature sprouting, thus prolonging the storage period of this important crop.

In the field of insect control, the screwworm fly has been almost completely eradicated in parts of the country. This was done by sterilizing male screwworms with nuclear radiation and then releasing them in infested areas. Similar techniques are being tested on many other insects with encouraging results—this may be a partial answer to the furor raised by Rachel Carson's book "The Silent Spring."

Horticulturists are using nuclear radiation to speed up mutations in plants in the interest of developing new strains that are more disease-resistant, produce larger crops, or have other desirable properties. This work has already paid off handsomely—in Michigan, a new strain of pea bean, called "Sanilac," developed by irradiation techniques, has almost completely displaced previous varieties because of its resistance to disease and larger yields. Florists now have greater variety of colored carnations, thanks to irradiation.

Industrial applications of both nuclear radiation and radioactive isotopes are legion. Radiation improves the properties of many materials, including some plastics, and *gamma* rays are used extensively for the nondestructive inspection of welds, castings, and the like. Radioactive tracers are widely employed, for example, in checking the wear on piston rings, locating leaks in pipes buried in concrete, checking the efficiency of washing machines, and in many other applications too numerous to mention. And nuclear power sources for satellites, remote weather stations, unmanned navigation buoys, and the like have been developed in which the heat resulting from the disintegration of a radioactive isotope, such as strontium-90, produces electricity directly through the use of thermoelectric elements.

In the medical field, significant advances have been made in the use of radiation to treat cancer and other diseases. Radioactive isotopes are now fed to or injected in human beings, and the paths followed by these isotopes are checked in various diagnostic and therapy applications, such as a diseased thyroid. Selective radiation in various parts of the body can be carried out by administering radioactive isotopes which concentrate in the portion of the body under treatment. Very precise, localized treatments can be administered in this manner.

We could fill an entire book by merely listing the many applications of nuclear radiation. However, the foregoing examples will serve to drive home the point that this field is expanding rapidly and that it touches most of our lives in one way or another.

These examples also serve to emphasize another point. To

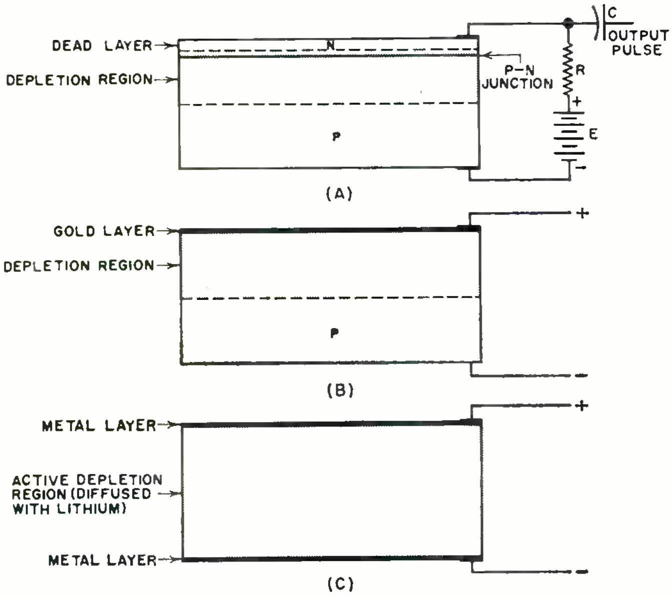
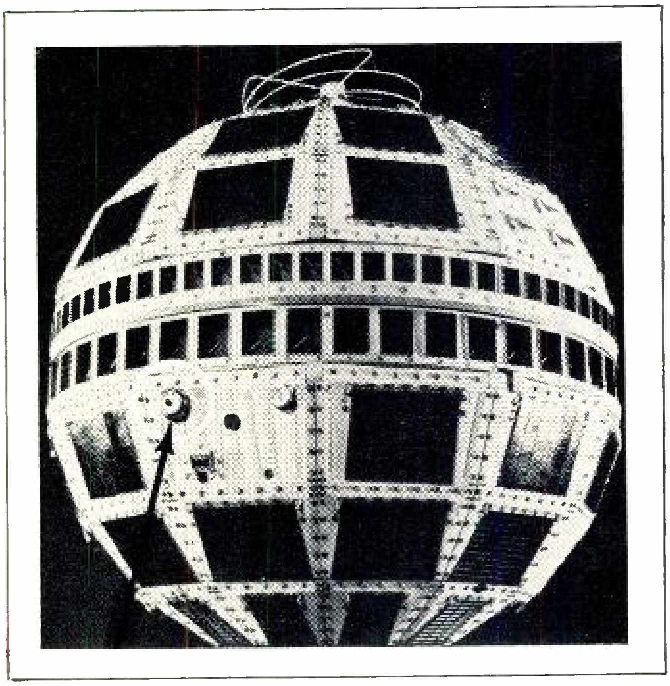


Fig. 1. Three basic types of silicon radiation detectors. (A) Junction, (B) surface-barrier, (C) lithium-drift types.



The "Telstar II" communications satellite. There are 3600 solar cells on its surface. The two rows of microwave antennas around the center receive signals sent up to satellite and relay them back to earth. On the panel at left center, just below the antennas, is a silicon radiation-measuring device. An electron detector, it measures electrons in the range of 750,000 to two million electron volts.

be useful, we must be able to measure radiation easily, precisely, and inexpensively. It might be said that the usefulness of nuclear radiation bears a direct relationship to the ease with which it may be measured. For we must be able to administer precise doses in many applications, and must be able to measure these doses so we will know what has been administered. For these reasons, measurements in the field of nuclear science play an extremely important role in its application.

However, before we can discuss measuring equipment, we must know what we are trying to measure. The main products of a nuclear reaction, and the products which we want to measure, are *alpha* rays (helium nuclei), the *beta* rays (electrons), *gamma* rays, and neutrons. In some cases we want to measure the intensity of the radiation, that is, the rate at which it strikes an object or area. Devices for making such measurements are called "ratemeters." In other cases, we are interested in the total amount of radiation, or dosage, calling for an instrument which is known as a "dosimeter."

In addition to knowing what we are measuring, we must have a standard to go by. The most commonly used unit is the *roentgen* (abbreviated *r*) which is defined on the basis of ionizing ability of the radiation in air. Multiples and submultiples of this unit are also employed. The *megaroentgen (Mr)* is a million roentgens, and the *milliroentgen (mr)* is one-thousandth of a roentgen. A total dose, or quantity of radiation, is then measured in roentgens.

If it is radiation intensity that we are concerned with, the customary unit is *roentgens per hour (r/hr.)* or, for low levels, *milliroentgens per hour (mr/hr.)*.

Conventional Measuring Instruments

A number of different physical phenomena have been exploited in the measurement of nuclear radiation. These deal with the effects produced by such radiation on different materials. For example, there is the phenomenon of ionization—*alpha*, *beta*, and *gamma* rays will all produce varying amounts of ionization in a gas. The rays will expose photographic films—and will cause chemical reactions in various chemicals. In certain materials, flashes of visible light will be emitted when struck by radiation. The materials are then said to "scintillate." All of these phenomena have been utilized in commercial units now on the market.

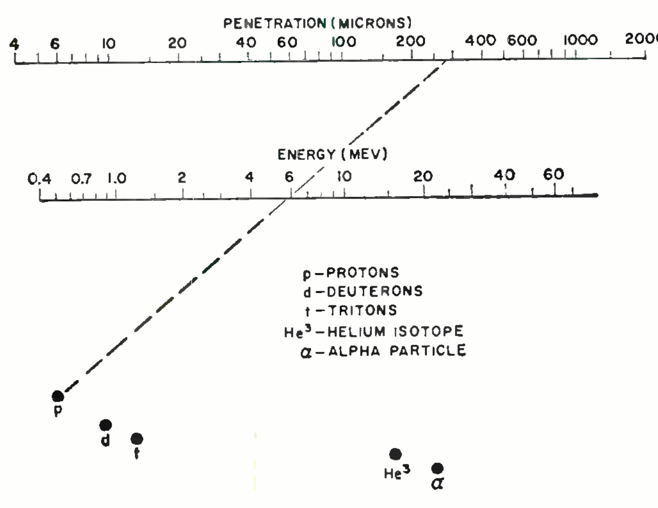
Ionization. Geiger counters make use of a Geiger tube, which is nothing more nor less than a gas-filled tube with suitable electrodes for sweeping out the ions. Some measuring instruments use ionization chambers—again, a gas-filled chamber with an arrangement for removing the ions produced by the radiation.

Photographic Film. The fact that nuclear radiation will expose photographic film is the basis for an instrument known as the "film dosimeter." This instrument indicates the total dose of radiation received during the time the film is exposed. The density of the developed film is a measure of the total exposure and, with proper calibration, the dose of radiation can be measured with a very high degree of accuracy.

Chemical Dosimeter. Chemicals of various kinds can be employed to measure the total dosage of nuclear radiation. Certain chemical reactions take place under exposure, and the extent of these reactions is a measure of the total dose. Changes in color, acidity, transparency, as well as other characteristics may be employed in order to determine total exposure.

Scintillators. In scintillation counters, the flashes of light which are produced by nuclear radiation are counted by a

Fig. 2. Nomogram for determining depth of penetration in silicon for particles having various amounts of energy.



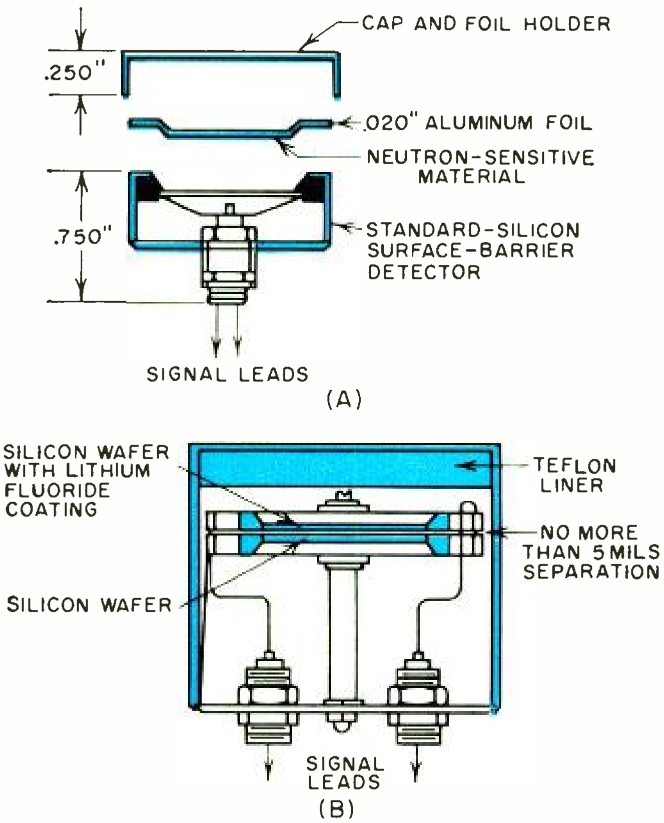


Fig. 3. (A) Cross-section of surface-barrier detector for neutron detection. Neutron-sensitive material is deposited on aluminum foil. (B) Fast neutron sandwich detector.

photomultiplier tube, together with suitable circuitry. The rate at which the flashes are produced gives an indication of the intensity of the radiations, and the total number of flashes indicates the total dose.

Semiconductor Detectors

There are three main effects to be considered when studying the use of semiconductors in measuring radiation. First there is an effect which is very similar to ionization in a gas, namely, the formation of electron-hole pairs in the material. Then there is the fact that semiconductors can become damaged when subjected to radiation. This damage is not the same as that suffered by the decoding transistors of "Telstar I," where trouble was apparently caused by gas ionization within the transistor encapsulation. Finally, there is the phenomenon in which electricity is produced when radiation strikes a semiconductor diode—as in a silicon solar battery.

As mentioned before, nuclear radiation will produce electron-hole pairs when it passes through a semiconductor material such as silicon. Harnessing this phenomenon then involves removing these electrons and holes from the material before they can recombine, and then counting or measuring the number of "pairs" that have been formed. The use of silicon instead of a gas has a very great advantage in that for a given amount of energy lost by the incident radiation, approximately ten times as many charge carriers are formed. About 3.5 electron volts of energy are required to form one electron-hole pair in silicon. The problem of sweeping out the electron-hole pairs has been solved in a number of ways.

Junction Detectors

Application of an electric field to a material such as silicon can result in large leakage currents, since silicon is not a perfect insulator. However, by first forming a *p-n* junction in the silicon and applying a reverse bias, that is, applying a negative potential to the *p* region and a positive potential to the *n* region, the leakage current can be kept extremely small. Application of this reverse bias produces a "depletion layer" in the silicon. This is a region in which all electrical charges are swept out as fast as they are formed, and thus the region is, in effect, an insulator. See Fig. 1A.

When a nuclear particle such as an electron or proton strikes this region, electron-hole pairs or ions are formed. The impressed voltage then sweeps these ions to the appropriate electrodes, where they are collected and measured by suitable electronic circuitry. A single ionizing event would then cause a single pulse in the output, the size of this pulse depending on the number of hole-electron pairs that were formed.

Conventional techniques, such as diffusion, are employed in forming the *p-n* junction. Slabs of ultrapure high-resistivity *p*-type silicon from .5 to 1 centimeter square are cut from a single crystal and are carefully cleaned and processed in the same manner as in the production of semiconductor transistors and diodes. The proper impurity, which may be phosphorus, is then diffused a very short distance into the surface, forming a thin layer of *n*-type silicon. Electrical contacts are then made to this surface layer and to the bulk material, and the detector is ready for operation.

It will be noted that electron-hole pairs formed in the surface *n* layer are not collected, and are lost. Therefore, every effort is made to keep this layer as thin as possible so that it will introduce a minimum loss. This so-called "dead" layer

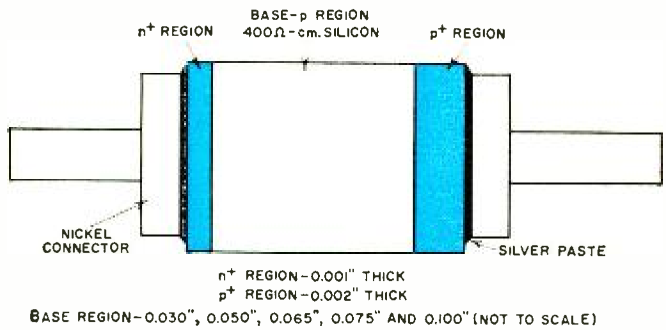


Fig. 4. An experimental silicon diode neutron dosimeter.

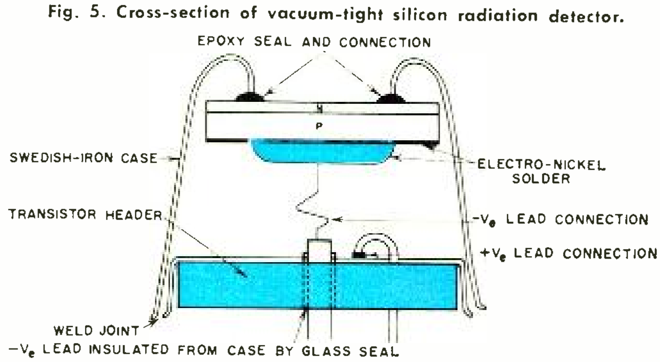
may be made as thin as 0.1 micron, so thin, in fact, that practically no hole-electron pairs are formed here, giving an essentially windowless detector.

The thickness of the depletion layer depends on a number of factors, the two most important being the resistivity of the *p*-type silicon, and the voltage applied across the junction. It is desirable to get as thick a region as possible in most cases, so that the incoming radiation will produce a maximum number of hole-electron pairs. Thus, high-resistivity silicon is employed, and a high bias voltage is used.

Reports from *Bell Laboratories* indicate that diffused junction detectors have been fabricated with a depletion layer thickness of as much as 0.7 millimeter at 400-volt bias. This is sufficient to stop a proton which has an energy of 10-million electron volts.

Another factor to consider in the use of junction radiation

Fig. 5. Cross-section of vacuum-tight silicon radiation detector.



Semiconductor radiation devices come in many sizes and shapes.

detectors is their capacitance. The output signal energy of the detector is inversely proportional to the capacitance of the device. Thus it is important to minimize this capacitance to as great an extent as possible.

Surface-Barrier Detection

A highly satisfactory junction detector can be made by using the surface-barrier technique, as shown in Fig. 1B. Such detectors are formed by evaporating gold onto *p*-type silicon, forming a junction. When a suitable bias is applied, a depletion layer is formed as before, and the device functions in much the same manner as the diffused-junction device. Both techniques have been employed extensively in commercially available devices.

In surface-barrier devices, the radiation must penetrate the gold layer before it can be detected. Therefore, the layer is kept very thin—on the order of 150 angstroms—so there is essentially no "dead layer" or absorption. The Oak Ridge National Laboratory has produced depletion layers as thick as 1.7 millimeters in its surface-barrier detectors.

Lithium-Drift Detector

For some applications, it is desirable to have a much thicker active layer than it is possible to achieve using either of the above techniques. Such devices might be necessary in measuring very penetrating radiation, such as protons in excess of 10-million electron volts. The lithium drift technique has been developed for producing thick layers (see Fig. 1C). Sensitive thicknesses of up to 5 millimeters have been reported.

In low-resistivity *p*-type silicon there is an excess of positive charges, or acceptors. By introducing carefully controlled amounts of lithium, these excess acceptors are compensated for and very-high-resistivity silicon and a large depletion layer result. The depletion layer can extend clear through the material. A big advantage of this device is that it can be operated at relatively low reverse bias voltages. However, it appears to be much more sensitive to radiation damage than the diffused silicon detector.

The detectors just discussed are not particularly suited to measuring *gamma* rays. Because of their penetrating power, such rays will readily pass through depletion layers of the thicknesses we have been discussing, forming few or no ions. However, most fission products, including *alpha* rays, *beta* rays, protons, deuterons, tritons, and fission fragments can be easily measured. If the particle is completely stopped in the depletion layer, the size of the output pulse is a direct measure of its energy. Thus, with suitable instrumentation, the silicon detector can be employed to measure the energy of incoming particles.

The penetrating power of various particles in silicon is given in the nomogram of Fig. 2. If the energy and type of particle are known, the range in microns can be determined directly. For example, the dotted line in Fig. 2 shows that a proton with an energy of 6 million electron volts will penetrate almost 300 microns of silicon.

Neutrons in general will pass through silicon without producing an appreciable number of electron-hole pairs. To use silicon diodes to measure neutrons, a "converter" layer is placed over the diode. This layer may contain lithium atoms, which react with neutrons to give a triton (isotope of hydrogen with an atomic number of 3) and a helium atom. These particles are then measured by the silicon diode. Typical construction for a device of this kind is shown in Fig. 3A. Sometimes, two silicon detectors are sandwiched together with a coating of lithium fluoride on one of the wafers. The basic detection principle is the same as before. See Fig. 3B.

Silicon radiation detectors have a tremendous dynamic range, that is, they can be employed for measuring radiation intensities varying from a small fraction of a milliroentgen per hour, or a few counts per minute, up to the limit of available electronic equipment which can be on the order of hundreds of thousands of counts per second. Also, since the size of the output pulse can be measured, the energy spectrum of the incoming radiation can be determined. This can be extremely useful in identifying the specific radiation or identifying the radioactive isotope which is producing the radiation.

An interesting application of silicon detectors is their extensive use in measuring radiation intensity in space, including the Van Allen belts. Systems were installed in both "Telstar" satellites, in the "Relay" satellite, "Explorer XV," and others. With appropriate shielding and the use of magnetic and electric fields, these detectors have been used to count electrons, protons, and other charged particles of widely varying energies in areas of outer space.

Radiation Damage

Radiation can damage semiconductor devices—both diodes and transistors. Some work has been done in an attempt to utilize this phenomenon in developing a radiation measuring device, but as far as the author knows, no such device is commercially available.

Radiation damage acts to slow down the rate of diffusion of minority carriers in silicon. The current-gain characteristic of a transistor made of silicon de- (*Continued on page 70*)

CALIBRATING TEST EQUIPMENT

Accuracy goals depend on applications and the quality of instruments being checked. For any situation, however, satisfactory standards or facilities can be worked out.

By WALTER H. BUCHSBAUM, Industrial Consultant

HOW MUCH precision should one expect and how much can actually be realized when one is calibrating test instruments? What standards can be or should be used? How does one go about doing the job or getting it done? The answers to these questions will depend on who wants the calibration performed, the type and quality of the equipment whose accuracy is to be checked, and finally the use to which this equipment will be put. These requirements allow for a wide variation in the results that will be obtained.

Consider one of the less demanding situations. When a technician wishes to check the "B+" in a radio or TV receiver, it is not too important if the nominal 250 volts is actually measured at 262.5 or 237.5 volts. If voltmeter accuracy is 5 per-cent, this alone could account for the 12.5-volt difference. Variation in line voltage could just as well be responsible. If both line voltage and the meter reading are down, only 225 volts might be read. Deviation would have to be at least this great and probably larger before the technician would begin to consider the possibility of a defect. Although the accuracy requirements here are not demanding, they do exist. If voltmeter error were, say, 10 per-cent or greater and the user did not know this, he could be misled.

In industrial and military electronics, on the other hand, standards are much more critical. Laboratories, factories, and installation facilities often allocate considerable time and money to the maintenance of test equipment accuracy. In fact, government contracts conventionally carry clauses requiring that all test equipment be calibrated carefully against approved standards at least once every six months.

Reference Standards

In the United States, the exact electrical values for voltage, current, frequency, resistance, capacitance, and inductance are determined by the National Bureau of Standards of the Department of Commerce. Laboratory or secondary standards for these electrical parameters are measured against the Bureau's primary standards at certain regular intervals and are then certified as to their accuracy.

Calibration against certified standards is generally a specialized job. Large organizations maintain special departments for this purpose. Smaller companies send or bring their equipment to nearby laboratories that offer a calibration service.

When such service is required on an outside basis, there should be little difficulty in locating a suitable agency. A request is addressed to the Bureau of Standards, either at Washington, D.C., or to the office in Boulder, Colo. The Bureau will advise where standards of the required type are available in the writer's locality. Each of the three armed services also maintains standards laboratories, which are available to qualified commercial firms. A qualified firm is one that holds a contract with the particular service. It can obtain permission to use standards facilities through the project director.

All major military bases involving electronics maintain standards facilities. Well known bases include the Signal Corps at Fort Monmouth, the Naval Research Laboratories, and the Air Force's Wright Field. For security reasons, the services avoid publicizing all such locations.

In addition, the Air Force maintains a fleet of trailer trucks, each of which carries a complete set of calibrating standards. These mobile laboratories insure precise measurements by making the rounds of various Air Force installations and enabling frequent checks on test equipment calibration.

Although elaborate facilities of this nature are a far cry from what the aforementioned technician would need, many of the problems and principles are common. The technician in a non-critical role is mostly concerned with calibrating a.c. voltage, d.c. voltage, direct current, and resistance on his v.o.m. and v.t.v.m. These will be the most important ones, although there will also be some interest in capacitance, inductance, and frequency. While the required accuracy is much greater in industrial and military applications, essentially the same quantities are involved.

There are a number of references and methods that can be used to insure accuracy in non-critical situations short of comparison against certified NBS standards. Since these involve measures that may be applicable at any level of calibration they will be discussed first.

Basic Meter Checks

Conventional voltmeters, used everywhere for measurement of basic electrical quantities, include the v.o.m. and v.t.v.m. Such instruments are most often specified to have an accuracy of ±3 per-cent for the d.c. scales, ±5 per-cent for the a.c. scales, and still less for resistance measurements. Many users still overlook the implication of the clearly stated qualification that the specified accuracy is with respect to full-scale reading.

Consider a typical instrument with a 250-volt d.c. range and a full-scale accuracy of ±3 per-cent. This means it could be off 7.5 volts not only at 250 volts, but at any other reading on that scale. This same voltage discrepancy would then amount to 7.5 per-cent error if 100 volts is being read. If 15 volts is being measured on the same range, allowable error could be as much as 50 per-cent.

Fig. 1. The Eppley Standard-Cell Voltage Reference, accurate to .005% or better, is tapped in ten steps up to 10.193 volts.

Fig. 2. An a.c.-powered, well-regulated standard, the VS-10 by North Hills Electronics, provides d.c. reference output.

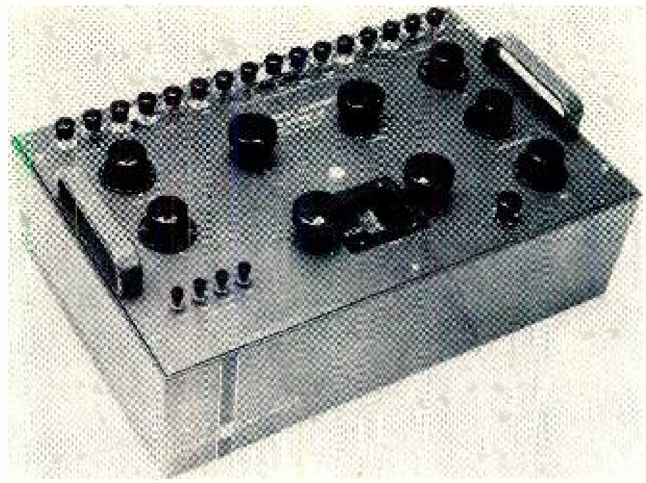


Fig. 3. A universal potentiometer by Leeds & Northup. It combines a standard voltage reference with precision resistors and a closely calibrated potentiometer for fine resolution.

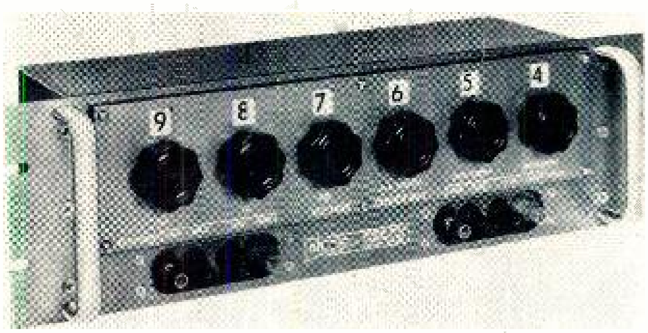


Fig. 4. A resistive voltage divider made by North Hills Electronics. It is made for use with an external voltage source.

In practice, down-scale accuracy is considerably better than what these figures suggest. If the meter movement were a perfectly linear device, percentage accuracy would be the same at any point on the scale. However, there is some non-linearity in the magnetic meter circuit and some introduced mechanically by the use of springs and weights that balance the movement. Since calibration by the manufacturer is made at the full-scale end, the cumulative effect of errors will be experienced at the low end of the scale. It is therefore preferable, when possible, to use a range that permits readings to fall in the higher end of the scale.

The first step in checking a meter is to make sure that zero indication is accurate. The pointer is set, if necessary, *via* the external adjusting screw with the instrument in its normal operating position. The instrument should be on its lowest d.c. range, with all test leads disconnected.

Meter bearing balance is checked next. While all calibration will be performed in the instrument's normal operating position, the pointer should show no tendency to stick when the meter is tilted through any of the three major axes. If the pointer does not return to zero after tilting, rebalancing is needed. This is a job for an expert. The instrument manufacturer or an authorized agency should be used.

If balance is good, d.c. voltage ranges are checked by measuring a known voltage source. The most elementary source is the widely available 1.5-volt, carbon-zinc cell which, under certain conditions, will give good accuracy. To begin with, a large cell with screw terminals is preferred to a flashlight size. The battery should also be unused, and reasonably fresh. The nominal voltage usually given for calibration is 1.55 volts. Actually an unused cell about two years old will probably still measure about that much, whereas a fresher one may read about 1.58 volts. However, this range of variation is no more than ±1%, which is well within the specified accuracy for conventional meters. As a rule, the owner will consider his instrument does not need recalibration if it reads anywhere between 1.5 and 1.6 volts. At worst, error in this case is not likely to exceed ±3%.

Higher d.c. voltages and scales can be checked by combining single cells in series. This is not recommended, however, as it builds up margin for uncertainty. Anyone who is really interested in maintaining a v.o.m. or v.t.v.m., or several such instruments, at good accuracy should consider investing in something better. Mercury cells, for example, are available that will maintain accuracy well within 1 percent over a period of several years. They can be obtained in calibration sets that include several in a single housing, in a series, with taps between cells, Still better, so-called "working standard" meters are available for less than $100. Typical of these is the *Weston* 931 series, accurate to ±0.5%. With one such, a single, accurate voltage source is not necessary. The instrument to be checked and the working standard monitor any voltage source or sources simultaneously, and readings at various voltage levels are compared.

On d.c. voltage checks, the lowest range is always calibrated first. In some meters, it is possible to adjust the series resistance here if calibration is seriously off. In most cases, a fixed resistor must be replaced. The next higher range is checked, and so on up to the highest. Resistors added in the voltage divider in each successive range are adjusted, if necessary.

