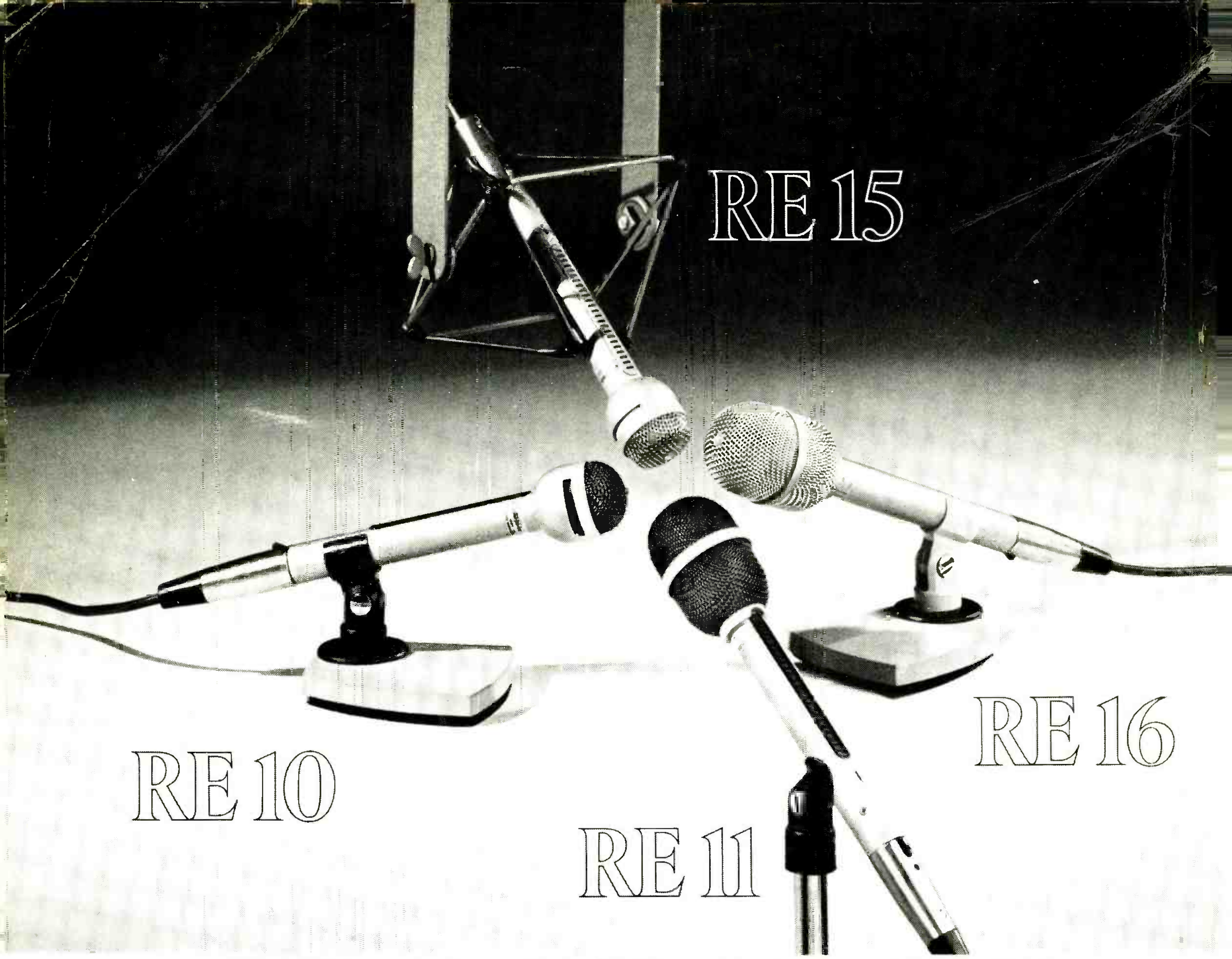
Electronics World

SEPTEMBER, 1969
60 CENTS

ARCHEOMAGNETISM & PALEOMAGNETISM—Keys to the Past
SIXTEEN-TRACK RECORDER CREATES "NEW SOUND"
MARINERS' EXPERIMENTS IN EXPLORATION OF MARS
AUDIO MULTIPLEX SYSTEM FOR NEW BOEING SUPERJET

New Developments in
PUBLIC-ADDRESS SYSTEMS



NEW Model RE10 $90.00, shown on Model 421 desk stand $10.50. Model RE15 $153.00, shown with Model 307 suspension mount $20.70. NEW Model RE11 $96.00, shown with Model 311 snap-out stand adapter $3.90. NEW Model RE16 $159.00, shown on Model 421 desk stand $10.50. All prices suggested net.

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Professional sound has entered a new era. It started with the Electro-Voice Model RE15. And now there are four E-V dynamic cardioid microphones that share its distinctive advantages — with some unique benefits of their own.

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The new RE10 is the economy version of the RE15. The same concept and quality, but for slightly less rigid requirements. And the RE11 is the lower cost twin to the RE16.

These four great cardioid microphones give you new freedom to head off sound problems before they start. Your E-V microphone headquarters has them waiting. Choose today.

*U.S. Patent No. 3,115,207. Trade mark registered.

ELECTRO-VOICE, INC., Dept. 991N
629 Cecil Street, Buchanan, Michigan 49107

FOR INFORMATION ON E-V PRODUCTS:

Microphones
CIRCLE NO. 111 ON READER SERVICE CARD

PA Speakers/Accessories
CIRCLE NO. 112 ON READER SERVICE CARD

Musician's speakers/microphones
CIRCLE NO. 113 ON READER SERVICE CARD

High Fidelity speakers/electronics
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A SUBSIDIARY OF GULTON INDUSTRIES, INC.

You can pay $600 and still not get professionally approved TV training.

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Before you put out money for a home study course in TV Servicing and Repair, take a look at what's new.

National Electronic Associations did. They checked out the new TV training package being offered by ICS. Inspected the six self-teaching texts. Followed the step-by-step diagrams and instructions. Evaluated the material's practicality, its fitness for learning modern troubleshooting (including UHF and Color).

Then they approved the new course for use in their own national apprenticeship program.

They went even further and endorsed this new training as an important step for anyone working toward recognition as a Certified Electronic Technician (CET).

This is the first time a self-taught training program has been approved by NEA.

The surprising thing is that this is not a course that costs hundreds of dollars and takes several years to complete. It includes no kits or gimmicks. Requires no experience, no elaborate shop setup.

All you need is normal intelligence and a willingness to learn. Plus an old TV set to work on and some tools and equipment (you'll find helpful what-to-buy and where-to-buy-it information in the texts).

Learning by doing, you should be able to complete your basic training in six months. You then take a final examination to win your ICS diploma and membership in the ICS TV Servicing Academy.

Actually, when you complete the first two texts, you'll be able to locate and repair 70% of common TV troubles. You can begin taking servicing jobs for money or start working in any of a number of electronic service businesses as a sought-after apprentice technician.

Which leads to the fact that this new course is far below the cost you would expect to pay for a complete training course. Comparable courses with their Color TV kits cost as much as six times more than the $99 you'll pay for this one.

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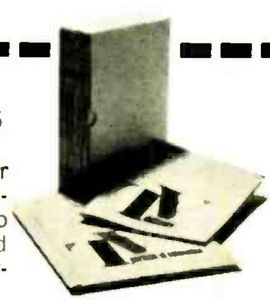

Yes, I'd like all the details about your new TV Servicing/Repair basic training package. I understand there's no obligation. (Canadian residents, send coupon to Scranton, Pa. Further service handled by ICS Canadian, Ltd.)

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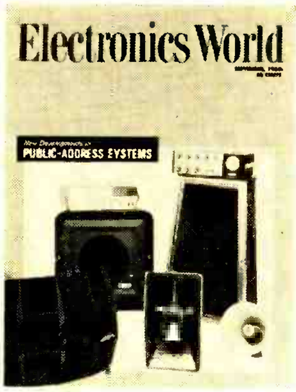

THIS MONTH'S COVER is related to our lead story on p.a. amplifiers. Further articles on this topic, scheduled for subsequent issues, will cover p.a. loudspeakers and matching. The amplifier at the left is University Sound's Model UPL-100DT, a 100-watt solid-state p.a. amplifier. The unit at the top right is the Bogen Model MTX-30B, a 30-watt solid-state p.a. amplifier. Beneath the University amplifier is the Electro-Voice "Musicaster IA", a wide-range, all-weather p.a. speaker. Beneath the Bogen amplifier is the Jensen "Vibranto" column speaker system designed especially for amplified musical instruments. The three p.a. speakers in the foreground are, from left to right, an Altec-Lansing multicellular horn, an Electro-Voice Model 848A compound diffraction projector horn and driver, and an E-V PA30R reentrant paging projector . . . .
Photograph: Dirone-Denner.

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CONTENTS

MONTHLY FEATURES

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COMING NEXT MONTH

SPECIAL ISSUE:

PRINTED CIRCUITS

A special 24-page section will be devoted to every aspect of PC technology ranging from wiring, laminates, connectors, and conformal coatings to information on high-density boards, special PC kits for short runs and prototype applications, and a discussion of the technology itself. Sal DiNuzzo of Hazeltine, Hal Roffman, Jr. of Sibley Co., Gaetano T. Viglione of Sanders, Dr. Norman Skow of Synthane-Taylor, P.C. Hecker and C.T. Novak of Amphenol, Victor Liebman of Columbia Tech., and Donald L. Steinbach of Lockheed will be among your "guides" to PC usage.

P.A. IMPEDANCE MATCHING

This is Part 2 of a three-part series on various aspects of public-address work. Abe Cohen of ISC/Telephonics provides complete information on how p.a. speakers can be matched to p.a. amplifiers, with special emphasis on 25- and 70.7-volt systems.

COLOR CODES CHART

If past experience is any criterion, our readers will welcome this updated, two-color chart showing codes for both resistors and capacitors.

ELECTRONICS AND THE LIVING PLANT

The author presents some very intriguing, but controversial, experiments being performed in plant research that raise such questions as: Can plants be used in electronic systems? Do plants possess emotion-like qualities?

All these and many more interesting and informative articles will be yours in the October issue of ELECTRONICS WORLD . . . on sale September 18th.

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

NEW YORK OFFICE 212 679-7200
Joseph E. Halloran

MIDWESTERN OFFICE
307 North Michigan Avenue
Chicago, Illinois 60601 312 726-0892
Midwestern Advertising Manager, Robert J. Ur

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STANDARD OF THE ELECTRONIC INDUSTRY

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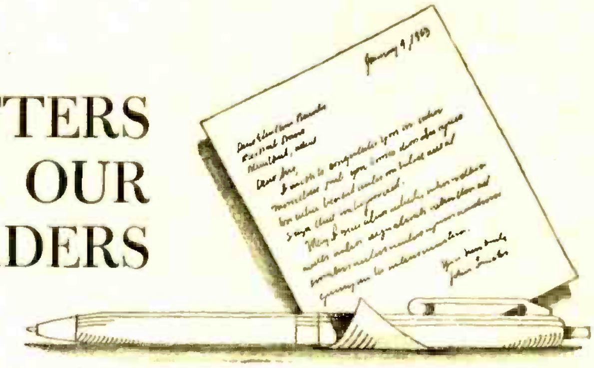
LETTERS FROM OUR READERS



DOLBY AND OTHER SYSTEMS

To the Editors:

There has been so much interest recently in noise-reducing systems that there is sometimes a tendency to forget there is really very little completely new in this world. Your article in the May issue covering the Dolby system is very interesting and mention is made of patents pending.

Along this line, however, I would like to point out that much early work on this same general type of system was done by John Hayes Hammond, and that patent number 2,606,971 in the name of Hermon Scott covers exactly the same fundamental principles described in your article—including dividing the audio range into several bands and operating on the soft passages. This patent, however, has lived its 17-year life and has expired.

This comment is not made in any deprecation of the Dolby system, but merely to point out that recognition of the noise problem is not new and that most of the noise-reduction methods mentioned in the article have been used in the past, often with considerable success.

VICTOR H. POMPER, Pres.
H. H. Scott, Inc.
Maynard, Mass.

* * *

THUMBWHEEL SWITCHES

To the Editors:

The report on thumbwheel switches appearing in the May issue is quite informative and interesting. The section on p. 41 comparing the cost of thumbwheel switches to rotary switches, we feel, however, is misleading.