The d.c. current ranges are checked out next, starting with the lowest first. If a standard calibration source is not available, a known voltage and precision resistors are required. Current is calculated with Ohm's Law. In addition to the value of the calibrating resistors, input resistance of the meter on each current scale must be considered in calculating current. Possible error introduced by deviation in the latter resistance value can be made insignificant by choosing calibrating resistors whose values are many times higher than that of the meter. Percentage accuracy of the calibrating resistors is determined by the degree of accuracy required. Proceeding from current scale to scale, the values of successive meter shunts are corrected as needed.

Accuracy of the a.c. ranges is affected by frequency and waveshape of the voltage being measured and by components in the rectifier system, as well as by divider resistors. A reasonably good oscilloscope will make a reliable monitor for checking sinusoidal waveshape and will also indicate voltages in terms of peak-to-peak values, if it incorporates a voltage calibrator or is used in conjunction with one.

Good waveform is needed because the average meter does not respond to r.m.s. value directly. It is calibrated to read r.m.s. equivalent value on true sinusoidal a.c. only. If the scope shows that waveshape of the available 60-cps or 400-cps source is distorted, a good audio oscillator can be used. To convert scope peak-to-peak readings to r.m.s. equivalents, divide the former by 2.83 (or multiply by .353).

Inaccurate readings on a.c. may be due to faults in the a.c. rectifier system in addition to deviations in the divider resistors. Rectifier faults are most likely to show up as inaccuracy in the lower end of all scales. (Even with a good system, meters tend to be less accurate in down-scale readings than they are on d.c.) Although a calibration resistor is usually included in the rectifier assembly, the best cure for a fault here is replacement of the entire system with a new assembly obtained from the meter manufacturer.

Resistance scales are checked last. At best, the ohmmeter function of a multi-purpose meter is not designed for high precision and should not be used when such accuracy is required. The ohmmeter tends to be more accurate near the center of its scale than at either end, so calibration should be performed with precision resistors whose values fall in the center portion of each scale. The best one can hope for is good accuracy and scale-to-scale uniformity in this portion. The degree of error in extreme up-scale and down-scale readings can then be recorded and used to compensate readings taken subsequently in actual measurement.

More Accurate Standards

Certification of a standard by the NBS does not necessarily mean it is the most precise type that can be obtained; it simply provides assurance that the standard does indeed meet whatever accuracy it specifies. How much certified accuracy should be obtained depends on the instrument being calibrated. For example, the *Eppley* Standard-Cell Voltage Reference, shown in Fig. 1, provides ten taps from 1 to 10 volts d.c. with accuracy within ±0.005%. It is available from the *Eppley Laboratory* in Newport, R.I., for about $240. Such cells must be used in bridge circuits where little or no current is drawn.

An establishment that maintains a considerable number of service-type voltmeters for ordinary work might consider such an investment. If these meters are rated at ±3% accuracy, the standard would be more than adequate, as standards should ordinarily be at least twice as accurate as the instruments they will be used to check. If the establishment also uses a digital voltmeter or several for more critical work, and the latter is rated at ±0.01%, purchase of the *Eppley* reference would be all the more worthwhile—but the standard would now be just about sufficient. These cells can be held to ±0.001% if ambient temperature is controlled.

While the mentioned sources depend on chemical action, there are also voltage and current references that are purely electronic. One such is the so-called "Solidcell" in Fig. 2, available from *North Hills Electronics* of Glen Cove, N.Y., for $750. Although a.c.-powered, it depends on a zener diode in a temperature-controlled box for an output of 10 volts d.c. Its guaranteed accuracy is also ±0.005%, but it does not suffer from changes due to aging, overload, and ambient temperature in the way that chemical sources do.

Some instrument companies offer specialized calibration sets that combine such facilities as voltage and current sources for d.c. and a.c. with precision resistors, capacitors, and inductors. *Weston Instruments* of Newark, N.J. offers such sets. A simple voltage source, after all, is not self-sufficient for calibrating a variety of ranges.

In voltage calibration, it is often advisable to use a standard high enough for the high scales and employ a precise resistance divider for lower voltage scales. A "universal potentiometer" of this type, made by *Leeds & Northrup* of Philadelphia, Penna., is shown in Fig 3. It combines a standard voltage source with resistors and a potentiometer of exceptional precision. Voltage accuracy is rated to ±0.01% and readable output down (*Continued on page 76*)

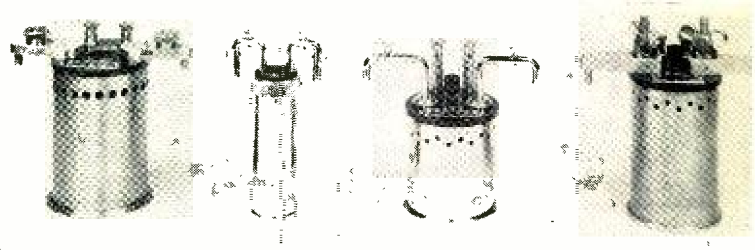


Fig. 5. Thomas standard resistor (left) is rated at 1 ohm to .0001%. Units to right are other low-resistance standards.

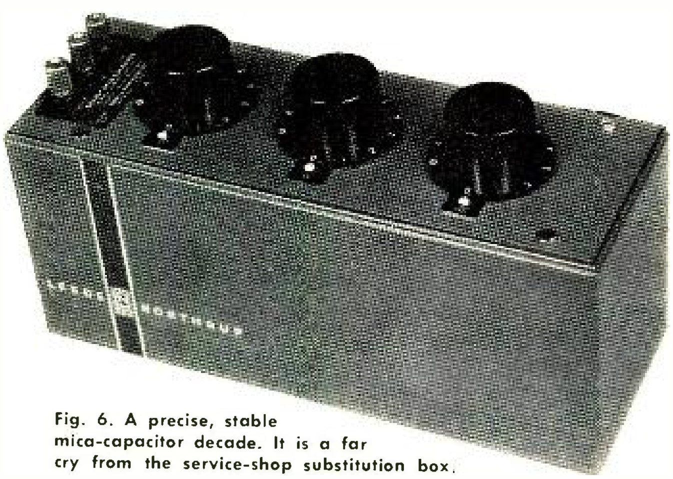
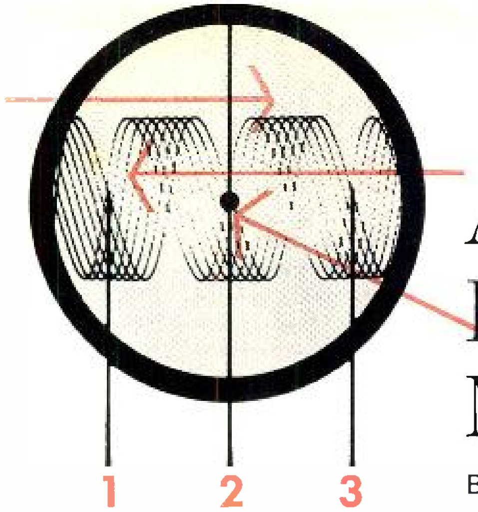


Fig. 6. A precise, stable mica-capacitor decade. It is a far cry from the service-shop substitution box.

Fig. 7. Three sets of carefully wound coils interact in the Brooks "Inductometer" for inductance readings on a linear scale.



ACCURATE AUDIO FREQUENCY MEASUREMENT

By AARON W. EDWARDS/Technical Research Laboratories

A novel method, accurate to within a few hundredths of a cycle, that requires only a scope, stop watch, and a source of accurate tones, such as from WWV.

TECHNIQUES for making absolute determinations of many physical quantities have been greatly refined in the past several years. Accuracies far beyond the requirements of ordinary practical application have been attained in a number of laboratories, including the National Bureau of Standards at Boulder, Colorado. Their announcements of the correctness of such quantities as time, for example, leave one shaking his head in profound admiration.

Less exacting accuracies, but still constituting a high order of precision, are achieved regularly in development laboratories, on missile ranges, and in various industries where research and data reduction are performed. It goes without saying that the apparatus required for the orders of precision produced at the National Bureau of Standards is very elaborate. Even the comparatively modest equipment of the other cited activities is far more costly than most individuals could afford.

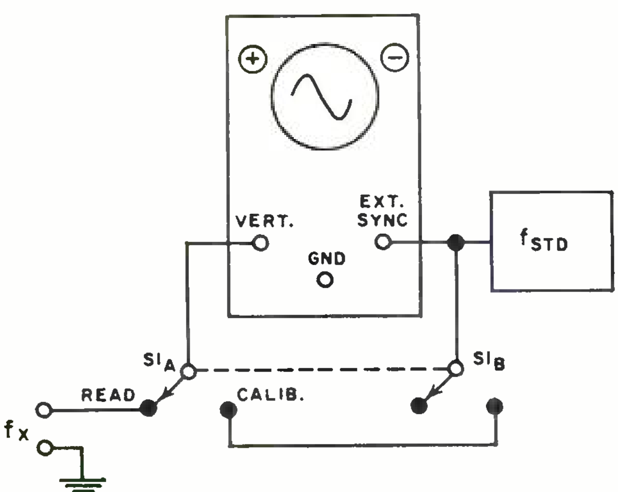
Thus the author feels justified in describing a technique by which satisfactory determinations of audio frequency—out to within a few hundredths of a cycle—may be made with "garden-variety" tools. The items involved in this cycle-slicing are: a reasonably good oscilloscope; a stop watch; and a source of accurate tones—such as those transmitted by the NBS's stations WWV and WWVH.

For several years the author has been concerned with making accurate quantitative measurements of certain data. Usually this data has been stored on magnetic tape and played back for analysis, but continuous "live" inputs are equally susceptible to analysis. The author developed many methods and techniques for extracting and analyzing the acquired data. He had at hand the finest oscilloscopes, electronic counters, and other auxiliary equipment that could be purchased. Yet, the accuracy usually required for the satisfactory solution of the analyses performed was less than that possible with the simple technique to be described here.

This possibly surprising statement may require clarification. The use of an electronic decade counter made possible rapid and accurate frequency determination to within the inherent counter readout error, which was ± one count. Since the quantities involved were mostly on the order of several hundred to several thousand cycles per second, an error of one count is negligible. Even at 100 cps, one count is only 1%; and at 1000 cps, the same error is only .1%.

Thus it is that, under certain conditions, the accuracy of an electronic counter may not only be duplicated, but may be exceeded, with the procedure to be described. This method is essentially an accurate, interpolative process of determining difference frequencies, or beats. One might say this method takes up where the counter leaves off.

Fig. 1. Suggested switching arrangement and equipment hookup.



Equipment Required

The mention of oscilloscope quality should be amplified, too. In this application, the scope is merely the display and indicating device; a comparator, if you please. The burden of accuracy is shared by the standard chosen and the finesse with which the timing operation is performed. The oscilloscope sweep speed must be capable of being controlled by an external source. This control signal is fed into the external sync binding post. The scope's sync circuit is required only to behave well enough not to lose sync during measurement. Most oscilloscopes will perform satisfactorily.

Fig. 1 illustrates the basic equipment connections and a suggested switching arrangement. For purposes of this illustration, let us assume we have as a standard a 1000-cps electronic tuning fork. (Some of these units are of exceptionally high accuracy and stability.) The actual choice of frequency for f_{std} will depend on the approximate value of the unknown frequency, f_x. Generally, it is desirable that the value of f_{std} be much greater than that of f_x.

Notice that the drawing of the oscilloscope includes the two symbols "+" and "−". These may be painted on the scope case if one wishes, or they may be marked on a piece of masking tape or gummed label and merely stuck in the indicated places; the "+" to the left side of the CRT, the "−" to the right side. Their use is in making the determination of whether the derived difference in frequency is additive or subtractive. The function of S1 is to switch the Y-axis or vertical input between the known (standard) and unknown sources.

The stop watch should, preferably, be one that is calibrated in hundredths of a second. This is not mandatory, but the use of such a watch reduces the likelihood of introducing counting or calculating errors.

Measurement Procedure

With the oscilloscope connected as shown and warmed up, check that the following conditions also obtain: The external sync pot is at a neutral (zero) position; that is, no sync is applied. The sweep frequency controls are set to the appropriate range for displaying the unknown frequency. The brightness, focus, and gain controls are set to give a good image. The image should be positioned so that it is totally visible and centered approximately on the center line of the CRT face. This being done, the actual measurement procedure is as follows:

Step 1. Place S1 in the "Read" position. The unknown frequency is now deflecting the scope trace. No sync voltage is applied. By adjusting the coarse and fine sweep-speed controls, obtain a single cycle of the unknown frequency on the CRT (see Fig. 2A). Carefully adjust the fine frequency-control pot to make the single cycle hold stationary, or as nearly so as is possible. *Do not use sync.* (This step is only to determine which fraction of f_{std} is involved.)

Step 2. Place S1 in the "Calibrate" position. It is unlikely that a stationary pattern will be obtained. (If this pattern *is* stationary, check to see that the sync control has not been turned off the neutral spot.) *Cautiously* re-adjust the fine sweep-control pot up or down in frequency, depending on which direction gives the shortest route to obtaining a stationary pattern. (Hint: If the pattern drift is left, or toward the "+" side, slowly turn the pot clockwise to arrest the pattern. If drift is to the right, turn slowly counterclockwise.) When the pattern consists of some whole number of sine waves (say 3, 5, or 8), first attempt to stabilize the pattern by carefully adjusting the fine sweep speed. Then carefully inject the sync signal, *via* the "Ext. Sync" control, so that the pattern is firmly locked. At this point the sweep rate is being accurately controlled by the standard frequency.

Step 3. Suppose that the pattern obtained in this manner consists of 8 sine waves. Note: It will be necessary to allow for a missing portion of the last cycle, due to flyback time. See Fig. 2B. The exact sweep speed is now the frequency of the standard being used (1000 cps in this case) divided by the number of cycles seen, or 1000/8 = 125.00 cps.

Step 4. Return S1 to "Read" position. Observe the direction of trace movement, but *do not touch any controls.* On a sheet of paper, record the sign "+" if the pattern drift is left (Fig. 2C), or "−" if it is right. This is the sign of the correction to be applied to the last calculation.

Step 5. Immediately begin the timing operation. If the CRT has a transparent scale, or graticule, refer to it. If not, mark with grease pencil some portion of the CRT face through which a part of the trace is drifting. (See Fig. 2D.) This is the reference mark, or index. As each succeeding wave passes through this index, it will be counted.

The technique of timing and counting is very important and, if not properly done, can be a source of error. Be sure that the first counting utterance is "zero" and not "one." After observing the pattern drift long enough to pick up the rhythm of the trace movement, begin the timing. At the same instant the selected portion of the wave passes through the index, start the stop watch and simultaneously count "zero (the watch is started), one, two, three . . . etc." The greater the number of cycles counted, the more accurate is the result. For very slow drifts, or beats, a count of from 10 to 20 may be sufficient. For faster ones, it is advisable to count a minimum of 50 to 100. When a sufficient number has been counted, stop the watch. Example: " . . . 48, 49, mark!" The watch is stopped at "mark," or 50.

All is now done except the calculation. Recall that the sign of the correction was established from the prior observation of drift movement in Step 4. The amount of the correction is calculated as follows: Assume that 50 cycles were counted, and the stop watch recorded 21.42 seconds. This is equivalent to 50/21.42 = 2.334 cps. Assuming that in Step 4 an additive correction was indicated, then 125.00 (exact sweep speed) + 2.334 (difference frequency) = 127.334 cps, which is the actual value of the previously unknown frequency f_x.

Depending on the skill with which the timing is performed, the figure in the hundredths place is of questionable accuracy. (The figure in the thousandths position is only a division result, and has little significance.) An average of three to five runs should enable the actual value of that decimal to be determined with reasonable accuracy. Recall, too, that any timing error becomes smaller the more beats that are counted. Whatever the error may be, it is divided by the total count taken, just prior to the final calculation.

Discussion of the Technique

All of the foregoing instructions are theoretically sound and practical. If, however, one is restricted to a single, or

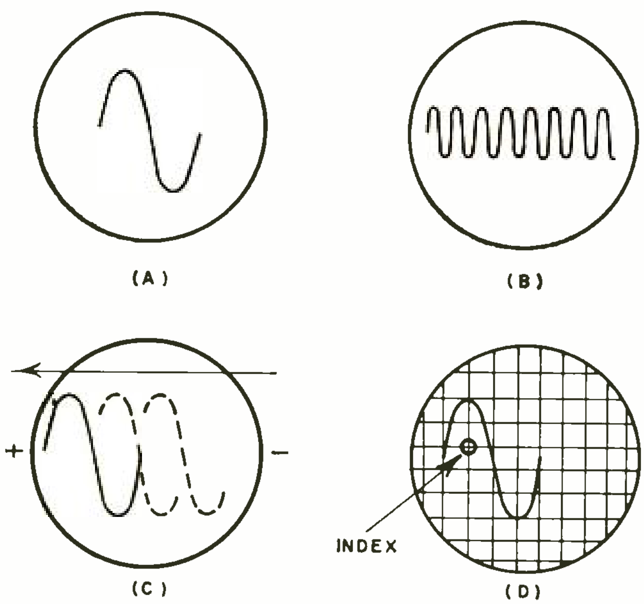


Fig. 2. Waveforms obtained during the measurement procedure.

even two sources for f_{std}, it will not be long before some inherent limitations will make themselves known. The technique has been presented in its simplest form. To make clear what kind of pattern is a desired indication, only a sinusoidal presentation has been described, as it is the most easily recognized. The patterns obtained in Step 2 are the simplest derivatives of f_{std}, that is, they are $f/2$, $f/3$, . . . $f/8$, etc. Drift rates faster than about 6 cps are quite difficult to time, by eye. Thus, strict adherence to the patterns described would permit readouts of ± about 6 cycles, of the frequency f/n.

Happily, these limitations have several solutions. Some of these do not involve a departure from the principles of economy that make this measurement technique available to the average reader. And, in any case, the limitations should not detract from the fundamental excellence of the general method. These solutions take the following form: (1) providing additional satisfactory sources of f_{std}; and (2) providing ways to count the more rapidly drifting beat pattern.

A very simple way to get more mileage from a given standard frequency is illustrated. Suppose that, for example, the unknown frequency (*Continued on page* 75)

THE OPERATIONAL AMPLIFIER

By JACK E. FRECKER / Applied Research Lab., University of Arizona

PART 2 / Applications of the unit, previously discussed, as a voltmeter calibrator, a frequency-sensitive circuit, an oscillator, a capacitance bridge, and as a multivibrator.

LAST month the theory and design of operational amplifiers were discussed and the circuit and construction of a two-amplifier unit were shown. The reader will recall that in the most general usage, shown in Fig. 1A, $Gain = E_{out}/E_{in} = -Z_f/Z_{in}$. Output impedance was assumed to be negligibly small, input impedance at point A was simply the value of Z_{in}, and the effective impedance from point B to ground was quite low. The output current capability of either amplifier was 3 to 5 ma. max. depending on output voltage.

When using the operational amplifier, the open-loop frequency-response curve in Part 1 should be kept in mind. As a rule of thumb, if the open-loop gain at any particular frequency is reduced by a factor of 100 or more by feedback, less than 1% error in calculated gain will result. In the following discussion it will be assumed that the amplifiers are always carefully zero-adjusted and that no attempt is made to use them beyond their frequency capabilities.

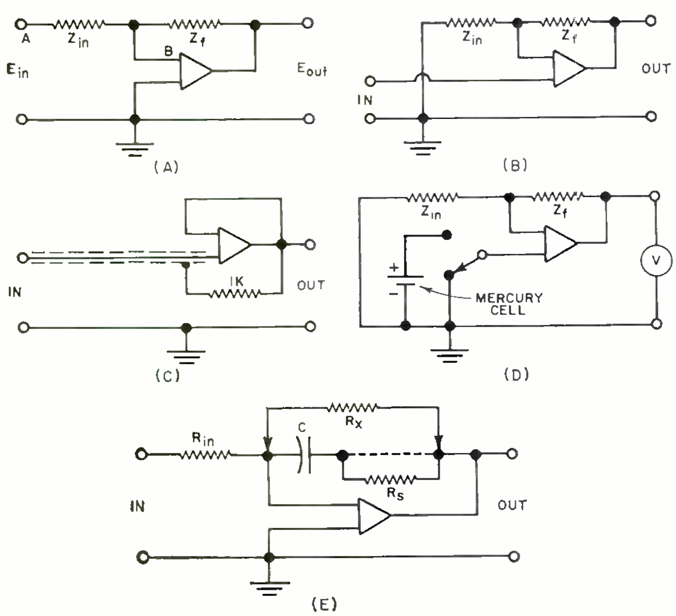
Amplifiers and Calibrator

The simplest application is that of Fig. 1A. This is a good general-purpose d.c. and low-frequency (audio) amplifier. Fig. 1B illustrates a second class of circuit and makes use of the differential input feature of the amplifier. In this circuit $Gain = (Z_{in} + Z_f) / Z_{in}$ and is non-inverting. The input impedance is between 100 megohms and 10,000 megohms, depending on the condition of the 6AU6 tubes.

By making Z_{in} an open circuit and Z_f a short circuit in Fig. 1B, the unit becomes a unity-gain amplifier similar to a cathode-follower. It is useful as an isolation device to over 100 kilocycles. Another use of this device is shown in Fig. 1C. The unity-gain amplifier is used as a coaxial-cable shield driver. As the shield is at the same a.c. voltage as the inner conductor, the effective capacity to ground of the inner conductor is reduced nearly to zero. The 1000-ohm resistor is employed in order to prevent parasitic oscillations.

Fig. 1D is the circuit of a voltmeter calibrator. With the switch in the ground position the amplifier is carefully adjusted for zero volts out. Then the switch is turned to the mercury cell and the output voltage, $E_{out} = 1.35 \times (Z_{in} + Z_f) / Z_{in}$ with a very high degree of accuracy.

Fig. 1. (A) Basic general-purpose d.c. and low-frequency amplifier. (B) Isolating amplifier. (C) Coax cable shield driver. (D) Voltmeter calibrator. (E) Integrator-circuit arrangement.



Integrators

Fig 1E is an integrator. This circuit provides a frequency-response roll-off of 6 db per octave. To use this circuit, select the frequency at which gain is to be unity and let $X_c = R_{in}$ at this frequency. Then at one-half this frequency the gain will be two, at one-hundredth this frequency the gain will be 100, and so on. R_x is necessary to provide some d.c. feedback to prevent the amplifier from drifting into its limits. It should be no larger than $1000R_{in}$. It may be less and, if so, will determine the maximum gain of the amplifier at low frequencies. Also, a resistor can be inserted in series with C. This resistor will determine the minimum gain of the circuit. With both present the circuit will have a frequency response as shown in Fig. 3A.

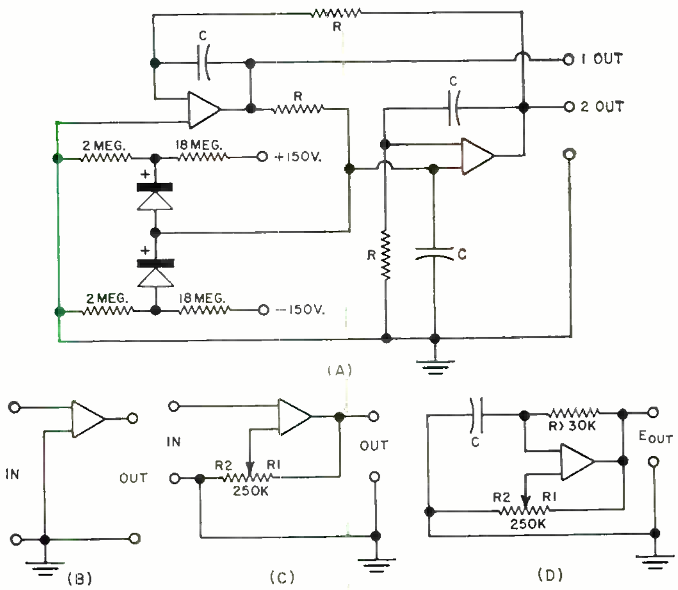
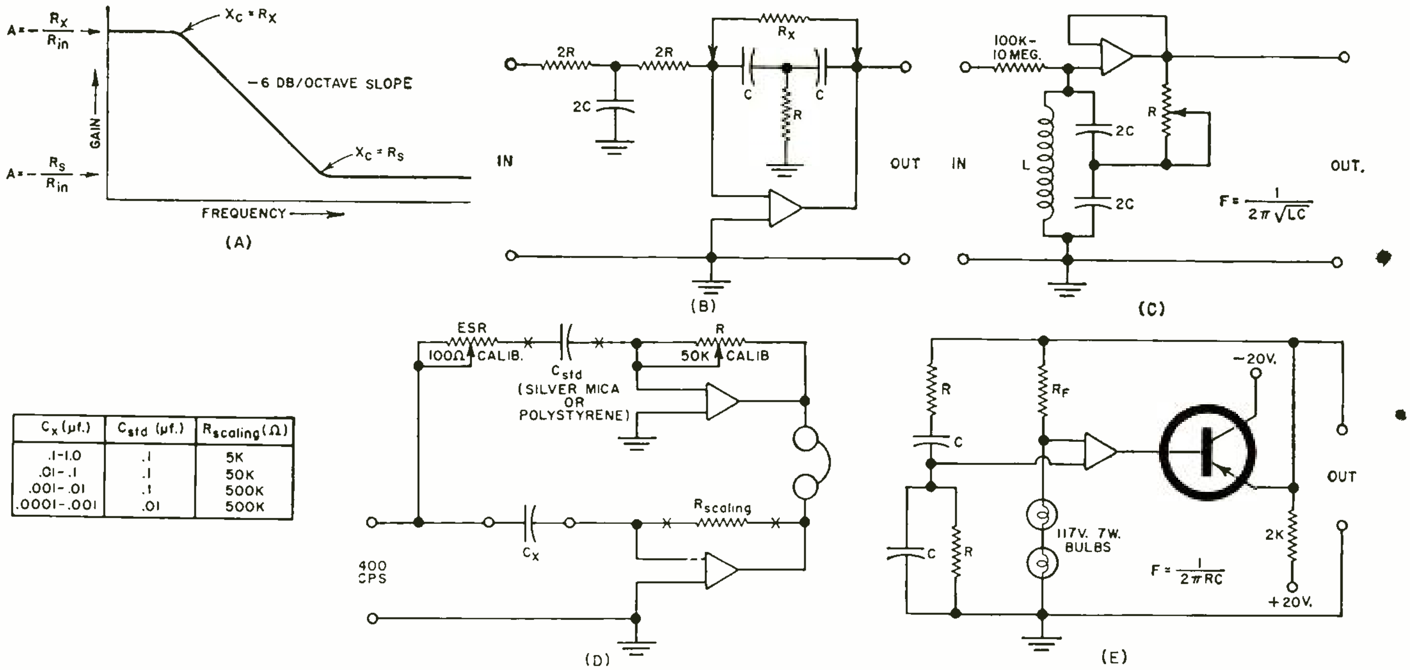


Fig. 2. (A) Modified sine-cosine oscillator. (B) Voltage comparator. (C) Circuit which adds hysteresis to transfer function. (D) One type of free-running multivibrator.

Fig. 3B is a double integrator. This circuit has a roll off of 12 db per octave. Select the frequency at which the gain is to be one-fourth and let $X_c = R$ at this frequency. Then at one-half this frequency the gain will be unity, at one-twentieth this frequency the gain will be 100 and so on.

"Q"-Multiplier and Bridge

Fig. 3C is a "Q"-multiplier. The unity-gain amplifier output is fed back into the tuned circuit in a regenerative fashion. The effective "Q" of the circuit can be raised by a factor of 50 or more with good stability, and R can be decreased to a point where "Q" becomes infinite and oscillations take place. This circuit is useful to 100 kilocycles but is at its



C_x (µf.)	C_{std} (µf.)	$R_{scaling}$ (Ω)
.1-1.0	.1	5K
.01-.1	.1	50K
.001-.01	.1	500K
.0001-.001	.01	500K

Fig. 3. (A) Frequency response of the circuit shown in Fig. 1E. (B) Double integrator circuit. (C) "Q"-multiplier circuit. (D) Use of operational amplifier as a capacitance bridge. (E) Wien-bridge oscillator connected to emitter-follower stage.

best when it is used within the audio-frequency range.

One of the most potentially useful circuits is the application as a capacitance or resistance bridge. The capacitance bridge is shown in Fig. 3D. In this circuit a low-level audio signal is connected to the input, the capacitor to be measured is connected at C_x, the appropriate values of C_{std} and $R_{scaling}$ are selected and the controls R and ESR are adjusted for a null in the earphones. Frequency is kept low in order that the amplifier open-loop gain will be high and the reactance of C_x and C_{std} will be high.

The most important advantage, to the experimenter, of this bridge over the completely passive bridge is that the bridge equations are an extremely simple matter of ratio and proportion rather than the gross and involved equations of the conventional types. If perfect components are used, the bridge can measure to an accuracy of .5 per-cent or better. When the bridge is adjusted for a null, $C_x = (R \times C_{std}) / R_{scaling}$. Since there are four different combinations of $R_{scaling}$ and C_{std}, they represent four different multipliers in decade steps. Equivalent series resistance of $C_x = (ESR \times C_{std})/C_x$. Dissipation factor then equals $100R/X_c$ or $200\pi fRC$ in per-cent with f in cps, R in ohms, and C in farads. An entire plug-in subassembly unit containing components, switching functions, and a transistor audio oscillator could be constructed along these particular lines.