The article refers to a miniature phenolic rotary switch with four decks as being the "applicable equivalent to a thumbwheel switch." We have produced and publicized the equivalent binary circuit on a single section rotary switch for many years. It is shown in *Oak's* standard rotary switch catalogue, and is also available from our distributors. Only in rare instances would an engineer use a four-deck switch and wire it as described (and illustrated) by the author of this article.

The author also states that the cost of a rotary switch with four decks is about $4. Even if someone wanted to purchase a four-section switch for this application, he would get it from us for $2.25 each in production quantities. A very simple single-deck switch of the commercial variety that would perform the same switch functions as a thumbwheel switch would cost only 60¢ in production quantities. The most exotic military rotary switch to perform the same switching would only cost $1.40 in production quantities. I cannot imagine a variation that would approach the $4 figure that the author mentioned.

The author further describes the cumbersome procedure of cutting and soldering 19 or 20 wires to assemble a rotary switch to provide a binary output. This is erroneous. Our approach requires only five connections to the section. That is no more than required by an equivalent thumbwheel switch. Further, the versatility of our tooling and selection of component parts enables us to provide almost any complex switching circuit without excessive jumper wires at no additional charge to the customer. With the printed-circuit concept used in thumbwheel switches, anything different that has not been supplied previously would require special artwork and preparation charges.

Finally, the typical contact resistance indicated for a thumbwheel switch of 100 milliohms is ten times greater than that of a rotary switch. In fact, the contact resistance that is stated in the article would be considered a reject with any of our products.

ROBERT R. GUSTAFSON, Mktg. Mgr.
Oak Manufacturing Co.
Crystal Lake, Ill.

The prices quoted in the article were for single-unit quantities and not production quantities.—Editors

* * *

FIRST TRANSATLANTIC CABLE

To the Editors:

I read with great interest the article on "Communications Satellites" in the July '69 issue by Francis A. Gicca. I notice, though, that he states that the first transatlantic cable was completed in 1956, his statement being "Only two years earlier the first transatlantic cable had been completed . . ." His previous sentence stated "When Score was launched in 1958 . . ." So that fixes the first transatlantic cable in 1956. However, the *World Almanac* states that the first Atlantic cable was completed in

1858. Although it was not successful, a successful one was completed in 1866. No doubt Mr. Gicca means the "first" transatlantic *telephone* cable, but he doesn't specifically say so.

PAUL E. SMAY
Chicago, Ill.

Reader Smay is correct in that the first transatlantic cable referred to by Author Gicca was a telephone *cable. Previous cables had been laid under the Atlantic, but none for telephony.—Editors*

* * *

ATOMIC RADIATION

To the Editors:

The first installment of your series "Atomic Radiation: Types & Relationships," May, 1969, contains an error on p. 47 just above the heading "Biological Hazards." Uranium-238 does indeed decay to thorium-234 by emission of an *alpha* particle, but the thorium nucleus is not stable, as stated. In fact, it decays by emission of a *beta* particle, with a half-life of 24 days, to protactinium-234, which is also radioactive. These are the first few members of a long series of decay products ending with lead-206, which is stable and constitutes 26% of natural lead.

ALAN R. BETZ
Vancouver, B. C.

Mr. Betz's comment concerning the instability of thorium-234 is quite correct. The original text contained no such statement; it was added by an editor. The error went undetected by the author in proof.—Editors

* * *

TV INTERFERENCE

To the Editors:

John Frye's explanation (in the June issue) of moving vertical stripe interference is misleading.

Once a television receiver, either black-and-white or color, is tuned to a broadcast, the receiver has no control over its own scanning rates. The station transmits color programs with a frame rate of 59.94 Hz and some black-and-white programs with the once-standard rate of 60 Hz. Of course, the line rates differ also.

Therefore, the situation described in Mr. Frye's column could occur only if two receivers (black-and-white and/or color) were tuned to different stations, one transmitting color, the other, black-and-white.

HAROLD J. TURNER, JR.
McLean, Va.

* * *

OLD ISSUES OF EW

To the Editors:

Kindly inform your readers that I have, at no charge, back issues of ELECTRONICS WORLD from the 1950's through the 1960's.

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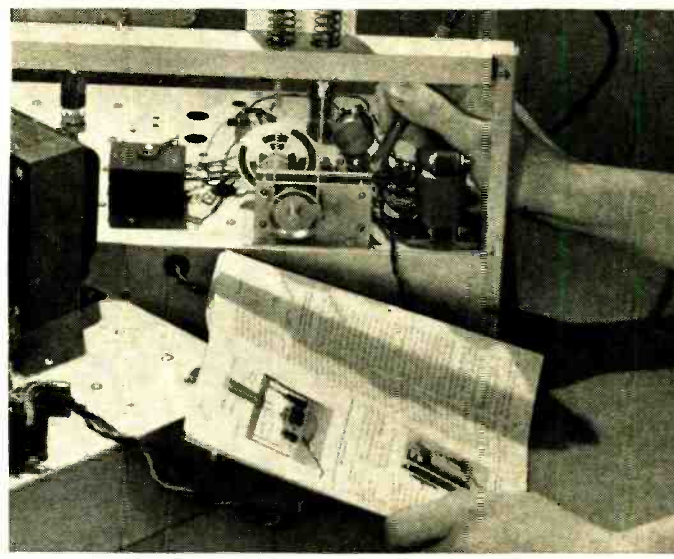

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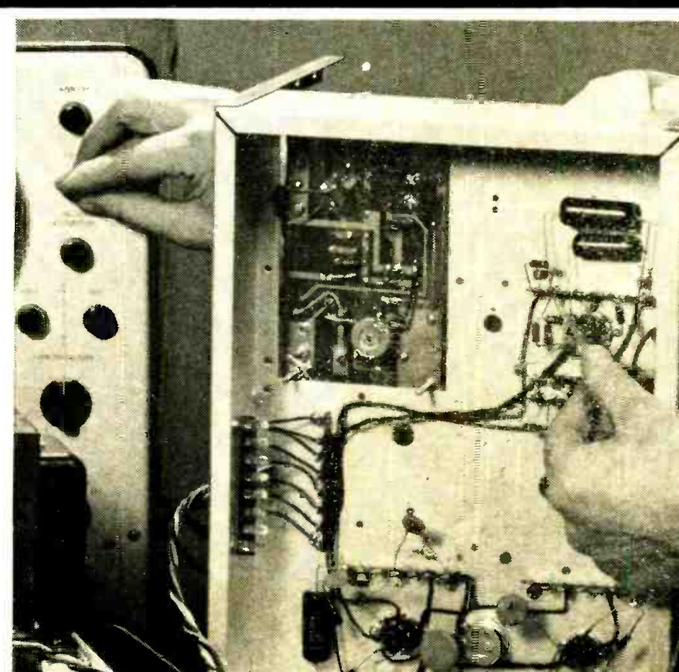

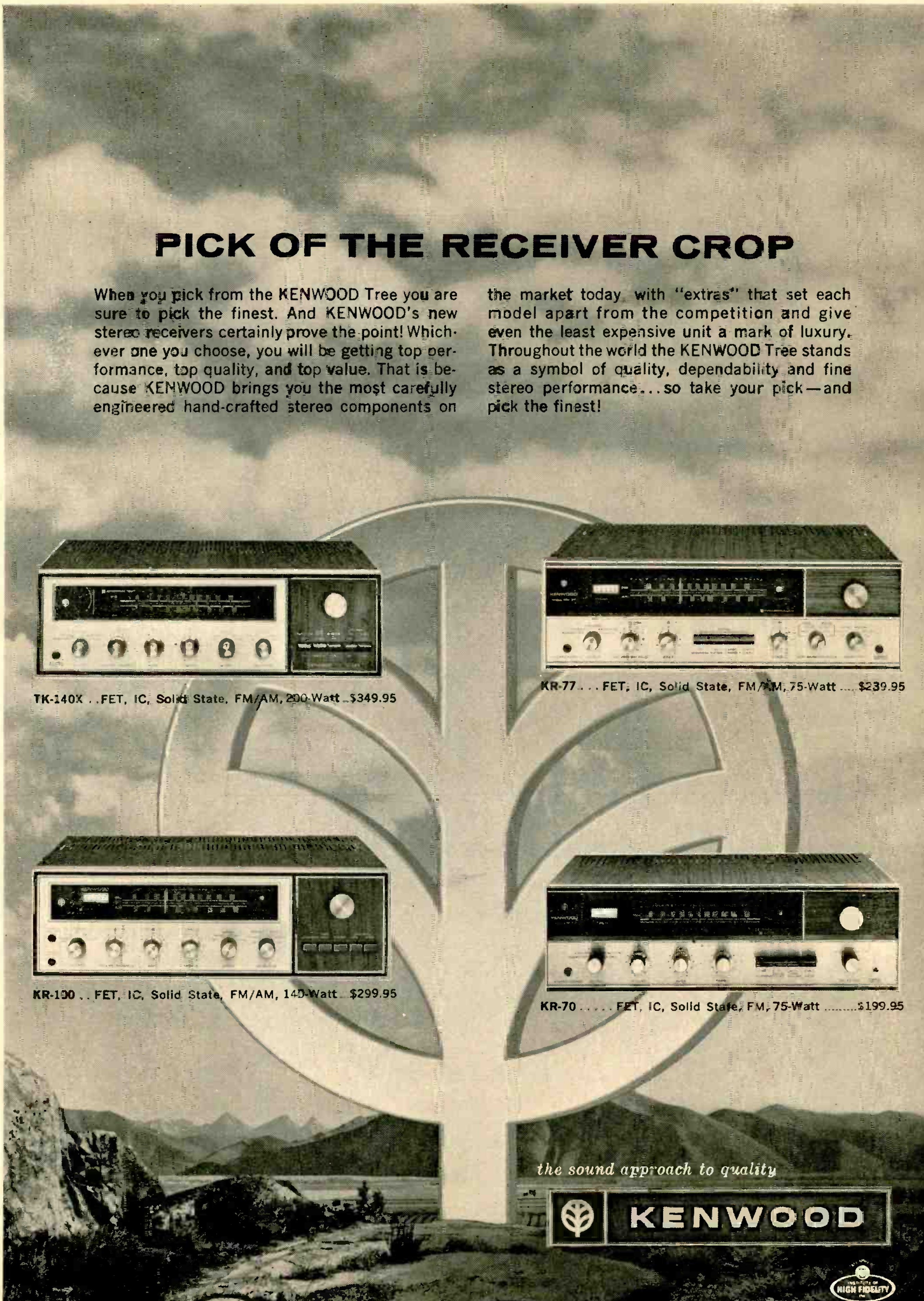
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KENWOOD

By FOREST H. BELT/Contributing Editor

CATV/Broadcast Agreement Didn't Click

The much-lauded get-together between the CATV and broadcast associations (reported here last month) didn't work out. Board members of the National Association of Broadcasters rejected the plan, which had been negotiated by staffers of both associations. The board cited numerous objections.

Once the word was out that there was no agreement after all, a lot of people found objections: the Justice Department felt it was trade-restricting. The courts doubted it could be upheld anyway. Congressmen would rather enact (eventually) their own ground rules for CATV's future. Some FCC people felt the proposal might circumvent proper regulatory procedures.

Considering how much the paper proposed shifting both parties from previous positions, it's no wonder it flopped. On the other hand, let's hope the basics aren't rejected for all time. Sensible accord is badly needed. And, whether they believe it or not, the broadcasters have the most to lose by not finding some grounds for agreement, and pretty quick.

Cassette Boom Brewing

Manufacturers and retailers alike expect big things from cartridge tapes this fall. Eight-track stereo is doing fine, but the cassette is what's stirring excitement. Big dollars are anticipated. More than 60 companies now offer cassette machines in countless shapes and forms.

Stereo cassettes are helping. More than half the 60 companies build (or import) stereo players. Sales of cassette dictating machines are growing too: they're simpler to operate than reel types, and they're cheaper than office-type machines. Considering all types, at the present rate of growth, the tape industry expects to have sold 3 to 3½ million cassette units by the end of 1969.

Silent Touch-Tuning for TV

Of all the gimmicks in the 1970 color sets, one real stopper is an 18-channel tuner that switches to any channel instantly at the slightest touch. The maker is *Electrohome*.