Sine-Wave Oscillators

Several types of sine-wave oscillators are possible with this unit. The Wien bridge, shown in Fig. 3E is one of the best. The emitter-follower is necessary in this circuit to supply the large amount of driving power required for the bridge. Frequency can be made continuously variable by varying either R or C. R should be always greater than 5000 ohms. R_f is selected to give an output of 7 volts r.m.s.

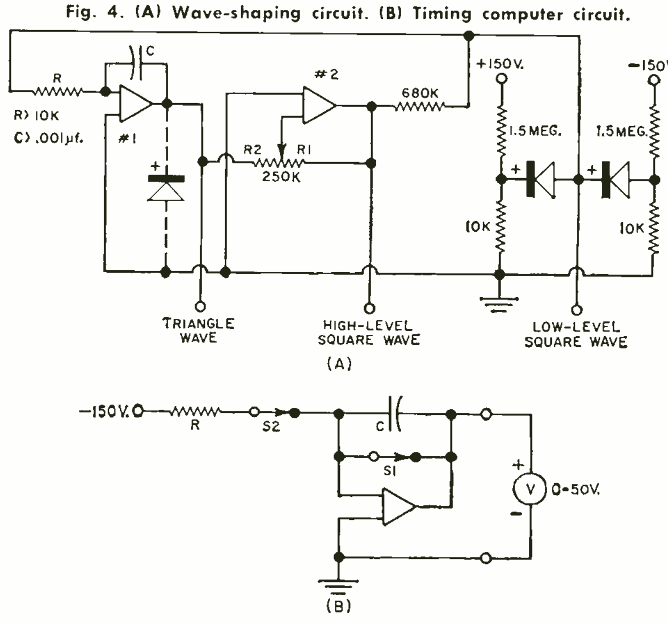
Another oscillator is a modified form of the sine-cosine oscillator used frequently in analog computer laboratories, and shown in Fig. 2A. The name comes from the fact that there is a 90-degree phase difference between the two outputs. Oscillations build up very slowly in this device and, when they are greater than sixty volts peak-to-peak, a weak diode limiting action takes place tending to hold the amplitude constant.

In the left-hand portion of the circuit, the output leads the input by 90 degrees at all frequencies. The right-hand portion is a non-inverting integrator and its output leads its input by 270 degrees. The total of 360 degrees phase-shifted signal is fed back to the left-hand unit, and oscillations take place just lower in frequency than where loop gain exceeds unity. This circuit is particularly useful at frequencies from .1 cps to 1000 cps. To cause the unit to start faster, momentarily connect +150 volts to any input through a 10-megohm resistor. All values of R and C should be equal. Typically, R has a value of 200,000 ohms to 10 megohms.

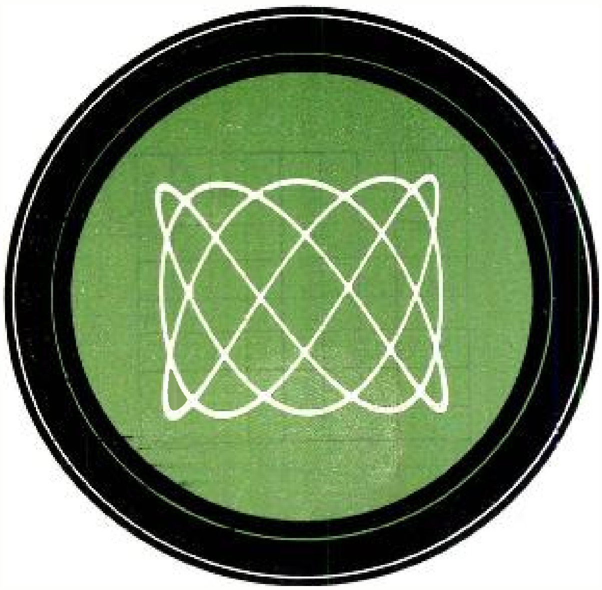
Non-Linear Operation

These amplifiers perform well in non-linear and limit-to-limit operation if not too much is expected in the way of high-frequency performance. A few basic functions will be shown here. The first is a voltage comparator, shown in Fig. 2B. When the input goes ever so slightly positive, the output goes into its negative limit, and *vice versa*. By connecting the secondary input to some reference voltage, when the input exceeds the reference voltage, the output will go into its negative limit, and *vice versa*. (*Continued on page* 84)

Fig. 4. (A) Wave-shaping circuit. (B) Timing computer circuit.



CATHODE-RAY OSCILLOSCOPES



By EDWARD K. MARRIE
Scientific Instrument Dept., DuMont Laboratories
Divisions of Fairchild Camera and Instrument Corp.

One of the most useful and most versatile test instruments has made many advances in design and performance over the past decade.

SINCE its commercial origin in 1932 the cathode-ray oscilloscope has become a primary instrument for measuring electrical waveforms. It is used in a wide variety of fields and applications. Although oscilloscope manufacturers employ techniques that have brought the instrument from a simple indicator to a device that can measure electrical quantities accurately, the basic system concept has not changed. Exceptions are the new traveling-wave and sampling oscilloscopes which are special-purpose instruments.

Unlike many measuring devices, the cathode-ray oscilloscope enables rapidly varying analog information to be obtained. If the applied signals have random amplitude and time fluctuations, the oscilloscope must be employed. Scopes are multipurpose instruments combining features of both a.c. and d.c. voltmeters, ammeters, frequency and phase meters, waveform analyzers, and a good many more.

Types and Applications

Because it finds use in so many diverse measurement applications, no one oscilloscope can contain all desired characteristics. If scopes were to be classified into three general groups, these would probably be: (1) general purpose, low-frequency, (2) general-purpose, high-frequency, and (3) special purpose.

Just what constitutes low and high frequency depends on the range of frequencies required by industry at the time. In the early years of the oscilloscope, much of the electrical industry was concentrated in the area of a.c. power where scopes having bandwidths of only 10 kc. were sufficient. As the radio industry began to grow, a need developed for oscilloscopes which could be used to check out carrier and audio channels, modulators, and discriminators. To make such measurements the bandwidth of the oscilloscope was pushed to 200 kc., a wide-band instrument around 1942.

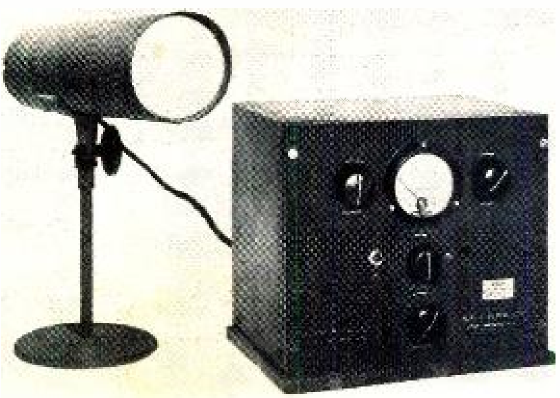
Techniques developed for military systems during World War II were quickly adapted for scope circuitry to keep up with the expanding electronics industry. Distributed amplifiers began to replace the cascaded pentode amplifiers to fulfill the 10- to 20-mc. requirements of post-war industry. Distributed amplifiers using tubes are now being phased out of newer equipment in favor of solid-state devices. High frequency in an oscilloscope today usually means 25 mc. or above. In two or three years this will probably be changed to 50 mc. or above.

The pressure for higher frequency instruments comes mainly from users and designers of advanced military systems and computer manufacturers. Already computers have reached a point where scopes with bandwidths of over 50 mc. are preferred in design work, or with 25-mc. passband for servicing.

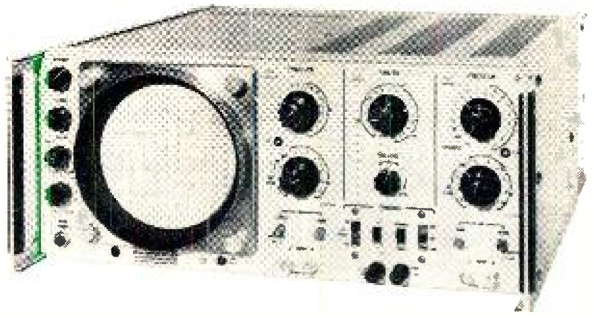
Oscilloscopes having low-frequency characteristics are still required in industry. Many applications where mechanical or hydraulic systems are involved need electrical test equipment having a bandpass of only 500 kc. This class of instrument has had a fairly constant market for the past few years but does not have the growth potential of the high-frequency instruments used in the electronics field.

New and more sophisticated sweep circuits had to be developed for the higher frequency instruments. Originally

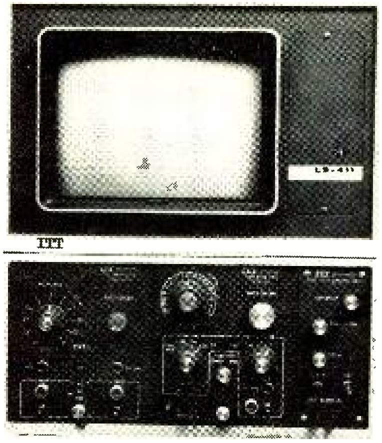
One of the very earliest oscilloscopes was the Type 126, manufactured in 1932 by the Allen B. DuMont Laboratories. Having developed a practical, long-lived cathode-ray tube, Dr. DuMont's first use for these tubes was in instruments of this type. The power-supply circuitry was in the cabinet shown while another cabinet, not shown, housed the sweep circuits that were employed with the separately mounted CR tube.



An example of a high-sensitivity, general-purpose lab scope is the Fairchild-DuMont 704. Identical vertical and horizontal amplifiers are used with sensitivities of 0.2 mv./cm. and bandwidths from d.c. to 500 kc. The triggered sweep is wide range from 0.1 μsec./cm. to 1 min./full scale. Critical circuits use silicon transistors. The amplifiers are within $\pm 1°$ relative phase shift to 100 kc. Price of the oscilloscope is $645.



Designed for production and servicing of black-and-white and color-TV receivers is the RCA WO-91A. The scope can measure color-burst signals and can be used to troubleshoot wide-band color circuits. Either wide-band (10 cps to 4.5 mc.) or high-sensitivity (50 mv. p-p/in.) operation is provided. Price of unit: $249.50.



Although most scopes use electrostatically deflected 5" tubes, the ITT LS-411 uses a magnetically deflected 14" CRT for display. With its plug-in amplifier and sweep modules, it can display low-frequency waveforms from d.c. to 25 kc. For use with analog computers and telemetry systems. Basic price, less plug-ins, $1965.

Another example of a general-purpose wide-band instrument designed mainly for black-and-white and color-TV servicing is the Jackson CRO-3. When switched to wide-band operation, the response is from 20 cps to 4.5 mc. When set for high sensitivity, 18 mv. r.m.s. signal produces a deflection of 1 inch. Price of unit is $234.95.

saw-tooth sweep generators used thyratrons. These were free-running sweeps which could be locked to the synchronizing signal. Gas-tube sweep generators of this type had a maximum repetition rate of about 40 kc., or a minimum sweep time of about 25 microseconds. To examine a 20-mc. sine wave, a minimum of 0.1 μsec. or 100 nanoseconds was required. More complicated and versatile saw-tooth generators such as the bootstrap and Miller integrator were devised.

In most present-day equipment, the Miller integrator is used because of its linearity and fast starting. The sync signal in this "triggered-sweep" system changes the state of a multivibrator which starts the sweep. Another feature is that the method or mode of triggering may be altered. By changing the mode of operation, a triggered repetitive, free-running, single or automatic sweep may be obtained.

Single sweeps have become more important since the development of oscilloscope recording cameras where a transient will start the sweep and activate the camera shutter at the same time. Triggered sweeps of this type produce linear sweeps of 5 nanoseconds.

To make scopes easier to operate, and due to the increased accuracy of the Miller sweep system (3%), newer instruments are calibrated directly in time. At present, the Miller sweep generator is restricted to either electron-tube or hybrid circuits. However, field-effect transistors, which are now becoming commercially available, will enable completely solid-state sweep generators to be built.

With the advent of pulse and digital circuitry, a new type of display was developed to single out and expand certain portions of a pulse train. At first it was sufficient to automatically change sweep rates during the sweep to produce a "notch." This notching technique, a forerunner of the delaying sweep, worked well for instruments which had a pass-band of 5 to 10 mc. As radar, pulse modulation, and computers became more refined and transportation of electrical information became faster, a new system was needed. It was important not only to know what pulse in a given train was being measured and its waveshape, but also its time relation to other waveforms in a system. To do all three jobs well, the modern delayed sweep was devised. Practically all missile projects require a number of scopes having delayed sweeps for systems check out.

Very accurate phase measurements at high frequency is another area which employs delayed-sweep scopes. In this method, a calibrated delay dial is used to measure phase.

Two types of instruments used for special high-frequency measurements are the traveling-wave and sampling oscilloscopes. The traveling-wave scope has been designed for measuring very fast, single-shot or low-repetition-rate signals. Unlike the general-purpose scope, it does not have a vertical amplifier, but connects the signal directly to the CRT deflection plates. Second, the vertical deflection plates are divided into sections to reduce the transit time of the electron beam through the plates. These various sections are connected together with a delay line so that the signal progresses from one plate to the next in much the same manner as in a distributed amplifier. This instrument, which is usually used with a camera, provides a means of recording very fast transients. Reduction in sensitivity and scan must be tolerated in this system to achieve necessary bandwidth.

For higher bandwidths, a more versatile instrument, the sampling oscilloscope, may now be obtained. Using new solid-state components, sampling oscilloscopes will yield bandwidths over 1000 mc.

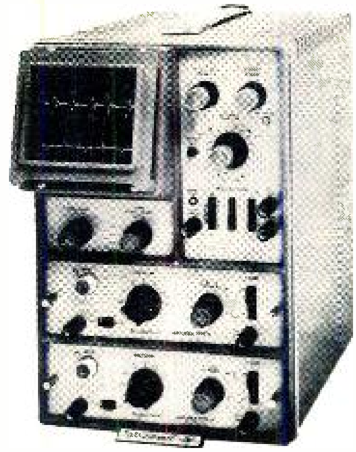
The sampling oscilloscope is closely analogous to a stroboscopic light for visual observation of rapid motion. Both techniques appear to slow down motion and depend on repetition of the phenomenon to build up the apparent image. Sampling differs from conventional display in that for each occurrence of the input signal only a single point or sample of the input is displayed. The amplitude of this point is proportional to the signal amplitude at the instant of time the sample is made. By sampling at slightly different times for each input cycle, a display showing the entire waveform is produced. With this method, the effective bandwidth of a fairly low-frequency amplifier may be extended upward and the loss of sensitivity and scan in the traveling-wave system may be overcome.

Plug-in Units

Not all improvements made to the oscilloscope have been in the electrical circuitry. More versatility has been built into the scope by the use of various plug-in units. At first only vertical preamplifiers were available. These enabled the user to select vertical characteristics for a given application. A few years ago this was extended to both vertical and horizontal channels. Sampling generators were packaged as plug-ins to permit operation of specific instruments as both standard and sampling scopes. At present scopes may be obtained which have all of the signal circuitry contained in the plug-ins. Such instruments may now keep pace with the rigid specifications of present-day industrial and military applica-

Another example of a wide-band laboratory oscilloscope is the Simpson 2610. This instrument was designed to fill the gap between service-type scopes, which have fairly limited performance but at reduced cost, and the very high-performance, high-cost laboratory instruments. Response is d.c. to 8 mc. (±1.5 db); sensitivity is 6 mv. r.m.s./in. The price of the unit: $575.

In order to view waveforms with very short rise times, a high-speed sampling technique is used in this Tektronix 661 with dual-trace sampling preamp unit. Small bits of the signal, sampled at slightly different portions of the waveform, recreate the display. The vertical passband is equivalent to d.c. to 3500 mc.; rise time is 0.1 nsec. Price of scope and plug-ins: $3500.



An oscilloscope that uses an unusual CRT to get a dual trace on the screen is the Telequipment (Avnet) D44. Although the tube uses a single cathode, control and focusing electrodes, two completely separate deflection systems operate on the electron beam which is split in two parts. Plug-ins are available for various bandwidths, gains. Price (basic unit): $350.

tions and yet provide maximum versatility for foreseeable future requirements.

As an example of improvements that have been made in general-purpose low-frequency scopes in the past 10 years, let us compare some of the major characteristics of the *DuMont* Type 304 and the newer *Fairchild-DuMont* 704. The following table shows the improvement in the electrical

Characteristic	10-Year-Old Oscilloscope	New Oscilloscope
Bandwidth	100 kc.	500 kc.
Sensitivity	100 mv./div.	0.2 mv./div.
Sweep Rate	30 kc.	0.1 μsec./div.
Phase Shift Between X-Y	Not Specified	±1° to 100 kc.
Identical Amplifiers	No	Yes
Accuracy	±5%	±2%

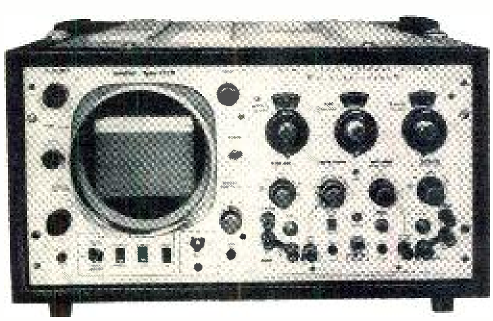
characteristics of the units. It should be noted that in the older instrument the sweep is calibrated in the number of sweeps per second whereas in the newer type instrument the horizontal axis is calibrated directly in time per division.

The latest development in oscilloscope circuitry has been the use of the transistor and other semiconductors. Although we know of no commercial oscilloscope that has been completely transistorized, semiconductors are now used in from 30 to 90 percent of the active stages in some present-day instruments currently on the market.

Advantages of Solid-State Oscilloscope

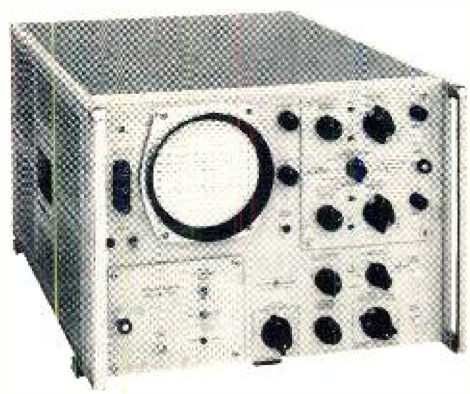
Obvious advantages of solid-state design are that the instrument will weigh less, require less space, and consume a smaller amount of power. Instruments which have the same electrical characteristics as the solid-state oscilloscope weigh from 2.5 to 3 times more, and consume over twice as much power. Tube instruments exhibit two problems which are directly related to tube aging. There is a slow degradation in the tube parameters with time. This causes trouble in the calibration and balance of the instrument. Certain types of silicon transistors, on the other hand, retain their original properties for practically their entire life.

A special cathode-ray storage tube is the heart of the Analab Model 1220, shown here with a dual-trace plug-in preamp. Information can be stored for many months or it may be erased in 30 seconds. Repetitive signals up to 100 kc. and single transients to several kc. can also be stored. Price of basic unit (no preamp) is $1600.



An example of an inexpensive general-purpose and service-type oscilloscope is the Precision ES150. The unit can also be used for low-frequency work as its response goes down to d.c. On the high side response is −3 db at 4.5 mc. Sensitivity is 70 mv./in. on d.c. and 25 mv. r.m.s./in. on a.c. Price of the scope: $149.95.

Designed mainly for industrial applications, such as general production testing, computer testing, and lab use, is the Hewlett-Packard 175A. The scope has a passband of from d.c. to 50 mc. with 7-nsec. rise time using a suitable plug-in preamp. A variety of vertical and time-base units are available. Price (basic unit): $1325.



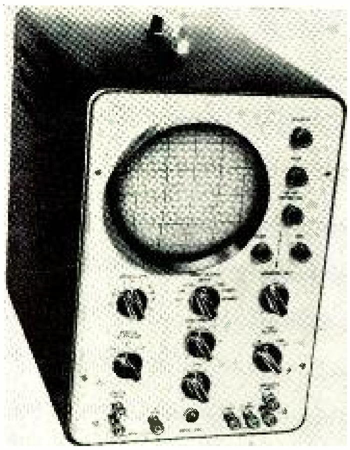
The second effect which is found in tube instruments is a tube disease known as "cathode interface." This trouble is inherent in the vacuum tube itself and has been a constant, but unavoidable, source of trouble in high-frequency scopes until the introduction of the solid-state scope. When the tube begins to age, a resistance is developed between the heater and cathode of the tube. It acts as if an *RC* network had been connected inside the tube. This reduces the gain at low frequencies while not affecting the higher ones. A gradual overpeaking is therefore developed in the square-wave response. Some large companies connect clocks to their oscilloscopes and replace all the tubes in the high-frequency amplifiers every 30 to 60 days. Since transistors have neither heaters nor cathodes, this problem is non-existent.

There is also more versatility when designing with transistors, since both *n-p-n* and *p-n-p* transistors are available. The *p-n-p* transistor has no tube counterpart, since the tube would have to operate with the cathode positive with respect to the plate. In direct-coupled systems, this is an easy method of keeping the power supplies at low values.

Not all types of transistors are suitable for use in oscilloscopes. To produce a stable, solid-state scope silicon transistors are usually used. The reverse current from collector to base in transistors doubles every time the temperature increases 10°C. Since the acceptable range of operation is between 0 and 50°C, an extremely low initial reverse current is a prime characteristic for transistors used in oscilloscopes. When germanium transistors are used, instability with temperature usually results due to their larger reverse currents.

Transistorized construction also makes it possible to package all the signal-carrying circuitry into plug-ins rather than having it distributed between a preamplifier plug-in and the main frame. The delayed sweep generator, which contains two complete sweeps, may be operated more easily than tube types due to its compactness. Automatic features within this unit, made possible by silicon planar transistors, decrease the number of controls on the front panel. Cabling, which had to be external in the past, is now done internally and may be changed by means of front-panel switches.

A 3-inch d.c. oscilloscope that is available in kit form is the Heath IO-10. Identical vertical and horizontal channels are used with bandwidths from d.c. to 200 kc. Sensitivities of amplifiers are 0.4 v. (p-p) per inch. This compact scope weighs about 16 lbs. There is less than 5° relative phase shift between channels. Price: $79.95.



Another example of a scope in kit form is the Conar Model 250. This is a 5-inch wide-band scope for general and TV service use. The vertical sensitivity of the unit is 23 mv. r.m.s./in., and the vertical frequency response is flat from 13 cps to 2.5 mc. and down 1.5 db at 3.58 mc. Price: $89.50, or $139.50 assembled.

The most elaborate scope in kit form is the Knight 10-mc. d.c. laboratory scope shown here. This is a research-quality unit with interchangeable vertical preamps. Built-in sweep timing markers are provided along with built-in voltage calibrator. Dual-trace preamp is available. Price without plug-in preamps is $395.

Choosing an Oscilloscope

When choosing an oscilloscope, there are certain questions which must be answered to obtain an instrument that will avoid erroneous readings, make the required measurement, or not become obsolescent soon. These questions are general and could be used as a yardstick for either a scope to do a specific job, or one for general use.

1. *What sweep rates are necessary?* Some measurements require that the instruments have fast sweep rates, while others need slow sweeps. An oscilloscope having the greatest spread between fastest and slowest sweep would seem to be the more versatile. However, two important points should be considered in determining what sweep rates are necessary.

Are the frequency response of the vertical amplifier and the maximum sweep rate compatible and what is the sequence of the sweep-rate switching? As a rule of thumb, if one cycle of the upper passband frequency can be displayed across the face of the CRT, then the sweep rate is adequate. For example, if the passband were 500 kc., then the period for 1 cycle would be 1/500 kc. or 2 microseconds. If this time is divided by the number of divisions in the horizontal direction, usually 10, then the fastest sweep rate required will be 0.2 microsecond per division. Applying this rule to a 25-mc. bandwidth scope would yield the 4 nanosecond per division (4 nsec./div.) sweep rate required. This sweep rate is not obtainable in high-frequency scopes at present and some other criteria are needed. The state of the art requires that a ratio of 5 to 1 will have to be used between the calculated sweep rate and what is available at the present time.

2. *What is the accuracy of the sweep?* If quantitative rather than qualitative information is required, the sweep accuracy timing should be no more than ± 5% from nominal. Most commercial manufacturers hold the tolerance to within 3% on all ranges.

3. *Is vertical delay required?* Above 5 mc. the oscilloscope should have a delay built into the vertical amplifier. An exception to this is when using the instrument as an X-Y plotter where the sweep is inactive. Another application where a delay line is not necessary is when the scope is always triggered from an external source, which activates the sweep at a specified time before the signal applied to the vertical channel. Such an application is the servicing of computers where the sweep is referenced to a given point in the computer and other signals measured from this point.

4. *What rise time and bandwidth are required?* Normally the rise time of the scope should be 1/5 the rise time of the signal being observed. This will cause an error of about 2% when making a rise-time measure- (*Continued on page* 74)

1963 Directory of Kit Test Equipment

Complete listing of all presently available test equipment kits. Over 200 designs divided into 29 categories, according to function, are covered.

THE philosophy of producing kits is as old as the electronics industry itself, but it wasn't until after World War II that test equipment in kit form was produced in quantity. The advent of television generated an immediate need for test equipment for the installation, service, and maintenance of this new entertainment phenomenon. Not only were new forms of test equipment needed, but if relatively accurate and stable equipment could be produced at reasonable prices, there was a ready-made market for such output. Industry more than fulfilled its promise in the way of kits whose quality and low price far overshadowed the inconvenience of assembling such equipment. The fact that equipment had to be put together ultimately proved a real selling point since technically oriented persons derived tremendous satisfaction from building their own units.

Almost simultaneously with the service industry, a new market opened up in test equipment for the home workshop. Hobbyists, experimenters, and even electronics engineers, found test equipment kits the answer to their needs.

Today one can find test equipment kits in every area, from industrial and military plants to electronics laboratories. Service departments; production-line testing departments for radio, TV, hi-fi, and industrial electronic equipment; medical and educational institutions are among the diversified places where such test equipment can be used. Test equipment kits have become so sophisticated that in many cases they are the equal of all but highly elaborate and specialized factory-assembled units. In laboratories, once they have been checked against calibrated equipment, they are ideal for making comparative measurements on all types of products.

Kits have achieved these advances for several good reasons: (1) Design standards, component quality, and accuracy are relatively high. (2) Technicians can assemble them during free time while drawing regular salary. In this way key employees can be kept busy without additional cost. (3) One of the most important reasons why kit test equipment has made inroads in the industrial area is that their circuits can be modified during construction to adapt the instrument to special applications. In many cases there is a need for specific individual tests, especially for production applications. Why tie up multiple-operation units in such cases?

Today, kits bear little resemblance to the first 5" scope kit that sold for $39.95 in 1947. Circuit design, performance, and versatility of present-day test equipment have kept pace with the industry. Transistors are now beginning to replace vacuum tubes in some kits.

Over 200 different test equipment kits are available ranging in price from $5.50 for a capacitor substitution box to $395.00 for a laboratory oscilloscope. There is actually no limit to the degree of complexity of the test equipment that can be designed and marketed in kit form. Why this is so is largely a matter of the painstaking detail and clarity of the construction manuals accompanying such equipment.