Most noticeable is how silently and instantly a channel appears when you touch its electrode. Slight finger contact between the electrode and the bus bar beside it triggers diode-switched tuner circuits. Before you can pull your finger away, the channel you selected pops onto the screen, no matter what channel was tuned in before—no switching through 3, 4, 5, and 6 to get from 2 to 7.

The tuner is a box that mounts in the console receiver or can be removed and attached to the end of a small, flexible cable about 20 feet long. The same box contains volume, brightness, contrast, color, and tint controls.

Another Modular Solid-State Color Set

A Canadian company that has had its ups and downs, *Clairtone*, has some good news. It's introducing a color-TV receiver that is solid-state *and* is built on functional modules. (Only *Motorola* and *Setchell-Carlson* have tried this so far.) The chassis is the MSS71. The modules are fiber glass circuit cards like those so popular in computers. Circuitry is etched on them, and components are mounted on a thin profile so they can slide into the chassis mounting. The cards are about 6 inches square. The chief reason for modular construction, says a *Clairtone* spokesman, is ease of servicing plus design upgrading. The set is expected to be for sale by late fall.

The Music Generation

In politics and business there may be a generation gap, but in music the separation is thinner than you might suspect. Old and young alike make more music at home than at any time in history. And they do it electronically. The chief differences are in choice of instruments and style of music. Youth shows a preference for amplified guitars, adults for electronic organs.

But indications are that the organ is gaining as more families find it an instrument they all can be enthused about. Its versatility is unmatched. It can produce almost any kind of sound, limited only by the talents or imagination of the person handling the keyboard(s). It can mimic virtually any instrument and produces some sounds no other instrument can.

Watch for greater popularity among "trick" accessories. One *Lowrey* organ has a cassette player built into it to supply play-along music, rhythm, etc. Many brands have chord buttons. Personal listening jacks let the budding musician practice privately (and quietly). Portable models for youth bands sport huge power. *Jensen* just brought out a speaker that handles 250 watts—that's auditorium power.

In-Board Warranty

That's a name being used for a warranty under which the manufacturer pays the repair charges as well as furnishing free parts. Most consumer-electronics manufacturers now have it in one form or another or having begun testing ways to do it. For small items, such as radios and cheap phonos, some find an over-the-counter exchange warranty brings fewer problems in the long run.

All too many manufacturers still try to get by with so-called "authorized" factory-service stations, independent repair shops that operate under a contract that gives them only token payment for handling each warranty repair. These contract repair rates are usually woefully low; they don't even pay technician wages, much less cover overhead and a business profit. Service-shop owners take this loss, hoping warranty customers return if trouble occurs after warranty; they seldom do . . . because they feel the servicer should have fixed the set so no other problem ever occurs. This drawback to "contract warranty service" is too often overlooked.

With consumer protectionists clamoring about warranties anyway, it's time for a close look at the quality of warranty repairs. No repair work can be done properly unless it is paid for fairly. A few enlightened manufacturers are now paying fairly—in fact, paying the shop's full regular price for repair work on in-warranty units. But here's a warning! If other set-makers don't do the same and if technicians don't insist on full payment for *all* their service work, neither has a right to complain when the government forces the issue, all in the name of getting dependable warranties for consumers.

Sound All Around

New realism in sound reproduction seems likely from a new tape recording system worked out by *Vanguard Records*. The idea is to capture for the listener the real acoustic effect of the original recording studio, music hall, or auditorium.

Instead of two channels like present stereo, the new "surround stereo" has four. In recording, two microphones are placed in the traditional stereo pickup positions; two others, highly directional, are aimed at the rear and sides of the sound hall to pick up reverberated sound. For playback, two speakers are placed in front of the listener as usual and two are placed behind. Reverberation effects come to the listener from behind, just as they would if he were in the hall.

What equipment to use for this idea hasn't been decided yet. It wouldn't be at all difficult to wire up an 8-track cartridge player to handle the playback; recording on four of the tracks in parallel at a time would make possible two programs per cartridge. No other record companies have commented on the system as yet, but *Vanguard* has six releases in the works. One, we were interested to note, is electronic music.

Color-TV X-Rays

We're at it again. Or yet. Headlines recently said color-TV x-rays were "more penetrating" than previously estimated. This was testimony from a member of the Department of Health, Education, and Welfare. We couldn't help noting that he was testifying before a House appropriations subcommittee to justify HEW's fiscal-1970 budget request. His specific testimony can be construed (or miscontrued) almost any way. One result, however, of this and other developments is likely to be a new 0.1 mR/hr standard for color sets within the next year—whether it's needed or not.

Flashes in the Big Picture

Consumer Electronics Show in June drew over 28,000 dealers, distributors, and manufacturers' representatives. . . . Heavy participation in that Show by hi-fi manufacturers may be partly responsible for cancellation of New York High Fidelity Show usually held in early fall, even though latter show is as much for public as for retailers. . . . Chromium-dioxide magnetic tapes, developed for computers, may be answer to fidelity problem at 1⅞ in/s cassette speed; need for high bias and erase current has been one holdback. *Teac* now has cassette record/playback machine that can supply it. Also *TDK* has a new cassette tape with improved iron-oxide formulation that is claimed to have extended high-frequency response. ▲

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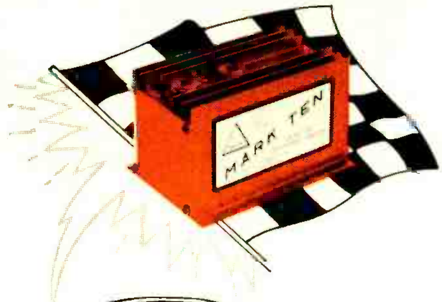

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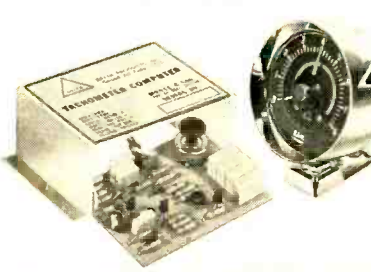

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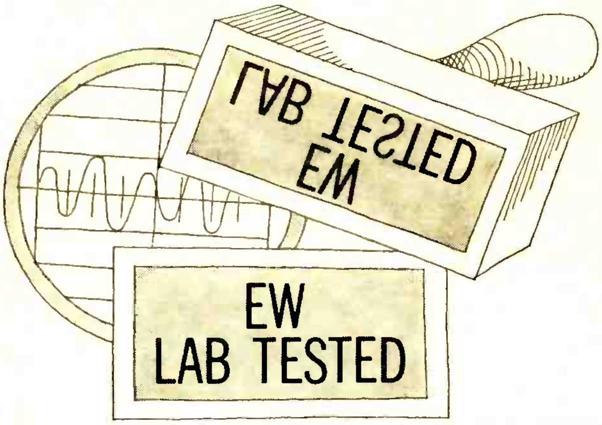


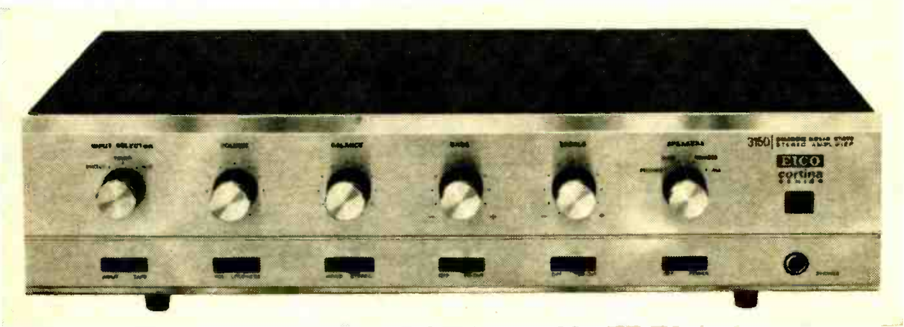
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Eico Model 3150 Stereo Amplifier
Ampex 1461 Tape Recorder

Eico Model 3150 Stereo Amplifier

For copy of manufacturer's brochure, circle No. 27 on Reader Service Card.



In the two years since the introduction of the *Eico* "Cortina" series of high-fidelity components, the line has expanded to include a low-powered, excellent-quality amplifier (the 3070), a matching FM tuner (the 3200), a combination of the two into a complete receiver (the 3570 with FM only, or the 3770 with both FM and AM), and most recently a high-powered amplifier, the 3150.

Our evaluation of the earlier components led us to the conclusion that they were of excellent quality, but that the amplifier was relatively underpowered in today's market. Its output of 15 watts per channel, although quite adequate for moderately efficient speakers, would not be suitable for use with the lowest efficiency speakers currently available. This problem has been solved most effectively with the new 3150.

Although the 3150 is only slightly wider than the 3070 (it measures 14½" wide × 3⅛" × 8⁵⁄₁₆" deep) it has well over twice the power of its junior partner. It is rated at 150 watts (music power) into 4 ohms, or 100 watts into 8 ohms. On a continuous-power basis, the 3150 is rated to deliver 50 watts per channel into 4 ohms, 40 watts into 8 ohms, or 25 watts into 16 ohms.

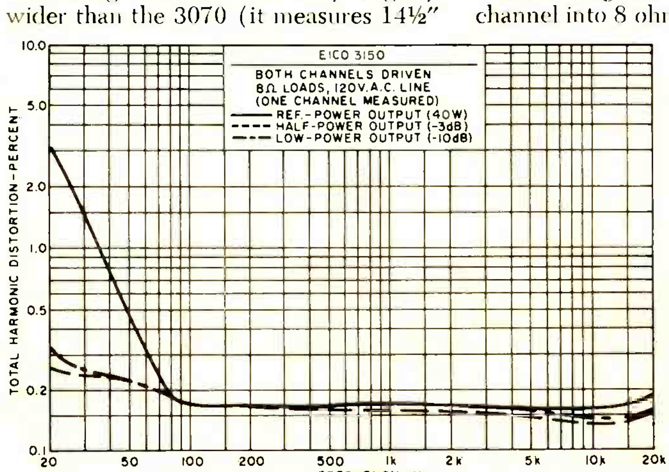
In appearance, styling, and control functions, the amplifier is virtually identical to the smaller 3070. It has volume and balance controls, tone controls, a speaker selector for either of two pairs of speakers (or both), and an input selector for phono, tuner, or another high-level input. A row of small rocker-type switches controls tape monitoring, loudness compensation, mono/stereo switching, high- and low-cut filters, and line power. There is a stereo headphone jack on the panel and two a.c. outlets in the rear, one of which is switched.

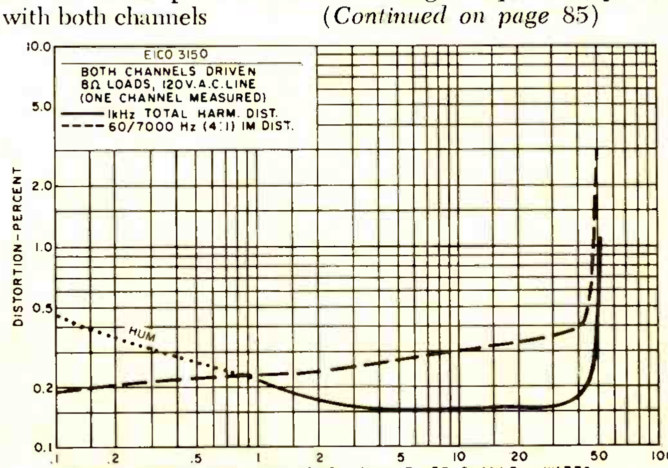
Delivering its rated 40 watts per channel into 8 ohms, with both channels driven, the 3150 had a measured harmonic distortion of 0.16% from 100 to 15,000 Hz, rising to 0.2% at 20,000 Hz, 0.5% at 50 Hz, and 3.1% at 20 Hz. At half power or less, the distortion was about 0.15% above 100 Hz, rising to about 0.3% at 20 Hz. At 1000 Hz, the harmonic distortion was less than 0.2% from about 1 watt to 44 watts, increasing to 1% at 50 watts. The IM distortion was about 0.2% for powers under 1 watt, gradually increasing to 0.5% at 45 watts. As these measurements show, the manufacturer's ratings for power and distortion are quite conservative, and the 3150 is clearly at least a "light heavyweight" among amplifiers.