If you have never assembled a kit, be assured that these manuals are well written with step-by-step instructions so clearly presented that an operating instrument is guaranteed. Calibration procedures are simple and provide a relatively high degree of accuracy. Should problems arise, manufacturers will, for a nominal fee, check out any kit that does not operate, calibrate it, and put it in top working order. ▲

R.F. SIGNAL GENERATORS

Mfgr.	Model	Freq. Range (fundamentals)	No. of Bands	Cal. Harmonics		Output		Modulation Freq. (cps)	Provision for Ext. Mod.	Audio Output		Price	Remarks
				Freq.	No. of Bands	Voltage	Z				Volts		
ALLIED	83Y953	160 kc.-112 mc.	5	none	—	.4	—	400	yes	yes	10	$19.95	
CONAR	280	170 kc.-60 mc.	6	none	—	.1	50Ω	400	no	yes	5	$21.50	
EICO	315	75 kc.-50 mc.	5	13-150 mc.	2	.1	—	400	yes	yes	—	$49.95	
	320	150 kc.-34 mc.	5	22-102 mc.	2	.1	—	400	no	yes	1.5-2	$24.95	Model 322 with 5 cal. bands $27.95
	324	150 kc.-145 mc.	6	111-435 mc.	1	.1	50Ω	400	yes	yes	10	$28.95	
EMC	502	115 kc.-110 mc.	6	—	—	.1	—	400	yes	no	—	$17.95	
HEATH	FMO-1	90, 100, 107 mc.	3	—	—	—	—	400	no	yes	—	$34.95	three switch-selected freq. var. 10.7 mc. sweep, 200 kc. to over 1 mc., 10.7 mc. crystal mark, 100 kc. submarker
	IG-42	100 kc.-31 mc.	5	—	—	.1	50Ω	400	yes	no	—	$56.95	panel meter indicates output voltage or percent modulation
	IG-102	100 kc.-110 mc.	6	110-220 mc.	1	.1	50Ω	400	yes	yes	10	$27.95	
LAFAYETTE	KT-208	250 kc.-120 mc	5	—	—	—	—	400	yes	—	—	$19.95	also a signal tracer
OLSON	KB-141	250 kc.-120 mc.	5	—	—	—	—	400	yes	—	—	$19.95	also a signal tracer
PRECISE	610K	300 kc.-110 mc.	5	60-330 mc.	2	—	—	60, 400	—	—	—	$27.50	available with precalibrated r.f. head as 610KA, $34.95
RADIO SHACK	22-068E	100 kc.-330 mc.	6	—	—	1.0	—	20-20,000	yes	20-20,000 cps	2.5	$39.95	meter indicates r.f., a.f. output; r.f., a.f. volts; db in 3 ranges; 0-1, 10, 100 v. a.c.
	22-026	160 kc.-110 mc.	5	—	—	.1	50Ω	400	yes	—	—	$18.95	

TUBE TESTERS

Mfgr.	Model	Type		Tests			Line-Voltage Adjust	Charts	*Sockets	Meter Scale	Special Tube Tests	Price	Remarks
		Emission	G_m	Shorts, Opens, Leakage	Grid Current	G_m							
ALLIED	400A	X		shorts only				book	7- & 9-pin miniature, oc., lok.	good-bad	—	$ 19.95	
	600B	X		X			X	roll	4, 5, 6, 7L, 7S, oc., lok, 9, com., nov., nuv., 10	good-bad	CRT with adapter	$ 39.95	counter model $35.95 performs gas check
CONAR	221	X	—	Shorts, opens, leakage			X	roll	4, 5, 6, 7L, 7-, 9-, 10-pin miniature, oc., lok., nov., com., 5-, 7-pin nuv.		CRT with adapter, VR, tuning eyes	$ 48.75	12 test levers, book for foreign tubes
EICO	625	X		X			X	roll	4, 5, 6, 7L, 7S, oc., lok. nov.	good-bad	VR's, "eye," CRT with adapter	$ 34.95	
	628	X		X			X	roll	7-9- & 10-pin miniatures; oc., lok., 5- & 7-pin nuv., com., nov.		VR's "eye" color & monochrome CRT's with adapter	$ 44.95	
	666		X			X	X	roll	4, 5, 6, 7L, 7S, miniature 7- & 9-pin, subminiature 5, 6, 7-pin (in-line base), oc., lok.	good-bad	CRT with adapter, VR's, "eye," ballast tube	$ 69.95	direct indication of leakage in ohms; transistor leakage and beta test
	667		X	X		X	X	roll	7-9- & 10-pin miniatures; 5-6- & 7-pin sub-miniature, sub-miniature 8-pin, oc., lok., 5- & 7-pin nuv., com., nov.		VR's, "eye" ballast, color & monochrome CRT's with adapter	$ 79.95	direct indication of leakage in ohms; transistor leakage and beta test
EMC	205	X		X			X	roll	9 sockets	good-bad	"eye," VR, CRT with adapter	$ 34.50	
	209	X		X				book	7- & 9-pin miniature, oc., lok.	good-bad	CRT with adapter	$ 25.90	rejuvenates CRT's
	211	X		X				book	7- & 9-pin miniature, oc., lok.	good-bad	—	$ 14.90	
	213	X		X				book	7- & 9-pin miniature, com., nuv., nov., 10-pin, oc., lok.	good-bad	VR's, "eye"	$ 18.90	$21.90 in wood carrying case
	301	X		X				book	7- & 9-pin miniature, oc., lok.	good-bad	CRT with adapter	$ 32.60	$33.20 in wood cabinet; rejuvenates CRT's
	302	X		X				book	7- & 9-pin miniature, oc., lok.	good-bad	CRT with adapter	$ 47.90	$49.90 in wood cabinet; rejuvenates CRT's
HEATH	TT-21	X		X			X	roll	4, 5, 6, 7L, 7S, 7, 10-pin miniature, oc., lok., nov., com., 5, 7-pin nuv.	good-bad	CRT with adapter	$ 44.95	
	TT-1A		X	X	1/4 μa. sensitivity	X	X	roll	4, 5, 6, 7L, 7S, 7- & 8-pin subminiature, oc., lok., 9-pin miniature, com., nuv., nov., 10-pin	0-3000 μmhos, VR test volts, 0-1 v. a.c.	VR's, low-power thyratrons, "eye" tubes	$149.95	
LAFAYETTE	KT-209	X		X				book	7 sockets	good-bad		$ 17.95	
OLSON	KB-142	X		X				book	7 sockets	good-bad		$ 17.95	
PACO	T-60	X		X			X	roll	7- & 9-pin miniature, oc., lok.	good-bad	VR's, "eye," CRT with adapter, gas rectifiers	$ 42.95	
	T-62	X		X	X			book	7, 9 & 10-pin miniature, 12 com., 5- & 7-pin nuv., oc., lok, nov.	good-bad	CRT with adapter	$ 49.95	has 0-1000 VTVM megohmmeter for external checking resistors, capacitor leakage, etc.
RADIO SHACK	22-064M	X		X			X	roll	4, 5, 6, 7L, 7- & 9-pin miniature, oc., lok., com., nuv., 10-pin	good-bad	CRT with adapter	$ 44.50	
	22-2001E		X	X		X	X	roll	4, 5, 6, 7L, 7S, 7 subminiature, oc., lok., 8-subminiature, 9- & 10 miniature, nuv., nov., com.	good-bad 0-30,000 μmhos		$ 94.50	tests transistors & zener diodes; fil. current indicated on meter

*com. = compactrons; nuv. = nuvistors; nov. = novar; oc. = octal; lok. = loktal.

OSCILLOSCOPES

Mfgr.	Model	Vertical Channel: Freq. Resp.	Vertical Channel: Sensitivity	Vertical Channel: Input Z (meg.—pf.)	Horizontal Channel: Freq. Resp.	Horizontal Channel: Sensitivity	Horizontal Channel: Input Z (meg.—pf.)	Sweep	CRT Size	Price	Remarks
ALLIED	83YU913	5 cps-5 mc. ±3 db	25 r.m.s. mv./in.	3.4-12	down 4 db @ 1 mc.	600 r.m.s. mv./in.	—	15 cps-600 kc.	5"	$ 69.95	
	83YZ945	—	—	—	d.c. to 2.5 mc. +0 —3 db	.1 v./cm.-1. v./cm.	—	.5 sec./cm.-50 nsec./cm.	5"	$395.00	intensity modulated time marks @ 10, 100, & 1000 μsec.
	83YZ946	differential amp. for 83YZ945: vert. chan. freq. resp. d.c.—100 kc., 0 to —3 db; sensitivity, 1 p.p.v./in.; input Z, 1 meg., 40 pf.								$ 59.95	5000:1 diff. ratio
	83YZ948	dual-trace preamp for 83YZ945: vert. chan. freq. resp. d.c.—10 mc., 0 to —3 db; sensitivity 50 p.p.mv./cm.; input Z, 1 meg., 40 pf.								$ 79.95	switching rate: 100 kc. chopped or alternate sweeps
	83YU910-J	d.c.-5 mc. +0, —3 db	d.c.-coupled .05 v. p-p/cm.; a.c.-coupled .005 v. p-p/cm.	1-40	d.c. to 500 kc. +0, —3 db	.15 v./cm. has variable attenuator	1	.05 sec./cm.-200 nsec./cm.	5"	$184.95	85 nsec. rise time
CONAR	250	flat 13 cps-2.5 mc., down 3.5 db @ 4.5 mc.	.023 r.m.s. v./in.	2.7 meg. @ 1 kc.	flat 20 cps-90 kc. down 3 db @ 250 kc.	1 r.m.s. v./in.	4.9 meg. @ 1 kc.	10 cps-500 kc	5"	$ 89.50	built-in pulse for flyback, yoke tests, etc.
EICO	427	d.c.-1 mc. +0, —6 db	10 p-p mv./cm.	1-30	2 cps-450 kc. +0, —3 db	.5 p-p v./cm.	10-40	10 cps-100 kc.	5"	$ 69.95	
	430	2 cps-500 kc. +0, —3 db.	25 r.m.s. mv./cm.	1-30	2 cps-300 kc. +0, —3 db	.25 r.m.s. v./cm.	10-40	10 cps-100 kc.	3"	$ 65.95	
	460	flat d.c.-4.5 mc. down 10 db. @ 10 mc.	25 r.m.s. mv./in.	3-35	flat 1 cps-400 kc.	.6 r.m.s. v./in.	5-35	10 cps-100 kc.	5"	$ 89.95	.06 μsec. rise time
FEILER	TS-7	20 cps-75 kc.	.5 r.m.s. v./in.	1-50	- - -	.5 r.m.s. v./in.	1-50	10 cps-32 kc	5"	$ 53.48	
HEATH	10-10	d.c.-200 kc. (2 db point)	.1 p-p v./¼"	3.6-35	same as vert.	same as vert.	3.6-35	5 cps-50 kc.	3"	$ 79.95	
	10-21	2 cps-200 kc. ±2 db	.25 r.m.s. v./in.	10-20	same as vert.	same as vert.	10-20	20 cps-100 kc.	3"	$ 49.95	
	10-12	3 cps-5 mc. +1.5 db to —5 db	.025 r.m.s. v./in. @ 1 kc.	3.3-12	1 cps-400 kc. ±3 db	.3 r.m.s. v./in. @ 1 kc.	4.9 @ 1 kc.	10 cps-500 kc.	5"	$ 76.95	.08 μsec. rise time 2 preset sweep freq. positions
PACO	S-51	5 cps-1.2 mc. ±3 db, to 2 mc. ±6 db	90 r.m.s. mv./in.	1.5-25	±6 db to 700 kc.	250 r.m.s. mv./in.	10-25	20 cps-150 kc.	5"	$ 69.95	
	S-55	a.c. & d.c. within 5 db @ 5 mc.	25 r.m.s. mv./in.	1.5-23	within 3 db 1 cps-400 kc.	.6 r.m.s. v./in.	5-23	10 cps-100 kc.	5"	$ 95.95	.08 μsec. rise time
PRECISE	300K	d.c.-5 mc. ±3 db	3.9 p-p mv./cm.	—	—	—	—	1 cps-80 kc.	7"	$169.95	
	308K	d.c.-5 mc. ±1.5 db	10 p-p mv./cm.	—	—	—	—	1 cps-80 kc.	8½"	$179.95	
	315K	a.c. coupled within ±6 db to 500 kc.	250 mv./in.	—	—	250 mv./in.	—	10 cps-100 kc.	5"	$ 59.95	
	3151K	flat to 5 mc.	10 mv./cm.	—	—	10 mv./cm.	—	—	5"	$ 69.95	
RCA	WO-33A	flat 5.5 cps-5 mc. within —3 db	.3 p-p v./in.	1-50	flat 3.5 cps-350 kc. within ±6 db	.9 r.m.s. v./in.	10-	15 cps-75 kc.	3"	$ 79.95	wideband response .1 μsec. rise time
		3 cps-1.5 mc. flat within ±6 db	.01 p-p v./in.	1-50	flat 3.5 cps-350 kc. within —6 db	.9 r.m.s. v./in.	10-	15 cps-75 kc.	3"	$ 79.95	narrow band response .1 μsec. rise time
RADIO SHACK	22-072E	10 cps-3 mc. ±5 db to 5 mc.	100 r.m.s. mv./in. single trace; 200 r.m.s. mv./in. dual trace	500 k. single trace; 100 k dual trace	flat to 100 kc. —6 db @ 1 mc.	100 r.m.s. mv./in.	—	10 cps-100 kc.	5"	$ 69.95	
	22-086E	d.c.-75 kc.	25 r.m.s. mv./in	5-100	20 cps-70 kc.	.6 r.m.s. v./in.	.5-100	20 cps-20 kc.	3"	$ 34.50	

TRANSISTOR TESTERS

Mfgr.	Model	Tests: Shorts	Tests: Gain	Tests: Leakage	Tests: Forward & Reverse Current	Voltage-Current Ranges	Price	Remarks
ALLIED	83Y149	X			X		$ 8.95	checks leakage-to-gain ratio checks diodes & rectifiers
EICO	680	X	d.c. beta directly—2-30, 2-300 a.c. beta indirectly	I_{cbo}, I_{ceo}	X	50, 500 μa., 5, 50, 500 ma.	$25.95	d.c. voltage ranges 5, 50 v.; three res. ranges, 2000, 200 k, 20 meg.; checks diodes & rectifiers
EMC	212		d.c. in three ranges to 200	X		80 ma., 12 v.	$13.50	checks transistors as a.c. current amplifiers & in-circuit
HEATH	IM-30	X	d.c. beta directly 0-300 d.c. alpha directly 0-.9967	I_{cbo}, I_{ceo}		15, 150 μa., 1.5, 15, 150 ma., 1.5, 15 a., 1.5, 5, 15, 50, 150 v. (100 k ohms/volt)	$54.88	collector current to 15 a.; provision for external d.c. supply; checks diodes & rectifiers
	IT-10	X		X	X		$ 6.95	
LAFAYETTE	KT-223		d.c. in 3 ranges to 200	X		80 ma., 12 v.	$12.75	in-circuit transistor checks include power types

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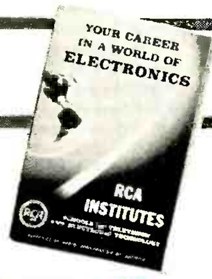

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GENERAL PURPOSE V.T.V.M.'s

Mfgr.	Model	Ranges* D.C., A.C. (r.m.s.)	Ranges* Ohms/ mid-scale	No. of Ranges	D.C. Input Res. (meg.)	A.C. Input Z (meg.-pf.)	Accuracy (full-scale) D.C.	Accuracy (full-scale) A.C.	Frequency Response	Price	Remarks**
ALLIED	83Y911	1.5-1500	1000/10 1000m./10m.	7	11	—	±3%	±5%	30 cps-5 mc. ±3 db.	$26.95	db range −10 to + 65; a.c. p-p ranges 4, 4000
ARKAY	VT-10	3-1500	1000, 1000m.	7	11	—	—	—	30 cps-5 mc.	$25.95	db range −10 to + 58
CONAR	211	3-1200	1000/10 1000m./10m.	6	12.2	1.5-	±2%	±3%	30 cps-6 mc.	$31.95	uses switchless single probe lead
DEVRY	—	1 d.c., 5 a.c.-1000	100/100k. 4 ranges	4	10	1.85—	—	—	—	$64.50	d.c. current 50-500 μa., 5-50ma. transistorized, battery operated
EICO	221	5-1000	1000, 1000m.	5	25	3-	±3%	±5%	20 cps-200 kc.	$25.95	db range −20 to + 55
	214	—	—	—	—	—	—	—	—	$34.95	same as 221 but 7½" meter
	222	3-1500	1000m.	5	11	1-	±3%	±5%	30 cps-3 mc.	$27.95	p-p with special probe
	232	1.5-1500	1000m.	7	—	—	—	—	30 cps-3 mc.	$29.95	a.c. p-p ranges 4, 4200
	249	—	—	—	—	—	—	—	—	$39.95	same as 232 but 7½" meter
EMC	106	1.5-1000	1000, 1000m.	5	16.5	2-	—	—	25 cps-100 kc.	$23.90	db range −24 to + 55
	107	1.5-1000	1000, 1000m.	6	16.5	1.5-	—	—	—	$34.50	a.c. p-p ranges 4, 2800; capacity 50 pf.-5000 μf.; inductance 1.4-140,000 hy.
	107A	—	—	—	—	—	—	—	—	$36.50	same as 107 but 6" meter
FEILER	TS-9	5-1000	1000m.	5	26	3-	±2%	±2%	—	$26.39	db range −20 to + 16; 0-1 ma. d.c. range
HEATH	IM-13	1.5-1500	1000/10 1000m./10m.	7	11	1-30	±3%	±5%	25 cps-1 mc. ±1 db	$32.95	db range −10 to + 65
	IM-11	1.5-1500	1000/10 1000m./10m.	7	11	1-35	±3%	±5%	25 cps-1 mc. ±1 db	$24.95	
LAFAYETTE	KT-174	1.5-1500	1000, 1000m.	7	11	150 v.-1.3 meg; 500 v., 1500 v.-1.5 meg; other scales 50-83 meg.	±2%	±5% (5v.) ±3% (others)	20 cps-4 mc. ±1 db	$44.50	low a.c. ranges 50, 150, 500 mv.; 4.2, 4200 p-p ranges
	KT-202	3-1500	1000/10 1000m./10m.	7	11	—	—	—	30 cps-5 mc.	$25.95	db range −10 to + 18; a.c. p-p ranges 8, 2000
OLSON	KB-140	3-1500	1000/10 1000m./10m.	5	11	—	—	—	30 cps-5 mc.	$25.95	db range −10 to + 58; a.c. p-p ranges 8, 2000
PACO	V-70	1.5-1500	1000/10 1000m./10m.	7	11	—	—	—	40 cps-4 mc. ±1 db	$31.95	db range −6 to + 66; a.c. p-p ranges 4, 4000
PRECISE	904K	1.5-1500	1000/10 1000m./10m.	7	—	—	—	—	—	$39.95	
	909K	5-1000	1000/10 1000m./10m.	5	25	—	—	—	—	$29.95	
	9071K	5-1000	1000/10 1000m./10m.	5	25	—	—	—	—	$39.95	7½" meter
RADIO SHACK	22-070M	1.5-1500	1000/10 1000m./10m.	6	11	—	±3%	±5%	flat to 2 mc.	$38.20	15, 150 mv. ranges; .15, 5 a. a.c. ranges; 0-1600 w. a.c. ranges 15, 30, 60 watts across 16, 8, 4 ohm leads
	22-078	3-1500	1000/10 1000m./10m.		11	—	±3%	±5%	flat to 3 mc.	$26.95	db range −10 to + 38; a.c. p-p ranges 8, 2000
RCA	WV-77E	1.5-1500	1000/10 1000m./10m.	7	11	—	±3%	±5%	40 cps-5 mc. ±5 db on 1.5, 5, 15 v. ranges	$29.95	a.c. p-p ranges 4, 4000
	WV-98C	.5-1500 d.c.	1000, 1000	7	11	.83-70	±3%	±3% (±5%, 1.5-5v.)	30 cps-3 mc.	$62.50	a.c. p-p ranges 4, 4200 .5 v. d.c.range

*Figures are highest scale markings for lowest and highest ranges.
**Peak-to-peak ranges, where shown, are true readings of complex waveshapes.

A.C. POWER SUPPLIES

Mfgr.	Model	Output Voltage	Output Current	Meter Ranges V.	Meter Ranges A.	Price
EICO	1073	0-140	1, 3 a.	140	1, 3	$35.95
	1078	0-140	2.5, 7 a.	140	2.5, 7	$42.95
HEATH	IP-22	90-130 in .75 v. steps	300 w. (cont.) 500 w. (inter.)	90-140	—	$54.95
RADIO SHACK	22-902E	0-150	5 a.	0-150	—	$20.21

GRID-DIP METERS

Mfgr.	Model	Range (mc.)	No. of Bands	Power	Price	Remarks
ALLIED	G-30	1.5-300	6	a.c.	$22.95	
EICO	710	.400-250	8	a.c.	$29.95	
HEATH	HM-10A	3-260	6	batt.	$34.95	tunnel diode

D.C. POWER SUPPLIES

Mfgr.	Model	Output Voltage Ranges	Current Ranges (amps)		Meter Scales	Price	Remarks
			Continuous	Intermittent			
ALLIED	83YX912	8, 15	15 (6 v.) 10 (12 v.)	17.5 (6 v.) 12.5 (12 v.)	15 v. d.c. 20 a. d.c.	$38.95	
EICO	1020	6, 30	150 ma. (0-12 v.) 200 ma. (12-24 v.) 300 ma. (24-30 v.)		6 v. d.c. 30 v. d.c.	$23.99	.005% 120 cps ripple at full load
	1050	8, 16	10 (8 v.) 6 (16 v.)	20 (8 v.) 12 (16 v.)	20 v. 20 a.	$29.95	not recommended for transistor work; accessory filter #1055 available
	1060	8, 16	10 (8 v.) 6 (16 v.)	20 (8 v.) 10 (16 v.)	20 v. 10, 20 a.	$39.95	ripple 16 v. range: 3% @ 2 a., 1% @ 6 a., 1.5% @ 10 a.; 8 v. range: 1.5% @ 2 a., 2% @ 6 a., 4.5% @ 10 a.
	1064	8, 16	10 (8 v.) 6 (16 v.)	20 (8 v.) 10 (16 v.)	20 v. 10, 20 a.	$45.95	ripple same as 1060; lightweight version of 1060
EMC	905	6, 12	—	—	2 meters	$28.90	with extra filtering for transistor applications $34.90
HEATH	IP-12	8, 16	10 (6 v. unfiltered) 5 (6 v. filtered) 5 (12 v.)	15 (6 v. unfiltered) 7.5 (12 v. unfiltered)	2 meters	$47.50	ripple .3%
	IP-32	0-400 v. 0 to – 100 v. (bias voltage)	100 ma. 1 ma.	125 ma.	150, 400 v. 150 ma.	$56.95	6.3 v. @ 4 a. a.c. output; ripple 10 mv. d.c. output impedance 10 ohms; output regulation 1% from no load to full load, ± .5 v. for ± 10 v. line voltage variation from 117 v.
	IP-2D	0-50 in 5 v. steps	1.5	—	15, 50 v. & amp.	$72.50	transistorized, ripple & noise 150 μv. max., overload protection, load regulation ± 15 mv., output imp. .01 ohm to 10 kc. — .5 ohm 10 kc. & up
PACO	B-10	8, 16	10 (8 v.) 6 (16 v.)	20 (8 v.) 12 (16 v.)	2 meters	$43.95	low ripple output; 8 & 16 v., 5 a., 3%
	B-12	0-400 v. 0 to – 150 v.	150 ma. 2 ma.	—	150, 400 v. 200 ma.	$69.95	6.3 v. @ 3 a. and 12.6 v. @ 3 a. a.c. outputs; d.c. output impedance 10 ohms; regulation .33% from no load to full load; .4% for ± 10 v. line voltage variation from 117 v.
PRECISE	711	15 v. 30 v. 110-180 v.	10 10 .750	20 20 1	— —	$59.95	90-140 v. a.c. (isolated) output @ 1 a.; Model 713 90-140 v. a.c. @ 3 a. output $69.95; other a.c. output on both models: 24 v. @ 20 a., 90-140 v. @ 10 a. continuous (not isolated)
	760	140-450 v. 0- + 1000 v. @ 1 ma.	100 ma.	—	2 meters	$49.95	6.3 v. @ 4 a. and 375 v. @ 50 ma. a.c. outputs; ripple .01%

SIGNAL TRACERS

Mfgr.	Model	Indicators		Test Speaker Function	Out. Trans. Function	Wattmeter Function	"B+" Output	Component Noise-Test Function	Price	Remarks
		Speaker	Eye							
ALLIED	83Y955	X	X	X	X	X	X	X	$26.95	
CONAR	230	X	X						$39.95	calibrated attenuator for r.f. & a.f. gain measurement, tuned & calibrated 175 kc. to 1500 kc. in two bands
EICO	145A	X		X	X		X	X	$23.95	
	147	X	X	X	X	X	X	X	$29.95	
EMC	802	X	X	X	X		X		$24.95	generates 400 cps and modulated 455 kc. signals
FEILER	TS-1K	phone							$ 7.76	meter, phone, battery extra
	TS-3K	X							$26.16	can be used to convert v.o.m. to r.f. v.t.v.m.; battery operated TS-2K $17.95
	TS-5K	X							$23.52	can be used to convert v.o.m. to r.f. v.t.v.m.
HEATH	IT-12	X	X	X	X		X	X	$19.95	
LAFAYETTE	KT-208	X							$19.95	also signal gen., see listing; output for v.t.v.m. & phones
OLSON	KB-141	X							$19.95	also signal gen., see listing
PACO	Z-80	X	X	X	X	X	X	X	$32.95	calibrated attenuator for gain measurement

SWEEP AND MARKER GENERATORS

Mfgr.	Model	Freq. Range	No. of Bands	Output		Sweep Width	Cal. Marker Ranges (fund.)	No. of Bands	Provision for Marker Crystals	Provision for Ext. Markers	Price	Remarks
				Voltage	Z							
ALLIED	83YX123	300 kc.-250 mc.	4	.15		0-13 mc.	—	—	2	yes	$44.95	
EICO	360	500 kc.-228 mc.	—	—	—	0-30 mc.	—	—	1	no	$39.95	
	368	3-216 mc.	5	—	50Ω	0-15 mc.	2-225 mc.	3	1	yes	$69.95	
	369	3.5-216 mc.	5		50Ω	20 mc.	2-75 mc. to 225 mc. on harm.	3 fund. 1 harm.	1	no	$79.95	post marker adder
HEATH	IG-52	3.6-220 mc.	4	.1	50Ω	0-42 mc.	19-60 mc.	1	1	yes	$54.95	
PACO	G-32	3-220 mc.	5	—	—	0-20 mc.	—	—	1	yes	$85.95	marker adder

AUDIO GENERATORS

Mfgr.	Model	Range	No. of Bands	Output		Output Waveforms	Accuracy	Distortion	Price	Remarks
				Max. Volts	LoadΩ					
ALLIED	83YX137	20 cps-1 mc.	5	10	600	sine	—	.25% from 100 cps through audible range into high Z	$35.95	
EICO	377	20-200 k (sine) 60-50 k (square)	4	10	1000	sine-square	±3%	less than 1%	$37.95	—
HEATH	IG-72	10 cps-100 kc.	sw. sel. freq.	1 v. 10 v.	600 10,000	sine	±5%	less than .1% from 20-20,000 cps	$41.95	output meter calibrated in volts and db
	IG-82	20 cps-1 mc.	5	10 v. (sine & square)	high Z	sine-square	±1.5 db 20 cps-1 mc.	.25% from 20-20,000 cps	$51.95	square-wave output voltage is p-p; rise time .15 μsec.
PACO	G-34	6 cps-750 kc.	6	10 v. (sine) 18 v. (square)	600 600	sine-square	—	—	$64.95	square-wave output voltage is p-p; rise time .15 μsec.
PRECISE	635	20 cps-200 kc.	5	—	—	sine-square	—	—	$39.95	
	630	20 cps-20 kc.	5	—	—	sine	—	—	$44.95	has additional r.f. band .3 mc.-100 mc.

A.C. V.T.V.M.'s

Mfgr.	Model	Range* A.C. (r.m.s.) v.	No. of Ranges	A.C. Input Z (meg.—pf.)	Accuracy (full-scale)	Frequency Response	Price	Remarks
ARKAY	AV-20	.01-300	10	1 meg. @ 1 kc.	—	10 cps-400 kc. ±1 db (.01-100 v. range) 10 cps-40 kc. ±2 db (300 v. range)	$29.95	db range −52 to + 52
	AW-30	5 mw.-500 w.	6	4, 8, 16, 600 ohms	—	10 cps-250 kc. ± 1 db	$29.95	audio wattmeter 25 w. continuous, 50 w. intermittent
EICO	250	.001-300	12	10-15	±3%	10 cps-600 kc. ±0 db	$49.95	amp. output 5 v.; max. gain 60 db
	255	.001-300	12	10-15	±3%	10 cps-600 kc. ±0 db	$44.95	db range −80 to + 52
	261	.01-1000	11	2-15	±4%	10 cps-150 kc. ±0 db	$49.95	wattmeter ranges (7) .15 mw.-150 w.; loads: 4, 8, 16, 600 ohms @ 40, 80, 40 + 40 watts
HEATH	IM-21	.01-300	10	(10-300 v.) 10-12 (.01-3 v.) 10-22	±5%	10 cps-500 kc. ±1 db 10 cps-1 mc. ±2 db	$33.95	db range −50 to + 53
RADIO SHACK	22-027 (TK-111)	.01-300	10	1 @ 1 kc.	—	10 cps-400 kc. ±1 db (.01-100 v. range) 10 cps-40 kc. ±2 db (300 v. range)	$25.95	db range −52 to + 52

*Figures are highest scale markings of the lowest and highest ranges.