At the clipping level, the output per channel was 72 watts into 4 ohms, 52 watts into 8 ohms, and 31 watts into 16 ohms. An input of 160 millivolts was needed at the high-level inputs for 10 watts output, and the hum and noise were almost 75 dB below 10 watts, which is totally inaudible. Through the phono input, 2.55 millivolts was needed for 10 watts, with a hum and noise level of −66 dB. An input of 88 millivolts was needed from a phono cartridge to produce visible waveform distortion, which is a virtual guarantee that the preamplifier stages will not be overdriven.

The tone controls have a sliding inflection-point characteristic which allows considerable control of response at the frequency extremes without significant effect on mid-frequencies. The loudness compensation, which boosts both low and high frequencies, proved

(*Continued on page* 85)





Reflections on the news

Heart and Hope

Artificial heart research is proving fruitful. Already, pacemakers that keep faulty hearts pumping rhythmically are well advanced; thousands are in use. Next step is nuclear power for them (pacemaker batteries run down in year or two and have to be replaced through surgery). Nuclear-powered units exist, using plutonium-236. They're working in animals. And Beth Israel Hospital in Newark, N. J. is ready to begin first human trials.

But what is wanted most is entire man-made heart. To make one, need long-lasting materials human body can accept, tiny motor that requires little power, nuclear power source that doesn't heat up or radiate. Recent breakthroughs suggest heart patients may not have long to wait.

Space Program Cutback

Air Force plans for Manned Orbiting Laboratory (MOL) were preemptorily canceled by Secretary of Defense. Typical of other sudden stoppages by Department of Defense, this one throws thousands of electronics experts out of work at *McDonnell Douglas, G-E, Martin-Marietta.* It's hard on careers. The good engineers and techs will find other jobs, demand being what it is. But . . . it's hard to get youngsters into scientific/engineering careers anyway; bombshells like this make it even harder.

An Underseas NASA?

Support is rallying for a National Undersea Space Administration (NUSA) that could do for oceanography what National Aeronautical and Space Administration (NASA) does for outer space exploration. We agree wholeheartedly. Undersea work is neglected, and therefore keeps having setbacks (see "Underwater Slowdown," this column, June issue). Some dollars and broad coordination would do wonders for the aqua-space situation.

Comsat Changes Tune

You've heard how countries resent U.S. domination of International Telecommunications Satellite Consortium (Intelsat). Comsat, our satellite corporation, has agreed to give up managing Intelsat operations. International secretariat will oversee financial, legal, and administrative details. Comsat will manage technical matters only, under contract.

U.S. negotiating team also agreed to regional satellite systems, which is good idea. Many areas of world can benefit from direct satellite reception; they might never be able to tie in with worldwide facilities. After all, technical compatibility, while desirable, isn't necessary when only a small part of world is served. But Comsat should stick to demand that regionals not interfere with global systems.

Debate Over Air Traffic

One new Federal Aviation Administration ruling relieves somes airways crowding. With flight-track computers, planes can move more freely on paths outside established airways, which only run from navaid to navaid. Some aviation "experts" deny that more and better electronics is the answer to congestion in airlanes and at terminals. We agree with FAA, which recently spelled out program of electronic improvements that include real-time computer flight control, more instrument landing system channels, alphanumeric radar displays, and special information-and-control consoles engineered for quicker and simpler human use.

Radiations from the Field

Tape speed-up, without change of pitch, makes handy device to let blind people "read" tape-recorded books faster. . . . Two-foot electronic "mirror" placed on moon by Apollo 11 astronauts bounces laser beams back for highly accurate distance measurement. . . . *Jervis Corp.* and *RCA* are working out day/night rearview mirror for cars—using, of all things, liquid crystals. ▲

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Paleomagnetism & Archeomagnetism

Twin Keys to the Past

By DONALD E. LANCASTER

Permanent records of the strength and the direction of the earth's ancient magnetic field lie frozen as magnetic recordings in many rocks and artifacts. Measurements of this field, using computers, magnetometers, demagnetizers, and other instruments, provides valuable data about our past.

HOW old is the Earth? What causes the Earth's magnetic field? Why has this magnetic field suddenly reversed dozens of times in the past? What relation is there between these reversals and the extinction of an old or the evolution of new species of animals? Is there anything to continental drift? What causes sea-floor spreading? Westerly drift? Polar wandering?

How does an archeologist accurately date a firepit with no wood present and only chance association with other datable materials? Which quarry did the stone for a Roman road come from? How far was tradeware pottery carried?

Answers to these tough questions and many more like them are now being answered by the twin sciences of *paleomagnetism* and *archeomagnetism*, sciences as old as the compass and yet as new as today's electronic technology.

Paleomagnetism is the study of past variations in the Earth's magnetic field, primarily through locked-in magnetic-rock recordings of the direction and intensity of the field. *Archeomagnetism* is basically the same game—only it is played by archeologists seeking cultural dates and relations, primarily over the past 10,000 years, instead of by geologists seeking the "how" and "why" of the Earth over its 4.5-billion-year history.

Only very recently have significant developments been made in these fields, aided by computers, magnetometers, demagnetizers, and other electronic instrumentation. So recently, in fact, that many of today's paleomagnetic results and tentative conclusions would have been considered highly controversial only a few years ago. Today, such concepts as the precession-driven magnetohydrodynamic origin of the Earth's magnetic field, continental drift, and dynamo-caused reversals have a broad base of experimental and theoretical evidence behind them.

Basic Principles

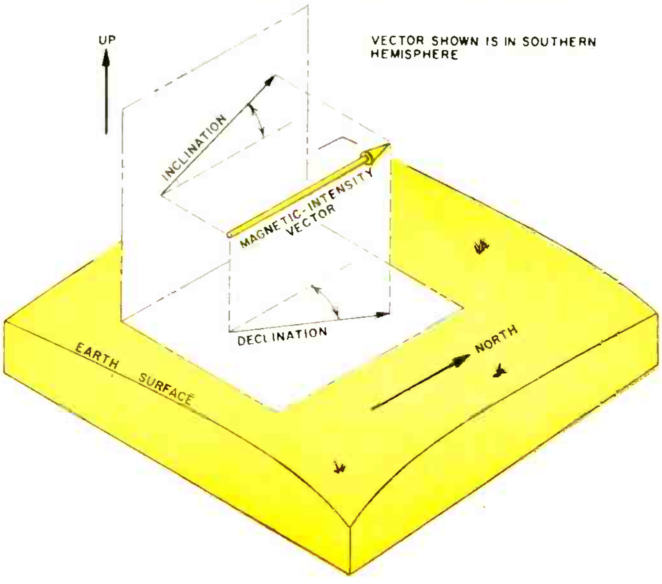
Just like any other magnetic field, the Earth's field can be represented at any given time at a specific place as a vector quantity. The field at any point has both a magnitude and a direction. With Earth magnetism, the vector is normally resolved into two components of direction, called the *declination* and the *inclination*, as shown in Fig. 1.