CAPACITOR CHECKERS

Mfgr.	Model	Out or In-Circuit Check	Capacitance Test Range	Resistance Test Range	Power-Factor Function	Test Voltages	Tests		Price	Remarks
							Shorts	Open		
ALLIED	83Y952	in	20 pf.-2000 μf.				X	X	$14.95	
	83Y901	out	10 pf.-1000 μf.	100 ohms-5 m.	0-50%	50, 150, 250, 350, 450 volts d.c.	X	X	$19.95	
ARKAY	CA-40	out	1 pf.-1 μf.						$29.95	
CONAR	311	out	10 pf.-1500 μf.	1 ohm-150 m.	0-50%	0-450 volts d.c.	X	X	$21.95	
EICO	955	in	.1 μf.-50 μf.			6.3 v. a.c.	to 2000 μf.	from 5 pf.	$19.95	
EMC	801	in	10 pf.-5000 μf.	.5 ohm-500 m.	0-60%	0-500 volt d.c.	to 20 μf.	from 50 pf.	$24.95	will not check electrolytics for short
HEATH	IT-22	in					to 20 μf.	from 50 pf.	$10.95	
	IT-11	out	10 pf.-1000 μf.	5 ohms-50 m.	X	3-600 v. d.c.	X	X	$29.95	direct reading scales; input provision for 10 kc. signal
PACO	C-20	out	10 pf.-2000 μf.	.5 ohm-200 m.	0-60%	0-500 v. d.c.	X	X	$23.95	bridge circuit for determining transformer turns ratio
	C-25	in	2 μf.-400 μf.				X	from 5 pf.	$19.95	
RADIO SHACK	22-088	in	4 μf.-400 μf.				X	X	$19.95	

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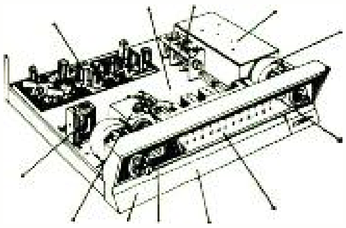

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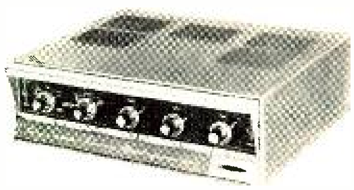

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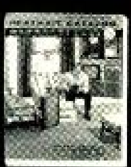

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CIRCLE NO. 122 ON READER SERVICE PAGE

V.O.M.'s

Mfgr.	Model	Ranges* A.C.—D.C.	Ohms/ mid-scale	D.C. Current †A.C. Current	No. of Voltage Ranges	Sensitivity ohms/volt D.C.	A.C.	Accuracy D.C.	A.C.	Price	Remarks
ALLIED	83Y128	1-5000	1000/60 100,000/150 1 meg./1500	a.c. & d.c. 1, 10, 100 ma., 1 a.	7	1 k	1 k	±2%	—	$15.95	db scale −20 to + 69;
	83Y149	same as 128 but with 5% resistors								$13.95	
	83Y140	2.5-5000	2000/12 200,000/1200 20 meg./120 k	.1, 10, 100 ma., 1, 10 amp.	6	20 k	5 k	±2%	—	$29.95	db scale −30 to + 63; output function
	83Y708	5-500 15-500 (a.c.)	30 k/1200	5, 10, 100 ma.	5	1 k	—	—	—	$ 7.95	
ARKAY	M4	1-5000	55-150-1500	a.c. & d.c. 1, 10, 100 ma., 1 a.	7	1 k	1 k	—	—	$13.50	db scale −20 to + 69; in 6 ranges
	MT-50	1.5-5000	15-150-15 k	150 μa, 15, 150, 500 ma., 15 a. d.c.	7	20 k	5 k	—	—	$29.50	db scale −12 to + 65 db
CONAR	240	6-600	1000, 10 m.	—	3	20 k	5 k	±3%	±5%	$17.95	
EICO	536	1-5000	5000, 1 m.	a.c. & d.c. 1, 10, 100 ma., 1 a.	7	1 k	1 k	—	—	$19.95	db scale −20 to + 69; with 1% res. Model 526
	565	2.5-5000	2000, 20 m.	100 μa., 10, 100, 500 ma., 10 a.	6	20 k	5 k	—	—	$24.95	db scale −12 to + 55; output function; with 1% res. Model 555
	566	1-5000	5000, 1 m.	1, 10, 100 ma., 1 a.	7	1 k	1 k	—	—	$16.95	db scale −20 to + 69 output function; with 1% res. Model 556
EMC	102K	6-3000 12-3000 (a.c.)	1000, 1 m.	6, 30, 130 ma., 1.2 a. †30, 150, 600 ma.	5	—	—	±2%	±2%	$12.50	
	103K	6-3000	1000, 1 m.	6, 30, 120 ma. †30, 150, 600 ma.	5	—	—	—	—	$14.90	db scale
	109K	6-3000 12-3000 (a.c.)	20 k-20 m. (3 ranges)	6, 60, 600 ma.; †30, 300 ma., 3 a.	5	20 k	10 k	—	—	$19.25	db scale
HEATH	IM-20	15-500 (d.c. only)	—	1 ma.	4	1 k	—	±10%	—	$14.95	cap. & res. substitutions; signal generator
	HM-1	1.5-5000	—20 m.	150 μa., 15, 150, 500 ma., 15 a.	7	20 k	5 k	—	—	$29.95	db scale −10 to + 65; output function; polarity rev. switch
LAFAYETTE	TK-10	10-1000	10 k, 1 m.	500 μa., 10, 250 ma.	5	20 k	10 k	—	—	$11.95	db scale −20 to + 36;
PACO	M40	1.5-6000 3-12k (a.c.)	2000/8.5 20 m./85 k	60 μa., 1.5, 15, 150 ma., 1.5, 15 a.	7	20 k	10 k	—	—	$31.95	db scale; output function
RADIO SHACK	22-079	1-5000	1000-1 m.	a.c. & d.c. 1, 10, 100 ma., 1 a.	7	1 k	—	—	—	$16.95	db scale −20 to + 69 output function
RCA	WV-38A	.25-5000 2.5-5000 (a.c.)	2000/12 20 m./120 k	50 μa., 1, 10, 100, 500 ma., 10 a.	d.c.—8 a.c.—6	20 k	5 k	±3%	±5%	$29.95	db scale −20 to + 50; output function; polarity rev. switch

*Figures are highest scale markings for lowest and highest ranges.

CAPACITOR & RESISTOR SUBSTITUTION & DECADE BOXES

Mfgr.	Model	Resistance Range (ohms)	Steps	Decades	Tolerance	Wattage	Capacitance Range	Steps	Decades	Voltage Rating	Tolerance	Price
ALLIED	83Y138	—	—	—	—	—	.0001 μf.- .22 μf.	18	—	600 v., .15 & .22 μf. are 400 v.	±20%	$ 5.95
	83Y139	15-10 k 15 k-10 m.	18 18	—	±10%	—	—	—	—	—	—	$ 5.95
EICO	1100	15-10 m.	—	multiples of 15, 22, 33, 47, 68, 100 ohms	±10%	1	—	—	—	—	—	$ 7.95
	1120	—	—	—	—	—	.0001 μf.- .22 μf.	18	—	600 v.	±10%	$ 6.95
	1140	—	—	—	—	—	—	—	—	—	—	$14.95 (combination of 1100 & 1120)
	1171	0-99,999	1 ohm	5	½%	1	—	—	—	—	—	$24.95
	1180	—	—	—	—	—	100 pf.- .111 μf.	100 pf.	3	350 v.	±10%	$17.95
EMC	900	15-10 m.	2	—	±10%	1	.0001 μf.- .22 μf.	18	—	—	—	$10.25
HEATH	IN-22	—	—	—	—	—	.0001 μf.- .22 μf.	18	—	600 v., 400 v. for three highest steps	—	$ 5.50
	IN-21	—	—	—	—	—	100 pf.- .111 μf.	100 pf.	3	—	±1%	$17.95
	IN-11	1-99,999	1 ohm	6	±½%	—	—	—	—	—	—	$24.95
	IN-12	15-10 m.	36	—	±10%	1	—	—	—	—	—	$ 5.95

UNCLASSIFIED TEST EQUIPMENT

Audio Analyzer

Heath: Model IM-22, $56.95. a.c. v.t.v.m. freq. resp. 10 cps-100 kc. ± 1 db; range .01, .03, .1, .3, 1, 3, 10, 30, 100, 300 r.m.s. v.; input impedance 1 meg. or 4, 8, 16, or 600 ohms. Wattmeter: 10 cps-50 kc. ± 1 db.; .15, 1.5, 15, 150 mw., 1.5, 15, 150 w.; 4, 8, 16, 600 ohm internal loads, 10,000 ohms across external load. IM analyzer: high-pass filter, 2000-12,000 cps, low-pass filter 10-600 cps; 1, 3, 10, 30, 100 per-cent full scale. Input impedance a.c. v.t.v.m., 1 meg. or 4, 8, 16, or 600 ohms switch-selected. Internal-generator frequencies: 60 cps, 6 kc. DBM: −40, −30, −20, −10, 0, 10, 30, 40, 50. Reads from −65+52 dbm. Accuracy: a.c. v.t.v.m. and wattmeter within 5% full-scale; IM analyzer within 10% of full-scale.

Battery Tester

Eico: Model 584, $9.95. Test positions (volts): 1.5, 4.5, 6.0, 7.5, 9.0, 22.5, 45, 67.5, 75, 90, spare.

CRT Checker

Eico: Model 630, $19.95. Bridge circuit measures peak beam current. Model 632, $54.95. Checks for opens, shorts, beam current, gas. Uses 1000 v.d.c. for rejuvenate-welding and to remove shorts.

Paco: Model T-63, $44.95. Checks screen brightness under high or low line voltage conditions; simulates the effect of a booster; can be used as a rejuvenator. Beam current type test circuit.

Bar and Dot Generators

Eico: Model 352, $19.95. TV channels 2-6; 16-23 vertical bars, 13-22 horizontal bars; output voltage .4 mv.

Heath: Model IG-62, $64.95. TV channels: 2-6. Output voltage 100-100,000 μv. Sound carrier: crystal-controlled, unmodulated, 4.5 mc. away from picture carrier. Positive or negative video output variable from 0-10 v. p-p open circuit. Modulation: white-dot pattern, cross-hatch pattern, horizontal bars, vertical bars, 10 vertical color bars, shading bar pattern.

Paco: Model G-36. $119.95. Produces color bars, white dots, vertical bars, horizontal bars, and crosshatch. Crystal controlled.

Electronic Switches

Eico: Model 488, $23.95. Switching rate 10-2000 cps continuously variable in 3 ranges. Frequency response d.c.-30,000 cps (−2 db); maximum gain 10 times (continuously variable gain control); input impedance 100,000 ohms; max. input at greatest attenuation 400 v. p-p; output impedance 50,000 ohms.

Heath: Model S-3, $23.95. Freq. resp. to 100 kc. ± 1 db.

Filament Tester

Eico: Model 612, $4.95. Checks filament continuity. Sockets are provided for 9 pin, octal, loctal, and 7 and 9-pin miniature tubes. Adapter provided for checking 14-, 12-, and 8-pin picture tubes.

Flyback Transformer and Yoke Testers

Allied: Model 83Y118, $21.95. Indicates shorts in coil with a "Q" greater than 1, and inductance from .0003-2 hy. Checks continuity of circuits with 0-.5 meg. resistance.

Eico: Model 944, $23.95. Checks all flyback transformers and yokes in- or out-of-circuit.

Harmonic Distortion Meter

Heath: Model IM-12, $54.95. Frequency 20-20,000 cps in three ranges; distortion 1, 3, 10, 30, 100 per-cent full-scale; voltmeter 1, 3, 10, 30 volts full-scale; input resistance 300,000 ohms; minimum input voltage for distortion measurements 0.3 v.; output voltage for monitoring 2.5 at full-scale meter reading. Meter scales calibrated in volts r.m.s., per-cent distortion, and db. When used with Heathkit IG-72 or IG-82, the IM-12 will measure harmonic distortion at any frequency between 20 and 20,000 cps.

Impedance Bridges

Eico: Model 950, $23.95. Measures capacity from 10 pf.-5000 μf. in four ranges, resistance from .5 ohm-500 meg. in four ranges. Comparator ratio from .05-20 (400 to 1). D.c. polarizing voltage 0-500 v.

Heath: Model IB-2A, $69.95. Measures resistance from .1 ohm-10 meg., capacitance from 100 pf.-100 μf., inductance from .1 mhy.-100 hy., dissipation factor .002-1, storage factor ("Q") .1-1000. Built-in 1000 cps generator and provision for input from external generator.

Paco: Model C-20, $23.95. Capacitance 10 pf.-2000 μf. in four ranges, resistance .5 ohm-200 meg., capacitor leakage test at 500 v. Ratio tests from .05-1 and 20-1 on capacitors, inductors, and resistors; power factor range from 0-60% at .1 μf.-2000 μf.

Q Meter

Heath: Model QM-1, $54.95. Frequency: 150 kc.-18 mc. in four bands. Inductance: 1 μhy.-10 mhy. "Q"; 250 full scale x 1 or x 2. Capacitance: actual, 40 pf.-450 pf.; effective, 40 pf.-400 pf.

RF Power Meter

Heath: Model PM-2, $12.95. Frequency range 100 kc.-250 mc, sensitivity .3 v. r.m.s. at antenna input terminals for full-scale deflection.

Vibrator Tester

EMC: Model 906, $17.05. Checks 6- and 12-volt vibrators with external power supply. Six sockets. The Model 905-6A, a combination of the 906 and the 905 battery eliminator, costs $44.90.

Voltage Calibrators

Allied: Model 83Y136, $12.95. .01-100 v. square-wave output.

Eico: Model 495, $19.95. Semi-square (clipped sine-wave) output waveshape at line frequency. 0-.1, 0-1, 0-10, 0-100 p-p v. Dial reading accuracy ± 5%.

Manufacturers of Kit Test Equipment

Allied Radio Corp.
100 N. Western Avenue
Chicago 80, Illinois

Arkay International, Inc.
2372-82 Linden Blvd.
Brooklyn 8, N.Y.

Conar Instruments Div.,
National Radio Institute
3939 Wisconsin Avenue
Washington 16, D.C.

DeVry Technical Institute
4141 Belmont Ave.
Chicago 41, Ill.

Eico Electronic Instrument Co., Inc.
3300 Northern Blvd.
Long Island City 1, N.Y.

EMC
Electronic Measurements Corp.
625 Broadway
New York 12, N.Y.

Feiler Engineering & Mfg. Co.
8026 N. Monticello Avenue
Skokie, Illinois

Heath Company
Benton Harbor, Michigan

Lafayette Radio Electronics Corp.
111 Jericho Turnpike
Syosset, L.I., N.Y.

Olson Electronics, Inc.
260 S. Forge Street
Akron 8, Ohio

Paco Electronics Co., Inc.
70-31 84th Street
Glendale, L.I., N.Y.

Precise Electronics & Development Corp.
76 E. Second Street
Mineola, L.I., N.Y.

RCA: Radio Corporation of America
415 S. Fifth Street
Harrison, New Jersey

Radio Shack Corp.
730 Commonwealth Avenue
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CIRCLE NO. 138 ON READER SERVICE PAGE

JOHN FRYE

Mac and Barney discuss the practical and philosophical considerations in servicing transistorized equipment.

SEMICONDUCTOR SEMINAR

STOPPING short in the doorway of the service department, Barney did an exaggerated Jackie Gleason double-take of Mac, his employer.

"Since when did you take up welding?" he demanded, looking curiously at the strange black object jutting from Mac's forehead and covering his eyes.

"These aren't welding goggles," Mac explained, pushing the object up on his forehead a bit and peering from beneath it at his assistant. "It's a "Magna-Sighter," manufactured by the *Fairchild Optical Company* in Chicago. It's really a binocular eye loupe with a magnification of 2¼ times. A prism is ground into each magnifying lens so that the eyes can converge at the proper focal distance. In this particular model, Model 5, that's ten inches; but they make other models that focus all the way from fourteen inches to four inches—from the eyes, not the lenses. Magnification in other models ranges from 1¾ times to 3½ times, with the greater magnification having shorter focal distance and also less depth of focus."

"How come the lenses are so far from the eyes? They must be at least a couple of inches in front of them."

"For one thing, that allows you to wear glasses, even bifocals, with the 'Magna-Sighter.' The instrument is adjusted so that the bottoms of its lenses are directly in line with the eyes. When you look up slightly, you peer through the upper section of the bifocals and the 'Magna-Sighter' lens. When you glance down, you see through the lower section of the bifocals as you do normally. Here, see for yourself."

Barney adjusted the headband to accommodate his slightly larger head and took a look at the printed circuit of a transistor radio.

"Wow!" he exclaimed. "That certainly makes things stand out sharply. The joints look kind of 3-D, if you know what I mean."

"I know. It reminds me of the way things used to look through the old stereoscopes every proper family kept in the front parlor. It gives you an almost exaggerated impression of depth."

"This thing is going to be the old berries for working on transistor sets," Barney exclaimed enthusiastically. "I can even read that postage-stamp-sized diagram pasted in the cover. I thought our jeweler's loupe and our illuminated magnifier were good, but this gadget has some definite advantages. For one thing, my unaristocratic eye gets tired of trying to hold that loupe in place like a monocle. Too, I have to take it out every time I want an unmagnified view of things. With this, I simply lower my head for a magnified view and raise it to see normally."

"If it helps your young eyes that much, think what it does for these tired old orbs," Mac suggested. "Transistor radios and accompanying printed circuits have really placed a premium on good eyesight. Visual inspection alone can spot many difficulties in these receivers. It used to be a technician's joke that customers were always suspecting a 'loose connection' or a 'broken wire.' These faults were actually rarely found in wired-chassis tube radios, but they account for a high percentage of difficulties in transistor receivers, probably because these little hand-carried receivers are more often dropped and subjected to other abuse. But a hairline crack in a printed circuit or a tiny break in a solder joint of one of these miniature receivers is darned hard to see."

"You're in phase there," Barney agreed. "The first thing I do after I've checked out the battery of a transistor set is to give it a really good looking over, no matter if the complaint is a dead radio, weak reception, distortion, or what have you. This eyeball inspection very often saves a lot of time. Of course, through experience, I've learned certain spots are hotbeds for these cracked-joints-and-broken-lead troubles.

"One good hunting place is where a comparatively heavy component is soldered to the board. This includes transformers, tuning capacitors, and occasionally speakers. A heavy impact that occurs when the radio is dropped is likely to break either the soldered connection to the component or the printed circuit in the vicinity of that component. A cracked board, naturally, usually means one or more broken leads. Sometimes rough handling of the tuning control knob or the volume control knob is all that's needed to fracture the board. I might mention the modern tough plastic used in the cases of these little receivers won't tattle on the owner for dropping his set. A jar that really messes things up inside often fails to leave a telltale mark on the case."

"Yes, and isn't it strange how reluctant most customers are to confess the set has been dropped? Either they must think we automatically up the bill when we hear the radio has been dropped, or they simply don't want to admit to having butterfingers. Wonder if you've noticed leads running along the edge of a printed circuit—quite often such leads are a part of the set ground system—are especially likely to develop hairline cracks. I suppose this is because the edge of the board is subjected to more flexing."

"I sure have," Barney agreed, "and a crack in one of these leads will often leave the set dead as a mackerel. Other spots I favor with close attention are those where wire leads connect to the printed circuit, especially if those leads are likely to be subjected to some pulling and bending. Battery leads are a good example. So are antenna leads, speaker leads, and leads going to the earphone jack. Some of these are subjected to stress simply by careless removal of the back of the case and changing the batteries; others have strain put upon them in the assembly of the receiver."

"I find a surprising number of sets in which those little hair-like leads from the antenna are broken off," Mac commented. "Apparently the owner doesn't see them when he's changing a battery and accidentally breaks them loose. I might mention it's much easier to break one of these leads off than it is to find quickly where that lead originally connected to the printed circuit, especially if the receiver is an import for which we have no diagram. I'm hoping the

'Magna-Sighter' will be a help in locating that little stub of broken wire sticking up out of a solder joint.

"Getting away from broken leads," Barney said, "I've decided that when the service data calls for a matched pair of transistors in the output stage and one of them goes bad, it's usually better to replace both with another matched pair. I've tried using a single general replacement transistor for the bad one, and it will work after a fashion, but checking the outputs of the two transistors with a v.t.v.m. reveals they are seldom close to equal. When the transistors have sockets and you have a good supply of substitutes on hand, you can try them one after the other and *may* find one that will match closely the one in the set; but if the transistors are soldered in, it's better not to fool around. Just remove both and put in a new matched pair."

"Those foreign imports for which we have no service data are a real pain," Mac mused; "but electronics magazines are doing their best to help. I cut out and save the pages giving American substitutes for foreign transistors and the names and addresses of importers who can furnish service data and special parts for the brands they import. Even so, when a customer insists on a preliminary estimate on one of these, I make it good and stiff to protect myself. I know from experience I'm likely to spend twice as much time locating the trouble as would be the case with an American-made receiver for which we have complete and detailed service information."

"You remember Dave, the salesman who used to call on us from Electronic Equipment," Barney said. "I ran into him at a lunch counter yesterday, and he tells me he's doing a good business servicing transistor radios for radio and TV shops. Most of the big TV shops consider transistor radio service a 'nuisance' business; yet they have to do it; so they're glad to give the work to Dave. He charges a flat five dollar service fee per set, no matter what's wrong with it. Parts, of course, are extra. He says he's doing very well and has all the business he can handle. He says he turns out the sets faster and faster as he gains experience."

"Sure he does, and he's a lot smarter than the fellows for whom he is working," Mac replied. "They are paying him to acquire experience they should be getting themselves. It doesn't take a seventh son of a seventh son to see that eventually transistors are likely to replace tubes in almost all household electronic equipment. They have a lot of things going for them: small size, long life, little heat, high efficiency, and small - size - low - voltage accompanying components. When transistorized TV "hits its stride, as it surely must, Dave will be in on the ground floor."

"I wonder why so many of the old-timers hate transistor radio servicing," Barney said. "Lots of them would rather horse a heavy TV chassis around half a day than troubleshoot one of the little jobs."

"Mostly, I suspect, it's a case of unfamiliarity breeding contempt," Mac suggested. "All of us tend to fear and distrust and even hate the unfamiliar. We have to learn some new things to understand it, and that requires effort, which is always distasteful. Exactly the same thing happened when the a.c.-d.c. receivers came on the market. Service technicians applied all sorts of contemptuous names to them: 'cigar-box radios,' 'punch-board radios,' etc. But eventually they wound up servicing these sets almost exclusively and doing just as well as they had done working on the big transformer-type console radios."

"You think the same thing will happen with transistor radios?"

"I have no doubt about it. But it would be well if all of us quit down-grading transistor receivers and began to appreciate their good points. I firmly believe a man has to like his work to do his best, and as long as we dislike transistor radio service we're not going to be very good at it—not really good.

"If you have visual aids, special soldering equipment for the printed circuits, adequate service data, a good grounding in transistor fundamentals, *and the proper attitude,* transistor radio servicing can be very rewarding, both in money and in personal satisfaction," Mac concluded as he slid the binocular eye loupe over his head and picked up the little transistor receiver chassis. ▲

"CUSTOM" CERAMIC CAPACITORS

By IRWIN MATH

OCCASIONALLY it is desirable to use values of capacitance that are not standard, as in certain types of wide-band amplifiers or phase-shift oscillators. Also, at times, it is necessary to match two capacitors rather closely.

When ceramic capacitors are used, it is a simple matter to vary the capacitance. Grinding the edge of the capacitor will lower its value, until the correct value is obtained. A good quality bridge should be used for exact values, however, an inexpensive capacity checker can be employed for less critical tolerance requirements.

After grinding the capacitor, the edges should be checked for shorts and cleaned with a fine emery paper. Sealing wax or paraffin can then be put on to seal the capacitor from moisture. It should be pointed out that a similar operation can be carried out with carbon composition resistors. ▲

FCC ESTABLISHES FEES FOR RADIO LICENSES

Amounts range from $100 for TV broadcasters down to $4 for radio amateurs.

EFFECTIVE January 1, 1964 the FCC will begin charging fees for handling radio station and operator license applications and renewals. Public hearings held early this year disclosed an almost unanimous opposition to setting up such charges. Probably the most vigorous opposition came from hams who felt that the fees would discourage experimentation and technical development which the Commission has the responsibility of promoting. As a result of the outcry, some of the charges were reduced and some were killed altogether. However, a good many users of radio will have to pay a nominal fee for this use beginning next year.

Some of the amounts to be charged are: For license application of a new broadcast station or for renewal of license, $50 for AM or FM stations and $100 for TV stations. For TV translator application, $30. For initial construction permit for land mobile radio system (including base station and mobile units), $100. For renewal of this license, $25.

In the amateur radio service a fee of $4 will be charged for initial and renewed licenses. For modification of license, $2 and for a request for a special call sign, $20. In the Citizens Radio Service, the fee is $10 for class A station authorization. For class D and all other classes of Citizens Radio stations, the fee will be $8.

Applications for commercial radio operator examinations must be accompanied by a fee of $5 for First Class License, $4 for Second Class, and $3 for Third Class. Application for license renewals, endorsements, and duplicates call for a $2 fee. Restricted Radiotelephone Permit applications also require a $2 fee.

Exempted from charges are all types of educational radio and TV broadcast stations and closed-circuit educational systems. Fees are not required for Novice Class applications in the amateur radio service nor for applications filed in the Radio Amateur Civil Emergency Service (RACES). There are also no fees for the experimental radio services (other than broadcast), nor for such safety radio services as those used by police, fire departments, highway maintenance, State Guard, hospitals, disaster relief organizations, school buses, and non-profit ambulance operators. ▲

Radiation Devices

(*Continued from page 42*)

pends on the rate of diffusion and, thus, by proper calibration, the change in current gain can be used to determine the total amount of radiation received by the transistor.

In a semiconductor diode, neutron radiation damage can result in a change in the forward current for a certain applied voltage, hence monitoring this current can give an indication of total radiation. The diode can then be employed as a neutron dosimeter. It is not necessary for the voltage to be applied continuously—it can be applied only when measurements are required. Readings can be taken as often as desired without affecting accuracy. An experimental diode of this kind is shown schematically in the diagram of Fig. 4.

Production of Electricity

Extensive tests conducted at *Bell Laboratories* indicate that silicon solar cells are very simple and useful devices for measuring high-intensity radiation. Cells of the *n-p* type are employed, as they are much more resistant to radiation damage than the formerly employed *p-n* type.

For most applications, it is only necessary to connect the solar cell to a relatively inexpensive microammeter. This microammeter can then be calibrated directly in intensity (rads per hour, for example). In a typical solar cell, an intensity of a million rads per hour of *x*- or *gamma* radiation would produce a current of 37 μa. With more elaborate instrumentation, 100 rads per hour can be measured, and intensities as high as a billion rads per hour can be measured if the radiation that is involved is not too energetic.

Commercial Devices

We will now describe briefly some of the commercial solid-state radiation counters currently available from a few companies. It should be clearly understood that this section is by no means complete, either as to manufacturers or as to products. However, the descriptions will provide some indication of the type of semiconductor radiation detectors on the market.

Most of the devices made by *Oak Ridge Technical Enterprises Corp.*[1] are of the surface-barrier type. A wide variety of depletion depths is available, including totally depleted units with thicknesses from 50 to 500 microns. All use a very thin gold electrode on the surface of *n*-type silicon. The devices can be employed for neutron detection using appropriate converter foils, such as lithium. Some of the company's detectors are so constructed that they can be stacked for work requiring greater depletion depths.

Molechem, Inc.[2] manufactures surface-barrier detectors with *n*-type silicon having a nominal resistivity of 1000 ohm-cm., and capable of being operated at bias voltages of 200 to 500 volts and even higher for selected units, producing depletion layers upwards of 1 mm. thick. Units with very large active areas up to 2.2 cm.^{2} are available. These detectors can be provided with an evaporated layer of lithium fluoride for neutron detection.

Solid State Radiations, Inc.[3] makes silicon-junction detectors primarily. The *p*-type silicon with a resistivity of about 1000 ohm-cm. is the base material and phosphorus is diffused into the surface to form a very thin *n*-layer, less than one micron thick. Some of the company's detectors have a coating which makes them sensitive to neutrons. Different coating materials are used, including boron-10, lithium-6, uranium-235, and others, depending on whether fast or slow neutrons are to be counted and to be measured.

Ferranti Electric, Inc.[4] also specializes in silicon-junction detectors. The base material is *p*-type silicon having a resistivity of 5000 ohm-cm. and the *n*-layer is formed by phosphorus diffusion. A cross-sectional drawing of a typical unit is shown in Fig. 5. A bias as small as 10 volts in these units will produce a depletion layer which will absorb 10-million electron-volt *alpha* particles. Maximum operating voltages vary from 50 to 200 volts for the different units in each series.

Nuclear Diodes Inc.[5] specializes in large-area silicon surface-barrier detectors, with active areas as large as 3.4 cm.^{2} in standard units. These detectors are made from nominal 300 ohm-cm. *n*-type silicon. Also available is the lithium-drift detector. This unit can be combined with a conventional detector to form a system for determining the energy of the units and combinations of units which are included in the company's line.

This account has given a general, over-all picture of the uses which can be made of semiconductor materials, particularly silicon, in detecting and measuring nuclear radiation. There is much interest in this field at present, and it may be expected that great strides will be made in the near future, both in the improvement of present devices and in the development of new materials and techniques. ▲

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2. Molechem, Inc., P.O. Box 531, Princeton, N.J.
3. Solid State Radiations, Inc., 2261 S. Carmelina Ave., Los Angeles 64, Calif.
4. Ferranti Electric, Inc., Plainview, Long Island, N.Y.
5. Nuclear Diodes Inc., 1640 Old Deerfield Rd., Highland Park, Ill.

ELECTRONIC CROSSWORDS

By JOHN D. OWENS

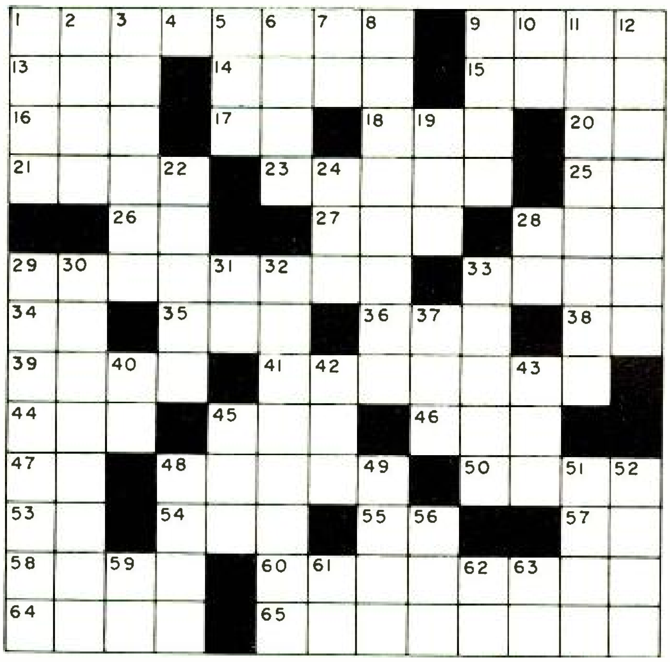
(*Answer on page 91*)

ACROSS

1. Video bandwidth.
9. Remains quiet.
13. Anthropoid.
14. Cathode-ray, for instance.
15. Part of a speaker enclosure.
16. Follower of (suffix).
17. As (Latin).
18. Numerical equivalent of red.
20. Non-drinkers' group (abbr.).
21. Power dissipating device.
23. Openly.
25. Common schematic notation.
26. Equals voltage in Ohm's Law.
27. Cold.
28. Request.
29. Vacuum tube heater.
33. Notoriety.
34. For example (Latin).
35. Substance used to coat coils.
36. It's used in some hermetically sealed capacitors.
38. Freudian term.
39. Finishes.
41. Movement of electrons through a conductor.
44. Use a shovel.
45. Some transistor heat sinks have several of these.
46. Poetic contraction.
47. Seminary degree.
48. Potting material used in early radio transformers.
50. .... inductance: property of coil which opposes any change in current flow.
53. Inert gas (abbr.).
54. Sash.
55. Western state (abbr.).
57. Equals watts in Ohm's Law.
58. Part of a loudspeaker.
60. Potential characterized by excess electrons.
64. Tangle.
65. Connected to earth or some conducting body.

DOWN

1. Moan.
2. .... facto (Latin).
3. Itemize.
5. Unit of heat.
6. Vehicle.
7. Pay attention (Latin abbr.).
8. Demodulation stage in a radio receiver.
9. Luminous area on a cathode-ray tube screen.
10. Chemical abbreviation.
11. Send a radio signal.
12. Describing some dipoles.
19. Sour.
22. Uses current (colloq.).
24. Wine in Paris.
28. All after (c.w. abbr.).
29. Transmission system whereby a fraction of the output is returned to the input.
30. Mercury-vapor control tube.
31. Thousandths of an ampere (abbr.).
32. Current in the primary of a transformer when the secondary is open-circuited.
33. Escapes.
37. Old name of engineering society (abbr.).
40. Unit of weight (abbr.).
42. Family member (colloq.).
43. Compass reading.
45. Small lie.
48. Lyricist.
49. French novelist.
51. Describing a wire that is carrying current.
52. Drive the following stage.
56. Greek letter.
59. Negative reply.
61. Schematic notation.
62. Chemical abbreviation.
63. The same (Latin abbr.).



Direct-Reading Instruments

(Continued from page 27)

of the wave analyzer, oscilloscope, and sweep generator in a sophisticated system extremely useful not only in electrical waveform measurements, but, with transducers, in studies of sound, vibration, heartbeats, and analogous phenomena.

The graphic level recorder is another type of voltmeter. A pen marks the voltage level on a piece of graph paper. Then, as the paper is moved under the pen, with the motion of the paper corresponding to changing time or frequency, the pen continues to plot the voltage level. The result is a response plot of the input voltage *vs* frequency or time.

The graphic recorder is widely used for spectrum analysis. Although it can't keep up with the sweeping rates of an oscilloscope, it has its own advantages, principally the permanence and greater resolution of its record.

Graphic level recorders measure a.c. or d.c. voltages. There is a wide variety of chart speeds, writing speeds, and voltage and frequency ranges. Some write with ink, some electrically. When the recorder is used with a variable-frequency source, a primary consideration is the means for transferring the frequency scale onto the chart paper. Some means of linking the oscillator frequency dial to the recorder drive mechanism must be provided, as well as chart paper especially calibrated for the setup.

Microwave Measurements

At microwave frequencies, where circuit dimensions approach wavelength, measurement techniques often differ from those at lower frequencies. The importance of physical dimensions makes partners of the development engineer and the machinist, especially at the higher microwave frequencies, where waveguide is employed to replace coaxial line.

Power Measurement. Voltage and current vary widely along a transmission line at microwave frequencies, and power becomes a fundamental quantitative measurement. In microwave power meters, the power is converted into heat and measured either in terms of temperature rise or of resistance change in a bolometer. The first type—the calorimetric power meter—is generally used for measurements above 10 watts, while bolometers are limited to lower levels.

Frequency Measurement. The effects of physical dimensions at microwave frequencies are used to advantage in several instruments unique to the microwave part of the spectrum. The cavity-type frequency meter is the microwave version of lower-frequency tuned-circuit wavemeters. The cavity is a simple waveguide or coaxial section that can be sharply tuned to resonance. The signal to be measured is coupled to the cavity, the cavity adjusted, and the resonant point noted on a finely calibrated scale. The mechanical nature of such a device limits accuracy to about ±0.01%; for higher-accuracy measurements, multipliers, mixers, and transfer devices are added to lower-frequency precision instruments.

V.S.W.R. and Impedance Measurement. Another important instrument peculiar to the microwave region is the slotted line. The slotted line is a section of coaxial line or waveguide that is slotted, with a movable probe sampling the field in the line. The slotted line can hardly be considered a direct-reading instrument; like the cavity frequency meter, it is simply a device for "coupling into" a transmission line to sample the standing-wave pattern. But whereas the cavity includes a calibrated frequency scale, the results of the slotted-line measurement (v.s.w.r., impedance, and associated parameters) are usually taken off a Smith Chart, slide rule, or auxiliary detector.

The admittance meter and reflectometer are alternate instruments for the measurement of impedance, v.s.w.r., etc. The admittance meter uses a bridge technique, in which pickup loops in the bridge arms are oriented to balance the unknown admittance against conductance and susceptance standards. The reflectometer is basically a power meter used to measure the ratio of incident to reflected power, or reflection coefficient.

There have been few changes in the fundamentals of microwave measurement over the past decade. Of course, the frequency range of interest is always expanding, and the instrument developer must keep pace. But the old bolometer and calorimeter still reign supreme in power measurements, even though they are now associated with the greater convenience of self-balancing bridges.

There is constant improvement in measurement accuracy throughout the spectrum, but one cannot expect the same accuracies at microwave frequencies as at 100 kc. Once you have entered the gigacycle area (1 gigacycle = 1000 mc.), you no longer talk about parts per million, and are very happy to measure within parts per thousand. A tenth of a percent is a very decent accuracy for a cavity frequency meter at 15 gc., and commercial microwave power meters are typically in the 3 to 5% class. ▲

REFERENCES

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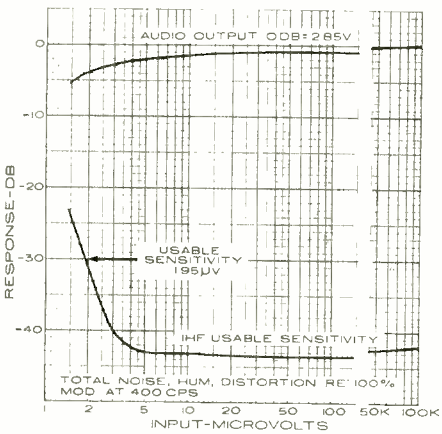
EW Lab Tested

(*Continued from page 12*)

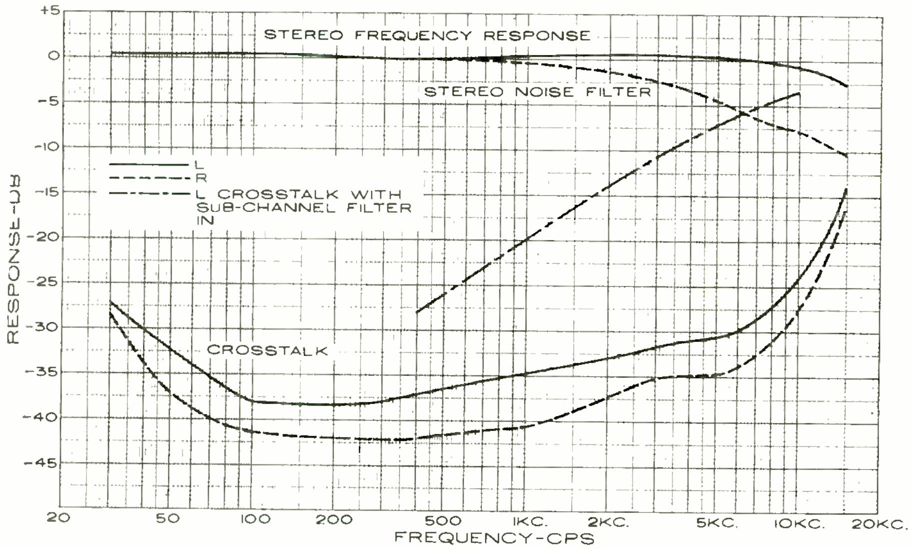


receiver circuits are altered to generate harmonics of the 19-kc. pilot carrier in a received signal, and the internal 38-kc. oscillator is shifted slightly in frequency. The beat note between the oscillator and the second harmonic of the pilot signal is heard in the speakers as an audio tone. If there is no pilot carrier present, only a slight hissing sound is heard.

Unlike visual indicators, the "Sonic Monitor" cannot be triggered by noise or high-frequency modulation peaks. When the signal is tuned in for the loudest and clearest tone, and the switch is returned to "Listen," the stereo program is heard with the best channel separation of which the tuner is capable. This is another advantage over visual stereo indicators, which give no clue as to the optimum tuning point. However, the "Sonic Monitor" does not signify a stereo broadcast automatically, but only when the switch is operated.

Our lab measurements on the 350-B showed an IHF usable sensitivity of 1.95 μv. Distortion at 100% modulation was −43.2 db or .69%. The steep limiting characteristics of this tuner provided quiet, low-distortion reception of signals as weak as 5 μv. The stereo channel separation was excellent, around 40 db at 400 cps, and averaging better than 25 db from 30 to 10,000 cps. Hum was −60 db, the residual level of our FM signal generator, and warm-up drift was negligible.

The Model 350-B is very easy and non-critical to tune. It has a happy combination of high sensitivity and stability, combined with excellent stereo performance. The tuner is priced at $219.95. ▲



NEON LAMP HOLDER

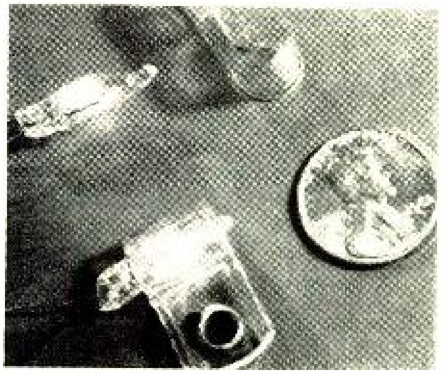
By ROBERT K. RE

THE mounting of pigtailed light bulbs, such as the NE-2 series, can be quite a problem, especially if extreme vibration is expected in the equipment.

A small, clear plastic cable clamp, as shown in the photo, not only serves as an inexpensive holder or mounting bracket, but also a lens to magnify the light. This feature is extremely useful if the lamp's "glow" must serve as an indicator.

Made in several colors (clear, amber, black) and diameters, these clamps are available from many radio parts distributors.

This handy clamp can also be used to hold other lamps or items, such as Sylvania's "Mite-T-Breaker" (in same NE-2 glass package), that are difficult to mount or require transparent holders. ▲



Cathode-Ray Oscilloscopes

(*Continued from page* 53)

ment. In general, the instrument which has the widest bandwidth is desired. However, when working with very sensitive oscilloscopes on the order of 200 μv. per division or less, the noise level goes up as the bandwidth increases. Excessive bandwidth in this particular case is a hindrance, since the minimum discernible signal is increased.

5 *What sensitivity must the scope possess?* Generally an oscilloscope is used with a high-impedance attenuator probe. Therefore, when the question of sensitivity arises, the requirement of a probe must first be determined. Ideally the sensitivity of the oscilloscope should be such that the smallest signal that will be applied will produce full screen deflection. A good rule of thumb would be the more sensitivity the better, down to 5 mv. per division. Below 5 mv./div. excess gain will produce a widening of the trace.

6. *What effect will the scope input impedance have on the item being tested?* The input impedance of an oscilloscope is a paralleled *RC* network. Its resistive component should always be high as possible (say, 1 megohm or more). If a 10 to 1 probe is used, this will be increased to 10 megohms. The importance of the capacitive component will depend upon the bandwidth of the instrument. Higher frequency scopes should have lower input capacities. The use of a probe will cut the input impedance of most high-frequency scopes, above 25 mc. to 10 or 12 pf.

7. *How will the scope be triggered?* The scope should be able to be triggered either from an external source or from a sample of the internal signal. A trigger level and slope selector are also desirable. This provides the selection of the voltage level at which the sweep will be triggered, and the sense (positive or negative) which this triggering signal must have to start the sweep.

8. *What sensitivity should the trigger circuits possess?* Normally a trigger sensitivity of ½ a major division is sufficient. Some manufacturers provide more sensitive systems. However, this extra sensitivity may cause false firing (starting) of the sweep on the random noise of the system under test.

9. *Is a switched input or dual-beam scope required?* Dual-trace scopes which time-share the sweep, having two vertical inputs, can normally be used in most applications where two signals are to be displayed simultaneously. This arrangement is usually smaller and less costly than the dual-beam scopes available. However, if each signal must be displayed at different sweep rates, a dual-beam scope generally is needed. Dual-beam scopes are really two oscilloscopes built into a single case. The only exception to the above is the *Fairchild-DuMont* Type 425, which is a time-shared scope that has the switching done in such a manner as to provide two sweep rates which can be switched in unison with the switching that occurs in the vertical channel.

10. *Will the instrument be useful 5 years from now?* This is hard to evaluate since no one really knows for certain what type of test equipment will be needed in the future. However, plug-in oscilloscopes can be adapted to new requirements readily. Scopes which have plug-ins in both horizontal and vertical channels extend the useful life of the unit still further. ▲

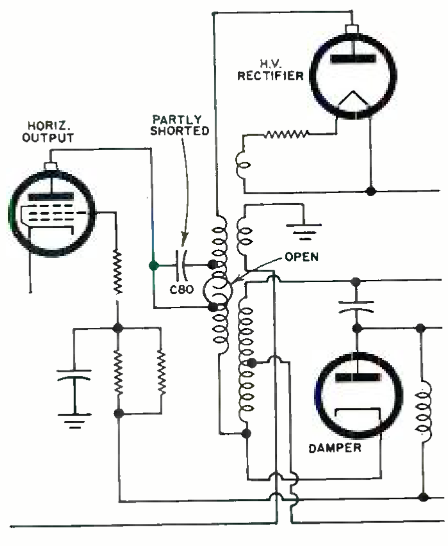
HORIZONTAL PUZZLER

By DON DUDLEY

SOFT focus and an oversized, washed-out picture marked a severe case of raster blooming on a Sparton 21S214 TV set. Also, one side of the picture was marred by a clearly evident horizontal sync bar, which could not be eliminated.

Replacement of the high-voltage, horizontal-output, and damper tubes made no difference. A ringing test, conventionally used to check the flyback transformer and associated components, was performed. It indicated that transformer and yoke were in good condition. Suspicious capacitors and resistors were replaced, but the symptoms remained. A continuity check of the transformer with an ohmmeter, usually less reliable than the ringing check, was then tried. Sure enough, the winding indicated in the schematic was open. In addition, capacitor C80 showed leakage.

The partly shorted capacitor, by restoring some continuity to the open primary, permitted the transformer to function, after a fashion, and to pass the ringing check. However, circuit constants changed by the two defects altered the phase of the a.f.c. system enough to shift the horizontal sync bar into a visible portion of the raster. Replacing the flyback and the capacitor cleared up this unusual and baffling problem. ▲



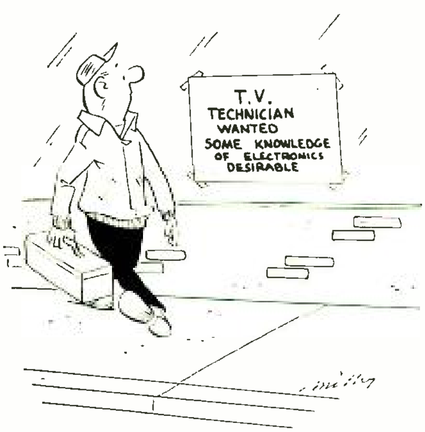
Frequency Measurement

(*Continued from page 47*)

is 259.00 cps. Using the same 1000-cps standard, it is obvious by inspection that the nearest fraction giving a sine-wave pattern is $f/4$, or 250.00 cps. However, it is also obvious that this choice will give a 9-cps drift. It is a rare individual who can count at the rate of 9 per second. But if we notice that this rapid drift is occurring, we can go back to Step 1, and instead of selecting one cycle, we can pick one-half cycle. Going to Step 2 will reveal that the nearest pattern is $f/8$, or 125.00 cps. The drift rate is going to be $(259/2) - 125$ cps, or $129.5-125.0 = 4.5$ cps. This rate is easily counted. One merely remembers to convert the final frequency back to the correct range by multiplying by the same factor used to obtain the desired patterns; in this case, a multiplication by two.

If one wishes to use Lissajous figures, the usefulness of a single standard frequency is greatly extended. Such patterns (ratios) as 5:3, 5:4, 6:5, can provide additional known fractional values of the standard, to overcome the difficulties of rapid drift.

Perhaps an even better way, short of going into more sophisticated and complex aggregations of equipment, is to employ an auxiliary audio-frequency oscillator. *If this oscillator is known to have excellent short-term stability*, it can be employed with satisfactory results in place of the WWV tones or the accurate tuning fork. The continuously variable feature of the audio oscillator offers the tremendous advantage of furnishing many basic values for the standard frequency. Of course it is necessary to synchronize, or compare, the oscillator with a known standard, just before making a measurement, and proceed directly to make the measurement. Dial readings are valueless and not used except possibly as guides, say, for the 100-cycle dial increments. The actual oscillator setting, if used as a standard, must in every instance be derived by comparison with a standard, just before use. ▲



Calibrating Test Equipment

(*Continued from page 45*)

to 0.1 microvolt is available. An instrument of this type is also useful in laboratory applications other than calibration.

A less complex resistance voltage divider is shown in Fig. 4. Designated model RD-1 by its manufacturer, *North Hills Electronics*, it is available for $425. Used in conjunction with an external voltage source, its output is that fraction of the input which is indicated by the numerals above each of the decade switches.

For precise resistance calibration, Thomas-type standard resistors (named after the person who developed them) are available from *Leeds & Northrup*. The one shown to the left in Fig. 5 is a 1-ohm unit certified to an accuracy of 0.0001% if temperature is controlled. Shown with it are other standard resistors with values of 1 ohm and less.

While d.c. standards and calibration methods have traditionally lent themselves to greater accuracy than is obtainable for a.c., recent developments have improved a.c. techniques considerably. Since there is no a.c. equivalent of the standard cell, most sources of a.c. voltage and current are refined, electronic signal generators. One company, for example, offers an a.c. standard at 400 cps that is accurate to ±0.1% in frequency and ±0.025% in voltage.

Aside from voltage, one dealing with a.c. may want to check such other parameters as impedance and power factor. Precise units of inductance and capacitance are called for. Figs. 6 and 7 show devices in this category made by *Leeds & Northrup*. Fig. 6 is a capacitor box made up of precisely calibrated, highly stable mica capacitors mounted on high-quality decade switches. Its rated accuracy is ±0.1%, +0.5 pf. Calibrating capacitors more precise than this set, although they will seldom be required, are available.

The Brooks "Inductometer" of Fig. 7, available for $550, consists of three sets of carefully wound coils. One set is mounted in the rotating disc, which is calibrated in millihenrys. One set of fixed coils is located above the disc, another below it. When the disc is rotated, mutual-inductance changes provide the variety of inductance readings possible. The coils have been carefully designed and shaped so that rotation over 170 degrees produces an almost linear change. At 1000 cps, the "Inductometer" is accurate to ±0.3%.

Conclusion

The relatively crude procedures outlined for the simple v.o.m. and v.t.v.m. in the early portion of this article can be improved considerably and also made easier with some of the devices described subsequently. Also, with these more refined standards, other types of instruments and parameters can be checked. Yet, of necessity, the special devices available have only been touched on. The complex matter of frequency calibration and standards, for example, has not been treated at all. Actually it would take more than one volume to give the broad area of calibration and standards comprehensive treatment.

Nevertheless, much has been achieved if interest in the subject has been aroused. On the practical level, further information can be obtained from the National Bureau of Standards and the manufacturers mentioned in this article on the following: standards, their prices, and organizations that specialize in providing calibration service.

Another practical alternative is available for individuals or small organizations that prefer to do their own work but cannot justify the required investment. If calibration checking is not done on a steady schedule, it is possible to rent precisely calibrated equipment on a short-term basis, either for a particular job that requires exceptional accuracy or to check regular equipment. *General Electric's* Instrumentation Service in Schenectady, N.Y., for example, offers a long list of rental equipment. While the manufacturer's own line is, of course, fully represented, instruments from other sources are included on the list. A Wheatstone bridge by *Leeds & Northrup*, to cite one example, is available for $18 a month. *G-E* also maintains, as do other manufacturers, an instrument repair and calibration service shop from which trained technicians are available on an outside-call basis.

Any firm interested in maintaining precision of its measuring instruments has a wide choice of alternatives that may be fitted in with its needs and its budgetary considerations. ▲

SIMPLE HUM-BUCKING CIRCUIT

By G. R. GILBERT

THE simple addition of a hum-bucking circuit to any high-gain amplifier is well worth considering. In almost all cases, residual hum will be reduced to virtual inaudibility and in every case substantial reduction will result.

Hum troubles usually occur when the preamplifier is connected, particularly if the compensation circuits have to cope with a pickup head with very small output. The simple circuit shown in Fig. 1 operates by feeding hum in opposite phase from the heater of the first preamplifier tube into the suppressor of the same tube. As there is a phase reversal between the control grid and the suppressor grid, hum voltage fed to the suppressor bucks the control-grid hum.

R1 is a wirewound pot of from 100 to 500 ohms with a preferred value of about 200 ohms. The potentiometer is wired as close to the *V1* tube socket as is convenient with the variable arm going to the suppressor. The usual pair of 100-ohm fixed resistors, *R2* and *R3*, are connected as shown, forming a center-tapped ground for the remaining tube heaters.

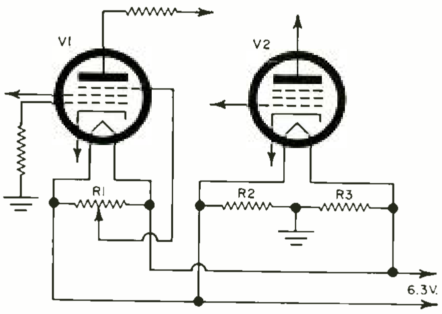
When wiring this circuit into an existing amplifier, or even when wiring a new amplifier, *V1*'s suppressor should not be connected to the cathode, as is usually the practice.

The adjustment is simple. Turn the volume control up so that the residual hum is clearly audible, then rotate *R1* until the hum either vanishes or is at a minimum. A well-defined null usually occurs.

This circuit is far more effective as a hum-reducer than the more commonly used "humdinger," which consists of a low-value pot connected across the heater supply with the moving arm going to ground.

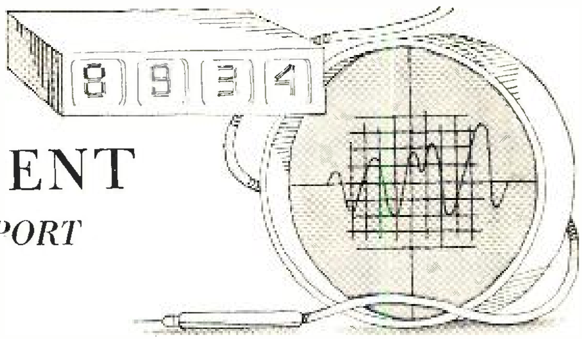
The circuit can be applied to as many tubes as required, as adjustment is made to each stage independently. ▲

Fig. 1. Circuit used to feed hum to the suppressor grid in order to buck it out.



TEST EQUIPMENT

PRODUCT REPORT



RCA Model WR-51A FM Stereo Signal Generator

For copy of manufacturer's brochure circle No. 58 on coupon (page 19)

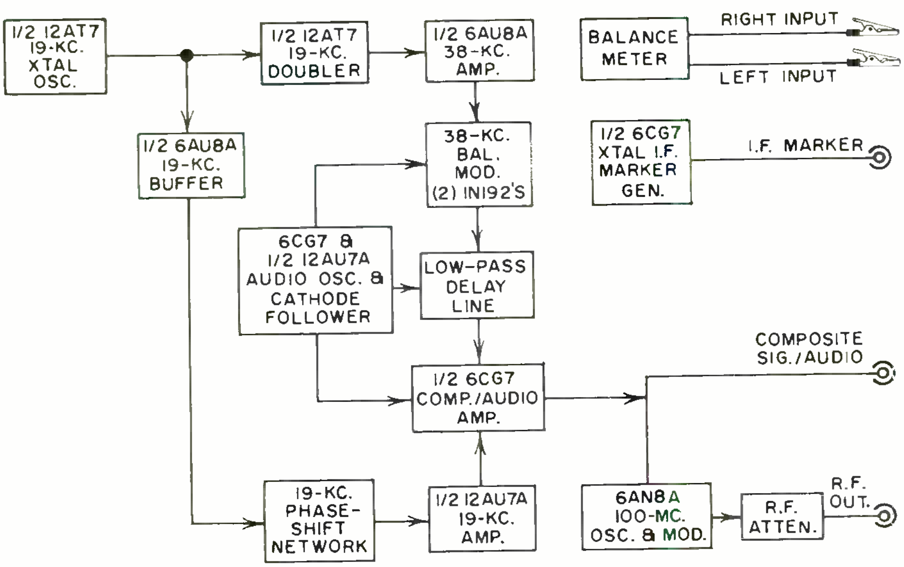
A VERY specialized signal generator is required for servicing and maintenance of FM stereo adapters, tuners, and receivers. The new *RCA* WR-51A is such a generator; it produces all the signals needed for proper adjustment of stereo circuits. This unit must be used in conjunction with a scope to observe response and output waveforms of the equipment being adjusted.

The generator produces a composite stereo output signal with either left-only or right-only modulation. A special left-plus-right signal is also available for accurate phase adjustment of subcarrier transformers. Various audio frequencies (400 cps, 1 kc., and 5 kc.) are utilized for modulation. A 19-kc. crystal-controlled subcarrier signal is provided for checking the lock-in range of stereo receivers. Sine-wave outputs at 28 kc., 38 kc., and 67 kc. are generated for band-pass and SCA filter network adjustment.

Built into this unit is a 100-mc. r.f. oscillator that may be frequency modulated with the above signals. This permits the stereo information to be applied to the front ends of FM tuners and receivers for over-all r.f.-i.f. alignment checks. In the event that there is an FM station right at 100 mc., it is possible to shift this frequency slightly by means of a front-panel control.

Another crystal oscillator in the generator (at 5.35 mc.) is used to produce a 10.7-mc. i.f. marker for the tuner's i.f. response curve. In addition, harmonics of this oscillator may be picked up at 90.95 mc., 96.30 mc., 101.65 mc., and 107 mc. for a check of a tuner's r.f. and oscillator alignment.

The instrument also includes a zero-center meter that measures 1.4 v. r.m.s. either side of zero. This meter is used to check the electrical balance of a stereo amplifier audio output. Two cables at the rear of the instrument are connected to the voice-coil output terminals of the amplifier. With a mono or an L+R signal applied to the amplifier, there should be equal outputs from both channels and the meter will read in the exact center. With a left-only signal, the meter will deflect to the left; with a right-only signal, it will deflect to the right.



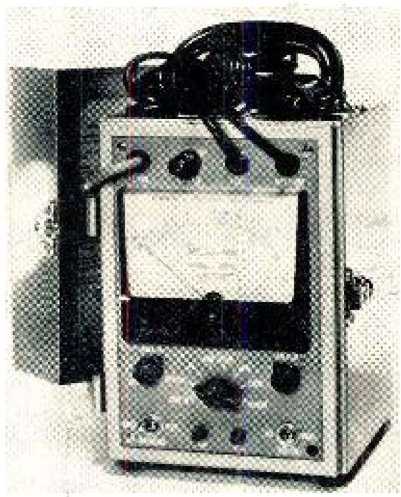
A block diagram of the instrument is included. Considering all the functions provided, the unit is remarkably simple. It uses only 6 dual-purpose tubes, 4 crystal diodes for the balanced 38-kc. modulator and meter rectifiers, 2 crystals for frequency control, and a silicon rectifier.

Accompanying the WR-51A is an excellent manual. This not only goes into complete details on the operation and use of the generator, but also includes a fine section on maintenance and adjustment of the unit itself. Some of our test-equipment manufacturers would do well to study this manual to see how it should be done.

The generator is fairly portable, weighing 14 pounds and measuring 13½"x 10"x 8". The price of the unit is $249.50. ▲

Associated Research 2850 Megohmmeter

For copy of manufacturer's brochure, circle No. 59 on coupon (page 19).



A NEW test instrument designed for field and bench testing of insulation on electrical components and equipment has been introduced by *Associated Research, Inc.* as the "Vibrotest" Model 2850. This is a megohmmeter that is able to measure resistances as great as ten million megohms at 500 volts d.c., or one million megohms at 50 volts d.c. Accuracy of ±2 percent is achieved over most of the range at 500 volts, and ±5 percent over most of the range at 50 volts.

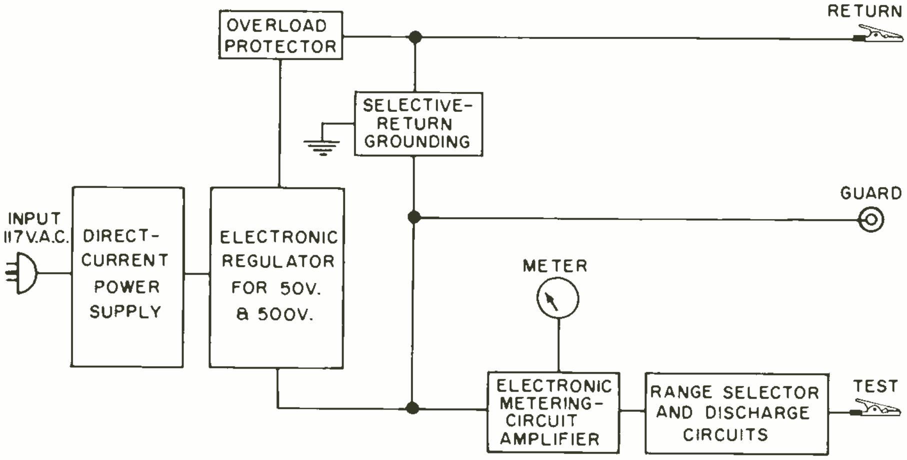
The meter can be used to measure resistance between conductors on a printed circuit, as well as insulation resistance of transistors, miniaturized parts, cables, and motors. It also measures leakage resistance of capacitors and can be used for measuring grounded and ungrounded sections of three-terminal resistors.

Many megohmmeters use a hand-cranked generator or batteries to produce the test voltages. In this instrument, a.c. line power is rectified by silicon diodes to produce the d.c. required. To prevent line-voltage variations from affecting the readings obtained, a cathode-follower voltage-regulator circuit is used (see block diagram).

A fused three-wire a.c. line cord grounds the case for shock protection. The instrument is protected from overload damage, even in cases of direct shorting, by an electronic overload circuit. The metering circuit uses miniature vacuum tubes, and the meter itself is a 200-μamp. unit.

Guard circuits are employed to control stray and leakage currents to assure accuracy at maximum sensitivity. A terminal for external guard use is provided, and a selective-return grounding circuit offers maximum guarding flexibility when the instrument is utilized to test production components or permanently installed equipment.

The instrument weighs about 10 pounds and is available for $250. ▲



Sencore CR125 Cathode-Ray Tube Tester

For copy of manufacturer's brochure, circle No. 60 on coupon (page 19).

THE most expensive component in a TV set is the picture tube. Fortunately, modern picture tubes are quite ruggedly built and they ordinarily last a long time. Although the tube's heater does burn out or open up completely, it is far more common for the tube to operate month after month but at reduced emission (and consequently, a darkened picture). Another common defect is the depositing of cathode or other foreign material between the tube's electrodes, resulting in inter-element leakage. This has many effects, ranging from lack of brightness control, poor contrast, dark picture, bright picture, and others, depending on the location of the leakage and the circuitry.

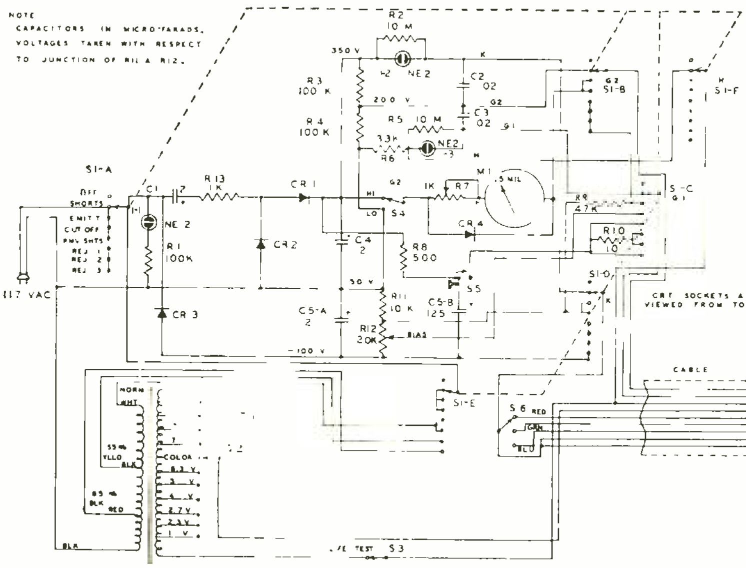
The new *Sencore* CR125 not only is a complete tester for picture tubes, but it also is frequently able to remove inter-element shorts, restore emission by rejuvenation, and weld together open cathodes. The instrument can check tubes ranging from an 8-incher all the way up to the 30-inch tube, and this includes color-TV picture tubes as well. The tests performed include those for inter-element shorts, cathode emission, and a check on the operation of the control grid. For these tests, d.c. is used on all tube elements (except for the heater) and emission of over 300 μa. is indicated as "good" on the meter scale. New tubes normally measure 900-1500 μa., but since the high end of the 500-μa. meter is suppressed by a crystal diode, the meter does not go off scale. The grid bias can be adjusted from 0 to −100 v., and the effect can be noted directly on the emission meter.

Suppose the tube you are testing shows leakage or a short between control grid and cathode. The tester can then be used to remove this short. It does this by applying momentarily to these electrodes a high voltage (450 v.) from a large electrolytic capacitor (*C5-B* in the diagram). The length of time that this voltage is applied depends on the amount of leakage; with high leakage (low resistance) a large current flows for perhaps 1/6 second or so; with low leakage, less current flows for a second or more. If the material causing the leakage is burned away during this process, you may see a momentary flash in the neck of the tube. This procedure can be tried several times until the short is burned out.

If the tube being tested shows low emission, then the CR125 is set up for rejuvenation. During this procedure, we attempt to bring new active emitting material to the surface of the cathode and to enlarge the aperture in the control grid. There are three steps available for the rejuvenation procedure. In the first step, a high voltage is momentarily applied to the control grid. If this does not do the job, then the second step is tried. Here, the heater voltage is raised slightly while the high voltage is applied. If the tube still does not respond, then the third step is tried. The heater voltage is raised still more and the length of time that the high voltage is applied is lengthened.

When color-TV picture tubes are tested or rejuvenated, each of the three guns is checked and connected to the tester separately, as determined by the position of the "Color Gun" switch.

Like all *Sencore's* instruments for the service technician, the cathode-ray tube tester is designed for convenience and portability. It is available at the company's distributors for $69.95. ▲



Signal-Generating Equipment

(*Continued from page 34*)

Crystal-controlled calibrators provide a 100 times improvement at frequencies corresponding to harmonics of the calibrator. This accuracy does not hold at other frequencies, though, simply because the tuning dials of the instruments cannot be read with that kind of precision.

However, frequency can be *monitored* with an electronic counter to a far higher degree of accuracy. With the aid of a precision transfer oscillator and heterodyning techniques, counters can determine frequencies as high as 18,000 mc./sec. (and higher) to an accuracy of 8 decimal places.

If an oscillator can be voltage controlled, phase-locking techniques can be used to maintain the output frequency at the same stability as a reference crystal oscillator. This can be done, though, only at spot frequencies corresponding to harmonics of the crystal oscillator frequency.

Precisely known signal frequencies are available from frequency synthesizers, which obtain various r.f. frequencies by dividing, multiplying, adding, and subtracting other frequencies derived from crystal-controlled oscillators. The newest signal source of this type generates frequencies all the way from 0.01 cps to 50 mc. in 0.01-cps steps by push-button control. All of these 5 billion discrete frequencies are derived from one highly precise 1-mc. crystal oscillator and all are accurate to better than 0.0000003%! This is three ten-millionths of one percent.

The accuracy of signal-generator output amplitude indications can't approach accuracies such as those available for frequency—primarily because highly precise standards of r.f. power never existed until only recently. High-quality generators have had output accuracies in the neighborhood of 1 to 2 db. Now that more accurate r.f. power monitors are becoming available, the trend is towards the use of power *leveling* for signal-generator output amplitude control. In these systems, the power monitor maintains constant output power by means of a wide-band, direct-coupled feedback loop which controls an amplifier control grid, or one of the new electrically controlled *p-i-n* diode modulator/attenuator units. Output power flatness can be held to within 0.2 db with this technique. The accuracy of the power monitoring system is typically ± 0.5 db over-all, however an additional ± 1 db should be added because of attenuator accuracy throughout the frequency range of the equipment.

Little effort has been expended on controlling the accuracy of pulse generators with respect to pulse width and amplitude; the major design effort being directed towards achieving good pulse shape. Pulse generator calibrations are used for no more than a rough initial indication of pulse amplitude, width, or repetition rate. Because pulse generators are most often used with an oscilloscope, the pulse generator controls are usually adjusted exactly while monitoring on the oscilloscope.

Choosing Equipment

The first thing to do is to take a good, hard look at what the equipment is intended to do. What frequency ranges are needed and which can be omitted? What kind of signals are desired—sine wave, pulsed, FM, AM, or what?

What stability does the generator have? That is to say, if you set it at one frequency how confident can you feel that the generator will stay exactly at that frequency? What is the amplitude stability? If you set the output for 1 volt r.m.s., will it stay at the exact 1-volt setting all afternoon, or if you change frequency?

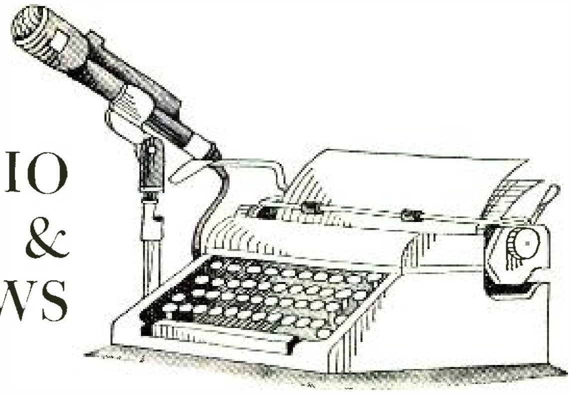
A design engineer is very much concerned with these matters. When designing an i.f. strip, for instance, he needs a generator with an output that is flat across the band, so that the detected response will show him where the i.f. strip isn't flat. The serviceman repairing the same strip can get by with a generator of lesser quality. About all that he can do is to set the traps to the right frequencies, get about the right slope to the band edges, and take excessive tilt off the passband. A few humps in the generator output won't affect these adjustments significantly.

Check the performance of the attenuators, which are needed to prevent overdriving high-gain equipment. Is the attenuator accurate, and is its attenuation constant with frequency? And watch out for r.f. leakage. A big attenuation factor doesn't tell you anything if r.f. power leaks into the tested circuit anyway.

How much harmonic content is present if you are supposed to be getting pure sine-wave output? If there are harmonics, you may think that a filter circuit is passing a certain frequency when it is really passing a harmonic. With r.f. generators, the standing wave of a harmonic may be much higher than the fundamental, providing a false indication.

Certainly, the reputation of a manufacturer is of considerable importance. Reputable manufacturers check the performance of many production units and then set specifications beyond the widest deviations. Sometimes their specifications may not appear spectacular, but with this kind of equipment performance will always be better than claimed. ▲

RADIO & TV NEWS



SPEAKING at a meeting of NATESA in Kansas City, Frank W. Mansfield, Director of Market Research for *Sylvania Electric Products*, said that their three-month national survey of color-TV set dealers and owners showed that at least 20 brands of color sets are available on dealer floors. About 70% of dealers indicated that their customers had little or no trouble with color repairs and set owners generally were not critical of tuning problems previously associated with color sets. The *Sylvania* survey also indicated that the average repair bill on a color set amounted to about $30.50 per year or less than 9¢ a day. About 40% of the set owners said that the cost of color repairs were no more than they had experienced with black-and-white sets. An additional 22% were so unconcerned that they could not recall what their repair bills were in the previous 12 months.

Mansfield also pointed out growth of American households from the present 55 million to an estimated 77 million in 1977 will be a factor in increasing color sales. At least 90% of these households can receive colorcasts on their black-and-white sets and about 45% have annual incomes in excess of $6000 which means that they can be considered prime prospects for color-TV receiver sales. This also means quite an upswing in sales of antennas, transmission lines, and test equipment for use by service technicians.

Soviet TV Expands

The 130th TV station in the Soviet Union has been opened in Krasnovodsk, a town on the Caspian Sea. The first broadcast coincided with the 25th anniversary of Soviet TV, which started March 9, 1938. Since then, the number of TV sets in the Soviet Union has climbed to over 8,000,000 serving a population of about 100,000,000. In addition to 130 TV stations, a large number of relay stations cover remote rural areas. Moscow TV programs are carried by 63 stations on a network that covers most of the country.

Color programs are already being carried in both Moscow and Leningrad, but according to Soviet authorities, further development is hampered by the high price of color sets. Like their American counterparts, Soviet engineers are currently engaged in a cost-cutting program. At present, color-TV sets are being used only in hotels, rest homes, clubs, and "Palaces of Culture."

Space—Far and Near

Those who followed Gordon Cooper's space flight on TV would be interested to know that at the lift off, a TV camera coupled to a telescope located about 20 miles from the launch site was used to supply TV networks with pictures of the launch.

Heart of the system is the BX-7 image orthicon developed by *Bendix*. Tests of the TV-telescope show it capable of spotting a basketball at 100 miles and resolving objects less than one-half mile long on the moon.

Electronics and Mud

A Cornell University research team is currently seeking the solution to a problem that has plagued humans since the first man got bogged down in the mud. The group is trying to develop a technique to electrically reduce the water content of soil then combine it with certain chemicals to stabilize the soil so it can bear a heavy load. Past experiments have shown that water in the soil attaches itself to positively charged particles and these particles, together with the water, would be attracted to a negative charge. The group is testing the feasibility of using a metal grid about 15 to 20 feet wide and as long as practicable over the muddy area. Buried beneath the grid would be a pipe or series of pipes. The grid would serve as one pole, either positive or negative, and the submerged pipe as the other pole. Conceivably, with a negatively charged grid and positively charged pipes, the water would move to the surface under the grid and be carried away in drainage ditches. At the same time, soil-stabilization chemicals are introduced through the submerged series of pipes.

The work is currently being conducted in the laboratory and if it works OK, it will then be field tested.

Give this some thought next time you get bogged down in the family wagon. ▲

Naval Time Signals

(*Continued from page* 30)

the signal is a series of rhythmic c.w. signals or "beeps," beginning 5 minutes before the hour and providing the listener with five separate time checks—one at the 56th minute; one at the 57th; one at the 58th; one at the 59th; and one on the hour. Due to mechanical or operator variance, the signal may not necessarily begin at the 55th minute, however, this is of no consequence, since the beginning is not to be used as a marker. As the signal proceeds through the 55th minute, the halfway point is indicated by the omission of the 29th second. As the "beeps" continue, you will also note a blank at the 51st second, followed by signals on the 52nd, 53rd, 54th, and 55th seconds. These four "beeps" following the 51st second is a code reference alerting the listener of the approaching 56th minute time signal. The 55th second c.w. signal is followed by a 4-second silent period, which is ended by the time signal, precisely indicating the 56th minute. This is the end of the first time check.

The 1-second "beeps" continue through the 56th minute as indicated in Fig. 1, with the 29th second blank as in the preceding minute; again denoting the halfway point. As the signal approaches the end of the 56th minute, the 52nd second is omitted (instead of the 51st second as in the preceding check), followed by the 53rd-, 54th-, and 55th-second markers, and then by the 4-second silent period. The silent period is ended by the time signal, precisely indicating the 57th minute. During this second time check, the three 1-second signals at the 53rd-, 54th-, and 55th-second markers serve as the code reference for the 57th-minute check.

This procedure is repeated for the 58th- and 59th-minute time checks with the 53rd and 54th seconds omitted respectively. A long dash, preceded by the 9-second silent period, composed of the omission of the 51st through the 59th second "beep," denotes the hour. The *beginning* of the long dash indicates the "on time."

To summarize, the listener need not laboriously count the "beeps" throughout the entire time signal, but only to note the number of second markers preceding each of the 4-second silent periods. If four 1-second indications are heard, he is alerted to the 56th-minute time check. If the listener hears three "beeps" preceding the 4-second blank period, he will know that the 57th minute is coming up, etc. And when he hears the 9-second silent period, he will be ready to set his watch or chronometer to the exact hour.

The time signals transmitted from

NSS Washington, D.C. are regulated to an accuracy of 0.01 second. This precision is obtained by observation of the stars, using special telescopes and transits. Accuracy is further enhanced by enclosing the equipment in environmental chambers, which maintain the delicate instruments at a constant temperature and humidity, thereby minimizing metal distortion. The signals from NBA, NPG, NPM, and NPN are rebroadcast from Washington by automatic relay and are correct to 0.25 second.

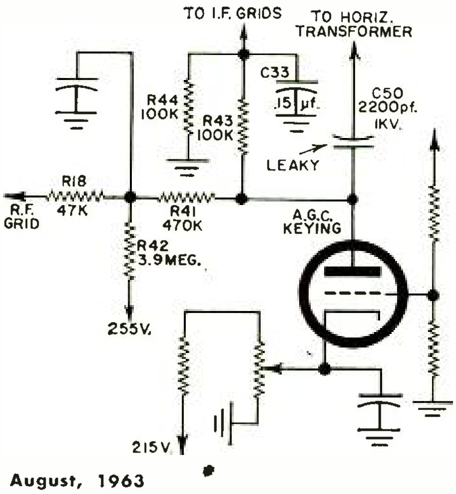
Thus we have precise time signals being transmitted by radio at frequent intervals throughout the day on frequencies ranging from 114 kc. in the l.f. range to 23,650 kc. in h.f. range. ▲

ODD A.G.C. FAULT

By DON DUDLEY

THE COMPLAINT, a snowy picture, was not an unusual one. The trouble persisted on this Sylvania 21C407 after replacement of the r.f., i.f., and keyed a.g.c. tubes. Tuner a.g.c. voltage was found to be high, but there was no indication of any a.g.c. voltage on the i.f. grids. At this point, it was noticed that a 100k resistor in the a.g.c. line, R13, was burned out. It accounted for the absence of a.g.c. on the i.f. tubes, but it did seem odd that a resistor with so little voltage across it could burn up.

After R13 was replaced, the set seemed repaired. A finger placed on that resistor was pulled away quickly, however—because R43 was quite hot. A quick voltmeter check showed no more than a normal a.g.c. d.c. voltage present. C50, which couples the keying pulse from the horizontal-output system, was checked and found to have a small amount of leakage. It measured 20 megohms resistance. However, it could not pass d.c. into the a.g.c. line, because the keying pulse was derived from a separate, isolated, a.g.c. winding on the flyback transformer. Nevertheless, when C50 was replaced, R43 no longer overheated. The defective capacitor evidently coupled a keying pulse of too great an amplitude into the a.g.c. system. The resistor was being burned out, not by d.c., but by a.c. ▲



Operational Amplifier

(*Continued from page 49*)

Fig. 2C adds hysteresis to the transfer function. Now the input must exceed a value determined by the output voltage, *R*1, and *R*2 to cause the amplifier to switch to its negative limit, and then must become less than some more negative new value to cause the amplifier to switch into its positive limit.

Fig. 2D is one type of free-running multivibrator using the above principles. The circuit starts out in one of its limits, but the voltage at *C*, being charged through *R*, eventually becomes great enough to cause the amplifier to switch to its other limit. Then *C* is charged through *R* in the opposite direction and the amplifier eventually switches back to the first condition described above and so on.

Waveform Generators

Fig. 4A is a highly refined circuit that simultaneously generates square waves and triangular waves with perfectly straight ramps of equal positive and negative slopes. The output of an integrator with a d.c. input, E_{in}, is a perfectly linear ramp whose slope in volts-per-second equals $-E_{in}/RC$. In Fig. 4A, when the positive-going voltage out of amplifier No. 1 reaches some value determined by the setting of *R*1-*R*2, amplifier No. 2 will switch to its positive limit. This output is clipped to plus 1 volt by diode action. This voltage is re-applied to the integrator, amplifier No. 1, and causes its output to decrease linearly to a new value. This causes amplifier No. 2 to switch to its negative limit. This, in turn, causes the integrator to produce a positive-going ramp, and so on.

The slope of the integrator in volts-per-second with the ± 1 volt clipping action of the diodes is 1/*RC*. The amplitude and frequency of the triangular wave output are both affected by the setting of *R*1-*R*2. This circuit has been used successfully from 1 cycle-per-minute to 1000 cycles-per-second. Typically, *R*1/*R*2 will be from 4:1 to 20:1.

By putting a diode in parallel with *R*, the waveform is changed from a triangle to a saw-tooth with the fast rise or fast fall determined by the polarity of the diode. Connecting a diode directly from the output of the integrator to ground, as shown, makes the device monostable, and it can be triggered by capacitively coupling a negative voltage spike into the secondary input of amplifier No. 2. This arrangement then makes a device capable of providing a perfectly linear slow triggered sweep for inexpensive oscilloscopes. The high-level square wave is then used to provide retrace blanking for the scope. Obviously, the above waveforms must be direct-coupled to the oscilloscope vertical-input terminals.

Timing Computer

In the foregoing section it was mentioned that the output of an integrator with a d.c. input is a perfectly linear ramp voltage whose slope in volts-per-second equals $-E_{in}/RC$. Because of this an integrator can be used as a timing device, with output voltage being proportional to time. Such an application is shown in Fig. 4B. In operation S1 is opened first. The output voltage, as measured on the meter, then increases from zero at a perfectly linear rate in respect to time. When S2 is opened, the output voltage will hold its last value. Then time, the interval between the opening of S1 and S2, equals $(E_{out} \times RC)/150$.

It is necessary to carefully zero-adjust the amplifier immediately prior to use. To do this, open S2 first and then S1. The meter reading should remain at zero volts. If it drifts off, reset the zero-adjust control to cause it not to drift off. *C* must be a low-leakage unit, preferably polystyrene, silver mica, or Mylar. Otherwise the d.c. leakage will cause errors and drift.

This circuit was used to measure the muzzle velocity of a *Crossman* carbon-dioxide pellet pistol. S1 and S2 were actually two strips of aluminum foil 1/8 inch wide and 2 inches long mounted on cardboard frames with cellophane tape. They were placed exactly one foot apart. The gun was then placed a few inches from S1, aimed to first break S1 and then S2, and fired. The anticipated time interval was about 3 msec. *R* was chosen as 100,000 ohms and *C* as .15 μf. After the gun was fired, the meter indicated 22 volts. Time was then calculated to be 2.2 msec. and velocity to be 1/.0022 or 455 feet-per-second.

Some of the circuits in this article were taken from material supplied by *George A. Philbrick Researches Inc.*, Boston, Massachusetts. ▲

"That's what IT says! 'In MY opinion. . . .' "

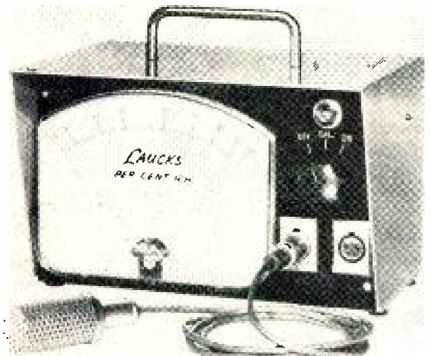
NEW PRODUCTS & LITERATURE

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, simply fill in the coupon appearing on page 19.

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

PORTABLE HUMIDITY METER

1 **Laucks Laboratories, Inc.** is now offering a portable humidity meter which provides instantaneous direct reading of relative humidity from 20% to 95%. Featuring all solid-state circuitry, the unit incorporates a precision meter



with damped d'Arsonval movement and full-range accuracy within ±5%. An electrolyte-type transducer is mounted on a 5-foot cord.

The metal cabinet is 10" x 6" x 7" and has a transistor-type self-contained power source. The rotary switch has "off," "on," and "calibrate" positions. The linear pot adjusts for voltage regulation.

V.O.M. FOR SEMICONDUCTORS

2 **The Triplett Electrical Instrument Co.** is now offering a v.o.m. specifically designed for semiconductor testing. The Model 630-L offers two special low-power ohms circuits on the X1 and X10 ranges. These ranges have been designed for safe testing of semiconductor circuits. The maximum open-circuit test voltage is only 0.140 volt. This allows testing below the breakdown voltage of the transistor or other semiconductor without damaging overloads. Maximum power dissipation in the semiconductor under test is less than 420 microwatts.

Housed in a molded case with transparent unbreakable Lucite window, the instrument measures 3 11/32" x 5½" x 7½" and comes complete with leather carrying handle. Weight is 5 pounds.

TRANSISTORIZED CCTV CAMERA

3 **North American Philips Company, Inc.** is now offering an ultra-compact, self-contained, completely transistorized CCTV camera for surveillance of inaccessible or remote areas. The unit will adjust itself automatically to changing light intensities on the order of 1:15 and will produce a bright clear picture with light levels as low as 1 footcandle.

The camera measures 13" x 7" x 4" and weighs

11 pounds. It can be mounted almost anywhere as it generates virtually no heat. It is completely ruggedized and will withstand shock and vibration. It is tropic-proof, resistant to extreme humidity, and will operate in temperatures ranging from 14 to 113 degrees F, indoor or outdoors. With a weatherproof accessory cover, it can be used in any weather.

The camera is capable of feeding up to 30 standard TV receivers or a lesser number of video monitors without any accessories or amplification.

METERED-KNOB VARIABLE TRANSFORMER

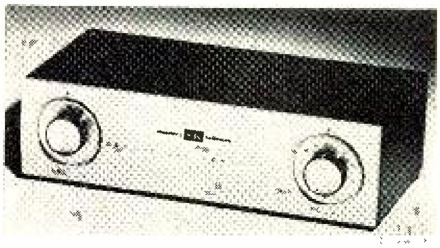
4 **The Superior Electric Company** is now offering sixty of its "Powerstat" variable transformers with knobs incorporating a direct-reading voltmeter as standard equipment. Single units with enclosed construction, with and without cord-plugs, are available for 120- and 240-volt single-phase service with loads up to 3 kva. Conversion kits consisting of a metered knob, enclosure, and complete wiring instructions are available for converting currently catalogued types.

The voltmeter is insensitive to stray magnetic fields. The meter reads load voltage, but line voltage can be checked by matching marks on knob and enclosure.

U.H.F. CONVERTER

5 **Standard Kollsman Industries, Inc.** is now offering a deluxe u.h.f.-to-v.h.f. TV converter which features a two-speed, ball-bearing planetary drive permitting single-knob fine tuning of the picture.

Designed for screwdriver installation, the circuit uses a 6DZ4 tube and nuvistor for longer life



and improved reliability. Sliding contacts have been eliminated in the main tuning circuit through use of a three-gang tuning element. A power receptacle is built into the back of the chassis to plug in the TV power cord. The set carries UL approval.

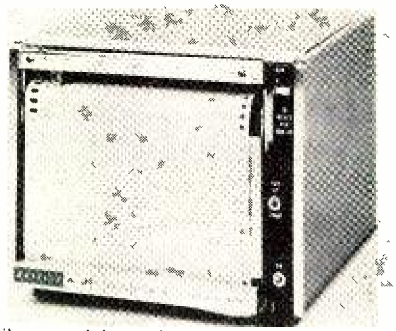
Frequency range is channels 14 through 83, with good performance on translator channels 70 through 83. The device is housed in a high-style cabinet measuring 11¼" x 5¾" x 3".

TEMPERATURE RECORDER

6 **F. L. Moseley Co.** has introduced a new, compact strip-chart recorder for tracing temperatures in research, testing, and industrial work.

The "Autograf" Model 682 is a servo potentiometer type instrument designed for rack mounting singly or in pairs, or for bench-top operation. It measures 6½" x 7¾" x 8⅜".

The input circuit features a plug-in unit incorporating a single cold junction compensated temperature range selected by the customer. The reference junction temperature is factory adjusted to any specified value. Accuracy, exclusive of thermocouple errors, is better than 0.2% of full scale.



The record is produced by pen and ink from a cartridge type reservoir or by stylus on pressure-sensitive paper.

INDOOR U.H.F. ANTENNAS

7 **Channel Master Corp.** has recently introduced two new u.h.f indoor antennas, the "Wonder Bow" and the "Double Wonder Bow."

The "Wonder Bow," Model 4170, is a single-bay bow and screen with a wire form dipole: while the Model 4160 is a stacked bow and screen, also using wire form dipoles. Rear pickup is eliminated because both antennas are reflector-designed and directional.

Both antennas are finished in a gold color and styled for use in the home.

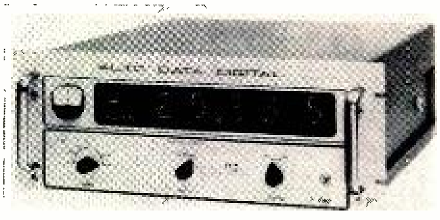
DYNAMIC ALTERNATOR TESTER

8 **Mar-Con Instrument Corporation** is now marketing a dynamic alternator tester, the "Mark I" DAT-100.

The instrument, designed for use by the average auto serviceman, will test for shorted or open alternator field windings and slip-ring assembly, test for shorted or open alternator diodes, and test for shorted or open alternator stator windings. Controls are kept to a minimum. A meter marked with "good" and "bad" zones is used as the indicator. The instrument is powered by the 117-volt, 60-cps power line and consumes 7 watts. Accessories include a three-wire test lead cable six feet long and a 4" jumper. A .6-amp "Slo-Blo" fuse is built into the line. The instrument measures 10" x 6" x 3½".

DIGITAL MILLIVOLTMETER

9 **Houston Instrument Corporation** has developed a digital millivoltmeter which measures d.c. voltages from 1 μv. to 1000 volts in six overlapping ranges. Known as the "Auto Data" Model 2660, the unit has 3-μv. accuracy with 100-



megohm input impedance on the lowest 00.000 to 29.999 millivolt range, making the instrument suitable for thermocouple, strain gage, low-level transducer, and small-signal semiconductor measurements.

Gold-contact, hermetically sealed reed relays are used in a decimal potentiometric bridge. Reed relays are switched under zero current conditions for long life. Accuracy is independent of changes in reed contact resistance. Floating input allows for operation at up to 500 volts above ground. Common mode rejection is greater than 100 db at 60 cps.

SEMICONDUCTOR TESTER

10 Fairchild Semiconductor is now offering a new "go/no-go" multiparameter tester, the Series 250. Capable of conducting tests at the rate of 900 units per hour, the new instrument features 16 various "go/no-go" tests per unit.

The tester features pulse testing and can be operated by non-technical personnel after only a few hours of training. The Series 250 is easily programmed with decade cards or fixed resistor cards. Accuracy at 1 μa. is $\pm 0.5\%$ ($\pm 1\%$ at 100 μa.). A system for priority sorting is optional.

TRANSISTOR IGNITION SYSTEM

11 Autotronics Inc. is now marketing a low-cost transistorized ignition system which is being offered in four different models to meet the requirements of various 6- and 12-volt automotive systems.

The ignition system consists of two major components: a coil manufactured by Bosch of Germany and a dual transistor control unit. The electronic control unit which is mounted on a flat bracket is installed directly below the ignition coil. The electronic assembly is hermetically sealed and completely embedded in semi-rigid epoxy.

The kit includes the coil, transistor control unit, wire, necessary hardware, and complete installation instructions.

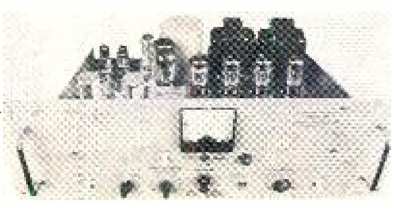
INSTRUMENT PANEL KIT

12 Electro-Kits is now offering a completely self-contained panel-production kit for the prototype electronics lab or the serious experimenter.

The kit produces up to four color-permanent aluminum panels in 20 minutes. No graphic skills are required and no darkroom or other special equipment are necessary. Since no dangerous chemicals are involved in the process, the complete operation can be performed on a table or lab bench.

PULSE ENERGY COMPARATOR

13 Electronics for Education, Inc. is now offering the Model 152 pulse energy comparator which provides a quantitative indication of the missing r.f. pulses coming from a magnetron. When used with a conventional external counter, it provides for stability tests in accordance with military specifications.



The instrument contains provision for measuring: the number of pulses having an energy content less than a preselected percentage of the energy content of the preceding pulses; or the number of pulses having an energy content less than a preselected percentage of a "standard" pulse.

U.H.F. PREAMP/CONVERTER

14 Jerrold Electronics Corporation is now marketing the "Ultra-Vista," a u.h.f. converter that includes a built-in stage of u.h.f. preamplification.

A top-of-the-set converter, the unit features slide-rule tuning, a 6DL4/EC88 frame-grid tube as the r.f. preamp, a K3D silicon diode as the mixer, an A15300 nuvistor as the oscillator, and a PADT-28 high-frequency transistor operating as the post or i.f. amplifier.

Gain is at least 10 db over the translator bands (channels 70 to 83) and a minimum of 11 db over the MPATI stations (channels 72 to 76). The unit conforms to FCC rules for radiation. Input impedance is 300 ohms with a v.s.w.r. of 1.5 maximum. Output impedance is 300 ohms.

SOLID-STATE PULSER

15 Digital Electronics, Inc. has developed a solid-state pulser, the Model 522, which can be used to provide fast-rise pulses from input waveforms of any type. The unit can also act as a frequency divider or a pulse shaper. With no input signal a single pulse can be generated by pushing the button on the front panel.

The output pulse width may be divided from less than 0.5 μsec. to greater than 0.1 second. Rise time is less than 50 nsec. for a negative pulse and 200 nsec. for a positive pulse. Fall times are the same. Amplitude of the output may be varied from 0 to 15 volts and is 5 volts into a load of 100 ohms.

HI-FI—AUDIO PRODUCTS

STEREO TAPE RECORDER

16 Roberts Electronics, Inc. has announced the availability of the Model 1057-PS stereo tape recorder with photo-sound-sync to provide sound-with-slide synchronization for amateur and professional photographers.

The fully automatic synchronizer which adapts to all automatic slide projectors utilizes a strip of special sensing tape on the shiny side of the recording tape to activate a "sensing" post. This automatically advances each slide in the projector.

The unit offers stereo and mono record/play; three speeds, 3.75, 7.5 ips with 15 ips available extra; sound-with-sound; sound-on-sound; sound-over-sound; four stereo outputs; 24-slot wave wound motor; full stereo record/playback system; stereo preamp outputs; stereo power amplifier outputs; dual professional-type vu meters; stereo self-contained speakers; vertical or horizontal operation; automatic tape shut-off; and facilities for FM/stereo multiplex.

LOUDSPEAKER IN KIT FORM

17 Electro-Voice, Inc. is now marketing a pre-finished loudspeaker kit that can be put together in less than 20 minutes without tools. Designated the "Coronet," the system combines an 8" extended-range loudspeaker with a ducted-port acoustic phase-inverter enclosure.

Three versions of the unit are available: "Coronet I" includes the enclosure kit and an 8" MC8 "Michigan" speaker; the "Coronet II" with enclosure kit and "Wolverine" LS8 speaker; and the "Coronet III" which includes the enclosure materials and an SP8B, the company's deluxe 8" speaker. All systems feature exterior surfaces of select hardwood veneers, pre-finished in oiled walnut.

MONO/STEREO TAPE PREAMP

18 Allied Radio Corporation has recently introduced the "Knight" KN-4002, a stereo tape record/playback preamp of flexible performance in either mono or stereo sound recording and reproduction.

Response is 30-16,000 cps $\pm$ 3 db at 7.5 ips and 30-12,000 cps $\pm$ 3 db at 3.75 ips. Hum and noise is −50 db minimum on playback. Twin visual indicators and concentric dual playback and record controls for each channel permit adjustment simultaneously or independently. A red "record" safety light shows when the preamp is set for the recording functions, while the indicator beacons permit peaking at correct levels on each channel for perfect tapes.

The unit measures 4⅛" x 15½" x 8¼". A grey metal case is available as an accessory.

TAPE-DUPLICATING SYSTEM

19 Ampex Corporation has recently introduced a tape duplicating system, the PD-10, which is designed to provide professional tape duplication facilities for schools. With the system, a single operator can produce up to 75 copies of 1200-foot tapes in an 8-hour day. The duplicating operation requires no technical training.

The standard system consists of one master and three slaves which will produce up to three duplicates at a time. Master and duplicate tapes can be half-track, two-track mono or two-track stereo. Master tapes may be any of the popular speeds from 1⅞ to 15 ips, producing copies at 1⅞, 3.75, 7.5, or 15 ips. Copies may be decreased in speed from the master by one standard speed

STEREO TUNER-AMPLIFIER

20 Radio Corporation of America has recently introduced a high-fidelity FM multiplex stereo/AM tuner-amplifier which incorporates a nuvistor FM front end.

Designated the MX-7, the unit includes FM multiplex, a high-fidelity FM tuner, AM tuner, and a "Master Control" 30-watt stereo amplifier. Special features include a new multiplex demodulation system, special high-fidelity tubes and

circuits, nuvistor r.f. amplifier tuner, and underrated components for trouble-free operation.

The control unit features touch lever controls, multiplex indicator lights, dual volume controls, optional remote unit, dual bass and treble controls, a.f.c., phono input provision for mono or stereo phono connections, and impedance matching for 4-, 8- and 16-ohm speakers.

STEREO POWER AMPLIFIER

21 **Dynaco, Inc.** has added the "Stereo 35" to its "Dynakit" line of audio equipment in kit form.

This new stereo power amplifier delivers wide-band, low-distortion output of 17½ watts per channel. The full 35 watts is available continuously over the 20 to 20,000 cps spectrum. The

design features both positive and negative feedback plus specially engineered transformers. The amplifier is designed to be used with the company's PAS-2 or other high-quality stereo preamps. It matches the PAS-2 in appearance and size.

PORTABLE SOUND ANALYZER

22 **B & K Instruments, Inc.** has developed a portable noise analyzer for general industrial applications involving noise control and as a basic instrument in acoustical or vibration-measuring systems.

The Model 2203/1513 consists of the Model 2203 sound level meter and an octave-filter set. Accuracy is ±1 db from 20 to 15,000 cps over the full-scale range of 22 to 134 db. The unit provides accurate readings for eleven frequencies from 22 to 25,000 cps with center frequencies as specified by ASA S1.6-1960.

The unit weighs 11½ pounds and is housed in a cast-aluminum case. A leather carrying and holding handle and removable leather shoulder strap make the unit portable.

STEREO RECORDER KIT

23 **Heath Company** is now marketing a portable, four-track stereo tape recorder in kit form as the Model AD-72.

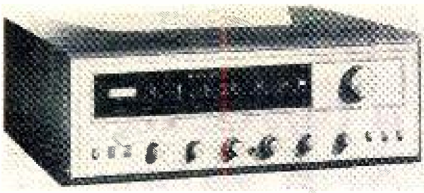
The kit comes complete with all amplifiers and speakers. The unit records and plays four-track

stereo and mono tapes, 7.5 and 3.75 ips speeds, has microphone and in-line inputs, concentric level and tone controls, bar-type level indicators, and dual two-way speaker systems.

The unit is housed in a factory assembled portable case with lift top lid and swing-out detachable speaker wings. A free head-alignment tape is included with the kit.

STEREO TUNER/AMPLIFIER

24 **H. H. Scott, Inc.** has recently introduced its Model 340B FM stereo tuner-amplifier. The new model features new panel styling, slide-rule tuning, convenient front-panel earphone receptacle, and "Auto-Sensor" circuitry which automat-



ically switches to stereo or mono mode of operation depending on which type of broadcast is being received.

An illuminated d'Arsonval meter permits pinpoint tuning of all signals. There is a powered third channel for direct connection of remote speakers or for a three-channel system. Complete tape monitoring facilities are also provided. All controls operate on playback.

SOLID-STATE P.A. AMPLIFIER

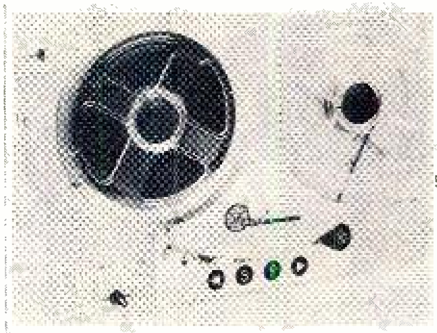
25 **Royce Electronic Developments, Inc.** is now offering the "Audio Robot" line of miniaturized solid-state p.a. amplifiers including 25-watt models to operate from self-contained batteries, vehicle batteries, or a.c. power lines. Three-speed phonograph facilities are available on any model.

Accessories available for use with these amplifiers include siren tone generators and automatic switch-over to batteries in the event of power failure.

INDUSTRIAL TAPE TRANSPORT

26 **Viking of Minneapolis, Inc.** is now offering the Model 230, a heavy-duty reel-to-reel tape transport designed for industrial and commercial applications. The unit will handle reels up to and including 7" and quarter-inch tapes of all types. Single tape speeds of 15, 7.5, 3.75, or 1⅞ ips are available as is a two-speed model for 15 and 7.5, or 7.5 and 3.75 and 1⅞ ips.

The transport is available with a wide choice



of head configurations, alternative choices of capstan drive motors, and with or without such features as digital counter or photoelectric or mechanical type run-out switches.

STEREO TAPE RECORDER

27 **Inter-Mark Corporation** is now offering a new stereo tape recorder which includes a heavy-duty detachable speaker system as its "Cipher VII."

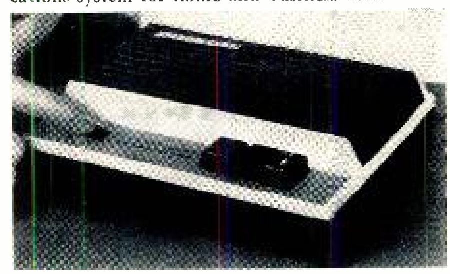
The unit features three-speed operation, two vu level meters, individual controls on each channel for volume and tone, instant stop lever which also operates when the machine is in the record mode, fast forward and rewind, digital counter,

automatic tape shut-off sound-on-sound recording, and stereo earphone connection. Jacks are also provided for radio, phono, and microphone.

Frequency response is 35-15,000 cps at 7.5 ips and signal-to-noise ratio is said to be better than 50 db. The unit can be operated in either a vertical or horizontal position. The control panel is finished in brushed chrome.

TRANSISTORIZED INTERCOM

28 **Channel Master Corp.** is now offering its Model 6555 transistorized two-way communications system for home and business uses.



The "Interphone" is battery powered and features push-button operation. The unit is light and compact and can be hung on a wall, if desired. Either unit, master or slave, can initiate calls. The master unit can be set to insure privacy, yet can be buzzed at any time. A volume control feature is included.

CB-HAM-COMMUNICATIONS

CRANK-UP ANTENNA TOWER

29 **Rohn Manufacturing Company** has announced the availability of its No. 6 crank-up type tower in heights from 18 feet to 54 feet for amateur and experimental applications.

The tower features a sturdy winch and cable which lifts the various sections upward easily and safely. The tower is available in heights of 18, 26, 37, and 54 feet. It is completely hot-dipped galvanized.

PRESELECTOR/CONVERTER

30 **Lafayette Radio Electronics Corporation** is now offering the Model HE-73, a crystal-controlled dual-function preselector/converter covering the 80, 40, 20, 15, and 10 meter bands. The unit operates on 80 and 40 meters as a preselector

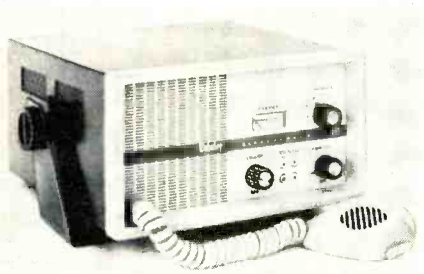
only and on 20, 15, and 10 as either a preselector or converter.

Tuned interstage circuits and two stages of r.f. amplification are incorporated to insure a high signal-to-noise ratio. Front-panel controls include antenna trim, function, bandswitch, and gain. The unit comes with three crystals for 20, 15, and 10 meter bands. The "Precon" is self-powered, operates on 117 volts, 50-60 cps a.c. and measures 10"x 6"x 8".

SELECTIVE-CALLING CB UNIT

31 **Webster Manufacturing** is now offering a full-service, CB two-way radio wired for selective calling as its "Band Spanner 412."

Designed primarily for heavy-duty business use, the six-channel unit will accommodate most tone alert systems for noise-free standby operation between calls. An "S" meter on the front panel in-



dicates the set's performance level at all times. A socket, built into the front of the transceiver, will accommodate an additional pair of crystals.

SIX-BAND PORTABLE RECEIVER

32 **The Hallicrafters Co.** has added a new six-band, battery-operated portable receiver to its line of communications equipment.

The Model WR-3000 is a general-coverage portable with extended low-frequency tuning, providing reception of consolan, aeronautical, and mobile frequencies as well as broadcast, amateur,

and international short-wave bands. The set has a drum dial with slide-rule tuning, b.f.o. tone control switch, and a fine-tuning control. There is a ferrite antenna for bands 1 and 2 and a whip antenna for short-wave reception. There is a self-contained 4"x 6" speaker and a headphone jack. The circuit uses 10 transistors, 1 diode, 1 thermistor, and 1 zener diode. The set is powered by eight standard "D" cells plus one "D" cell for the pilot light. It measures 4⅛"x 11½"x 8" and weighs approximately 12 pounds.

R/C CONTROL UNIT

33 **Perma-Power Company** is now offering a complete radio control system for the automatic operation of doors, lights, signals, motors, and similar devices.

Known as the Model RT-400, the system is designed for short-range applications. Operating distance is up to 500 feet when used outdoors in unobstructed areas. Indoors, distance will vary from 50 feet to several hundred feet, depending on the structure of the building and the presence of metal conduits, piping, duct work, etc.

The system consists of a portable pocket-sized transmitter with self-contained antenna and battery and a receiver housed in a metal enclosure with flanges for wall mounting. It operates from standard 117-volt a.c. lines.

ONE-BAND SSB TRANSCEIVERS

34 **Heath Company** is currently marketing three new one-band SSB transceivers for 80-, 40-, and 20-meter amateur service.

Suitable for either mobile or fixed station operations, the new transceivers are compact and lightweight. Construction includes a heavy-duty

circuit board, one-piece steel chassis, and a gimbal bracket for under-dash mounting in cars.

The 80- and 40-meter models operate lower sideband with the 20-meter model operating upper sideband. Provision is made for use with linear amplifier and plug-in 100-kc. crystal calibrator.

The transceivers measure 6"x 12"x 10" and weigh 12 pounds net.

MONITOR RECEIVER DECODER

35 **Hammarlund Manufacturing Company** has announced the availability of its TD-10 decoder, an accessory unit designed to be used with a radio monitoring receiver. Under normal conditions, the decoder silences the receiver's loudspeaker so that unwanted transmissions are not heard. When a radio signal, which is modulated by a sustained audio tone of specific frequency and duration, is intercepted the decoder energizes an indicator lamp and activates the speaker. The speaker remains alive and the indicator lamp remains lighted until the reset switch is operated momentarily.

The unit, which measures 3"x 2"x 7⅛", is normally equipped to respond to a 2805-cycle tone of 10-second duration. Filters for other frequencies are available and response time can be varied by replacing a capacitor. Power requirements are 225 volts d.c. (approx.) at 16 ma. standby, 23 ma. when tone is being received, and 22 ma. after actuation; and 6.3 volts a.c. or d.c. at 0.6 amp. continuous.

MANUFACTURERS' LITERATURE

BUSINESS ABBREVIATIONS

36 **Raytheon Company** has just released a second edition of its 32-page booklet, "Abracadabra" which contains abbreviations and related acronyms associated with defense, astronautics, business, and radio-electronics.

This glossary of space-age abbreviations has been expanded to almost three times the size of the first edition, many of which additions reflect recent organizational changes in the Armed Forces.

ELECTRICAL CONTROL METHODS

37 **Ohmite Manufacturing Company** is offering copies of its Bulletin 202 entitled "Sequence Coupled Rheostats" which describes a unique method of electrical control. The publication details a means by which two rheostats can be coupled to provide approximately 650 degrees of control rather than 325 degrees obtainable with a single unit.

ELECTRONIC WIRE CATALOGUE

38 **Columbia Wire and Supply Company** has issued a 44-page catalogue covering a variety of electronic items including TV wire and cables; coaxial cables; intercom and audio cables; TV service aids, rotator cable; hook-up wire; power cord and cable; cord sets; and antenna wire and kits.

The catalogue is indexed and a table listing the weight, diameter, and resistance of annealed bare copper wire is also included.

CARDIOID MIKE DATA

39 **Shure Brothers, Inc.** has issued a pocket-sized guide detailing specific unidirectional characteristics and performance features that should be expected of a true cardioid microphone.

In addition, the booklet describes six common sound problems caused by inefficient microphone rejection of unwanted sounds and microphone ineffectiveness in picking up the desired sound. Specific information for solving these problems is provided.

ANTI-R.F. LIGHTING PANELS

40 **Corning Glass Works** has issued a 22-page booklet explaining how r.f. interference can be drained from fluorescent lighting fixtures. The booklet points out that r.f. waves from fluorescent fixtures have been a frequent cause of interference with electronic equipment in laboratories, testing facilities, and schools.

The brochure then explains how the company's electrically conducting #70 glass lighting panels can be used to eliminate such r.f. waves. The product also meets MIL specifications MIL-I-16910A, MIL-I-26600, and MIL-I-6181D.

NEEDLE REFERENCE CHART

41 **Duotone Company** has issued a new edition of its replacement needle wall chart which it will supply to distributors and their dealers and service technicians.

The 1963 Wall Reference Chart lists replacement needles by manufacturers' cartridge numbers, illustrates the correct needle replacement, the record speed, and the firm's replacement needle in diamond, synthetic sapphire, or osmium.

INTEGRATED CIRCUIT CATALOGUE

42 **Signetics Corporation** is now offering copies of its new condensed catalogue covering integrated circuits available in custom design or off-the-shelf.

The 8-page, 2-color booklet gives specification on 25 integrated circuits and several integrated components. Also described are DTL elements, nand/nor gates, diodes and gates, power gates, binary elements, line drivers, one-shot multivibrators, and buffer circuits.

INSTRUCTIONAL TELEVISION

43 **Ampex Corporation** is offering copies of its special "Head Lines" issue covering instructional television.

This 16-page publication is devoted to a discussion of the firm's "Videotape" recorder in education and a detailed outline of actual installations and the results which have been obtained with this type of instruction in both elementary schools and colleges and universities.

The text material is lavishly illustrated with photos of actual installations and the equipment used in such systems.

CAPACITOR SELECTOR CHART

44 **Cornell-Dubilier Electronics** has added "The Mica Minder" as the sixth item in its series of capacitor selector charts. This 17"x 22" wall chart has been compiled to aid circuit designers in selecting mica capacitors for military, industrial, and commercial applications.

More than 40 types of mica capacitors are listed with line drawings and dimensions showing form factors and sizes. For each type, the chart shows capacitance, tolerance, voltage, operating temperature, temperature characteristics, and insulation resistance.

ENERGY DISCHARGE CAPACITORS

45 **Sangamo Electric Company** has issued a 10-page technical bulletin which provides detailed reference data for mechanical and electrical design criteria covering energy discharge capacitors. Graphs, tables, and definitions are utilized to clarify these highly specialized capacitor parameters.

Descriptive information and catalogue listings are given on an extensive line of energy discharge capacitors made by the company. The publication is Bulletin 2610.

ELECTRONIC TEST EQUIPMENT

46 **Electronic Measurements Corporation** has issued a 6-page product catalogue covering a complete line of electronic test equipment.

Pictured and described in this publication are transistor checkers, voltmeters, scopes, tube testers, substitution boxes, crosshatch generators, signal generators, battery eliminators and chargers, vibrator checkers, and other equipment of interest to service shops and small labs.

RADAR-TYPE ALARM SYSTEM

47 **Pinkerton Electro-Security Corp.** has issued a four-page brochure describing its "Radar-Eye Minuteman," a fully portable, self-contained burglar alarm system.

The unit itself consists of a bell alarm and detector which sets up a doughnut-shaped radar field covering a 30-foot circle. The device is powered by ordinary house current.

The brochure describes the equipment, various applications at home and industrial locations, and gives information on the operation of the device.

CARTRIDGE CROSS-REFERENCE

48 **Sonotone Corporation** has released a revised and updated edition of its cartridge cross-reference replacement manual. The data is divided into two sections: cartridge-to-cartridge and phonograph-to-cartridge. The manual is also indexed by models for fast and easy reference.

Over 4000 cartridges and phonograph models are listed. The final page of this 24-page manual lists all of the firm's replacement needles as well as cartridges. Other audio products made by the company are pictured and described briefly.

ELECTRONIC KIT CATALOGUE

49 **Heath Company** has just published a 48-page catalogue which provides an up-to-date listing of all electronic kits currently available in its extensive line. Included are photographs, complete technical data, mechanical

details, and price and shipping information on equipment for CB, the radio amateur, the boat owner, the car owner, plus radios of all types, intercoms, a transistor organ, stereo systems, TV chassis and cabinets, amplifiers, tuners, preamps, turntables and changers, tape recorders, cartridges, speakers and headphones, speaker systems and enclosures, and an extensive line of test equipment of all types for service, lab, and experimental applications.

INSTRUMENT CATALOGUE

50 **Keithley Instruments, Inc.** has issued a 44-page catalogue which covers a full line of sensitive electronic instruments for research and industry. The catalogue is arranged in convenient sections covering measurements of d.c. and a.c. voltage, d.c. current, low and high resistance, d.c. and a.c. amplification, as well as sections on d.c. high-voltage supplies, nuclear instrumentation, and space science instrumentation. Selection charts are also provided to serve as an aid in picking equipment.

TOUCH-CONTROL SWITCH DATA

51 **Tung-Sol Electric Inc.** is offering copies of its Form T-496 which illustrates how the "Dynaquad" touch-control module can be used in various applications.

The brochure discusses various ideas for the application of this device including its possible use in level indicators for liquid or bulk storage tanks, night lights, explosion-proof switches, machinery guards, limit switches, and variable lighting control.

Technical details on the module itself are included along with complete information on the wiring and installation.

TAPE HEAD REPLACEMENTS

52 **The Nortronics Company, Inc.** has just issued the third edition of its "Tape Head Replacement Guide" which includes all recorders listed in previous editions plus erase head replacement data on several models which were formerly shown as not available.

More than 200 additional recorders have been incorporated in this new listing with a total of over 440 separate models being covered. Information is tabulated and listed by make and model number, original part function, and the firm's replacement suitable to that particular tape-recorder unit.

INDUSTRIAL TUBES

53 **United-National Labs, Inc.** has prepared a 24-page catalogue covering an extensive line of industrial tubes it is prepared to ship from stock. The distributor handles transmitting, special purpose, industrial, and receiving tubes as well as semiconductors. All tubes listed are nationally advertised brands and prices are provided for quantity lots as well as for orders from 1 to 99 tubes.

SEMICONDUCTOR GUIDE

54 **Bendix Semiconductor Division** has issued a four-page semiconductor guide which covers, in concise tabular form, pertinent parameters on the firm's line of silicon planar epitaxial "n-p-n" and silicon diffused mesa "n-p-n" power transistors; silicon power varactor diodes; silicon single-junction diffused power rectifiers; diffused alloy power μsec. switching transistors; and high- and medium-power "p-n-p" alloy power transistors.

RECORDER CHART PAPERS

55 **Brush Instruments** has issued a four-page, two-color illustrated brochure describing its line of chart paper engineered for all types of direct-writing recorders. A pocket in the brochure contains specimens of chart paper with traces produced by ink, electric, pressure-thermal, and forced-fluid direct-writing techniques.

Engineering specifications for chart paper are tabulated. A detailed chart on the back of the folder lists the specific types of paper available for each recorder. ▲

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Answer to Electronic Crosswords

(Appearing on page 71)

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ELECTRONICS WORLD AUGUST 1963 ADVERTISERS INDEX

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