A compass measures declination, or the deviation of magnetic north from true north, usually expressed as 0-360 degrees clockwise. Declination (or compass variation) is the projection vertically downward of the magnetic-intensity vector compared against true (polar) north. (The angle is measured on the horizontal plane.) Compasses do not, of course, point due north, and corrections for declination must be made on all land surveys, aircraft flights, and other precise geographical measurements.

A dipping magnetized needle measures inclination, or the deviation of the magnetic-intensity vector from horizontal. (The angle is measured on the vertical plane.) Values of inclination vary from 0° (horizontal) just south of the equator to nearly +90° (straight down) at the far north and nearly −90° (straight up) at the extreme south.

The strength and direction of the magnetic-intensity vector at any given geographic location has changed radically

Fig. 1 At any point, Earth's magnetic-intensity vector may be resolved into two components, inclination and declination.



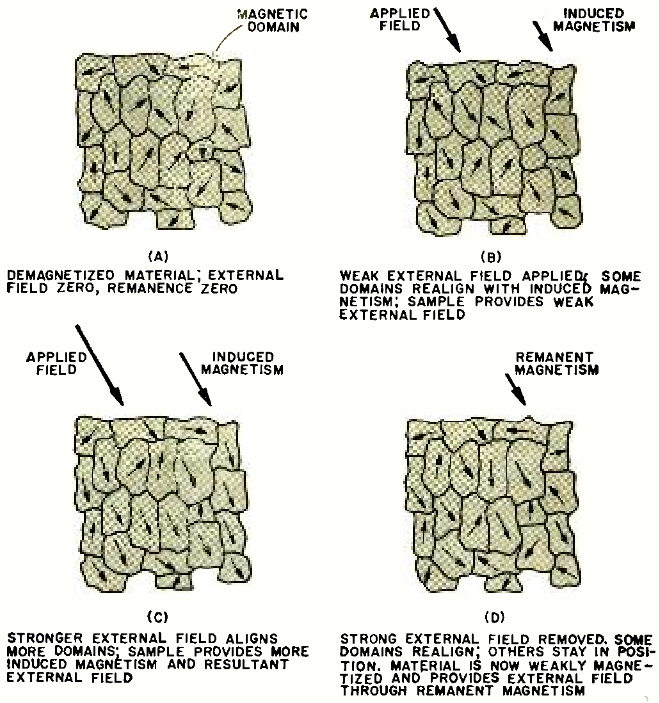


Fig. 2. How induced and remanent magnetism is obtained.

throughout time—so radically that an accurate history of these variations can be made well into the distant past. The variations can often be calibrated against such things as historic records, cultural cross-dating, stratigraphic layering, or the atomic decay dating processes using carbon-14 and potassium-argon-40. The variations in themselves may, in turn, be used as a secondary calibrated dating standard for new measurements. When many records from many areas are compared against each other, relative motions of the areas with respect to themselves and the magnetic poles become apparent.

Paleomagnetism and archeomagnetism are based upon "freezing" the intensity, declination, and inclination at an instant in the past as a permanent magnetic record in clay, rock, or other materials. This recording process usually takes place due to the intense heating of the material, either in its volcanic origin, by man in a firepit or kiln, or by accidental coal and forest fires.

If we are able to measure the intensity and direction of the magnetic vector with respect to the original position of the material (either at its location, or by the more common practice of removing the sample to a laboratory after carefully marking its orientation), and if the material has behaved properly magnetically, and if we repeat the process for many tens of thousands of samples, we can trace out the entire history of the magnetic variations of the Earth. From these histories, relative movement, either localized or on a continental basis, of the samples may be readily inferred. Relative ages and, given some calibration, absolute dates may also be obtained.

If we were to inspect a magnetic material under extreme magnification, we would find millions of well-defined, tiny areas called *magnetic domains.* Each domain by itself behaves somewhat like a miniature bar magnet in that it tries to align itself with an externally applied magnetic field.

In the absence of a magnetic field, each domain "points" in a random direction. While each domain has its own magnetic vector, the net external sum of all the randomly oriented magnetic-intensity vectors will be nearly zero. We say the material is *demagnetized.*

There are mechanical forces set up at the domain walls every time a domain tries to align itself with an external field. These are called *magnetostrictive* forces and they either prevent a domain from realigning itself or else they allow it to realign itself, dissipating any constraining energy in the form of heat or a change in sample size.

Some of these forces are strong; others are weak. Suppose as in Fig. 2A, we look at a demagnetized material with no externally applied field present. The domains remain the way they were, oriented in a random manner. Now, if we apply a weak magnetic field (Fig. 2B), some of the magnetic domains will align themselves with the field, but others will be constrained by the domain-wall forces and will not be allowed to realign.

A stronger magnetic field (Fig. 2C) will align more of the domains. An exceptionally strong external magnetic field could realign practically all of the domains and saturate the material.

We call the domain realignment in the presence of an external magnetic field *induced magnetism.* If we remove the external magnetic field (Fig. 2D) some of the domains will return the way they originally were, driven by domain-wall forces. Others will stay in their new positions. We say the material has been magnetized and the strength of the new magnetic-intensity vector produced is called the *remanence* or the *remanent magnetism.*

Eventually, any magnetized material loses its remanent magnetism and the internal domains re-orient themselves into random positions. The time required to demagnetize is called the *relaxation time* and depends upon the material, the temperature, and the domain size. Fortunately for paleomagnetic work, the larger domains in paleomagnetic materials compare with the best of man-made permanent magnets and have relaxation times of millions of years and longer.

A magnetic material is "soft" if it is easy to magnetize and "hard" if it is difficult to magnetize and resistant to demagnetization. Temperature has a profound affect on magnetic hardness and softness. Alnico and other good permanent magnetic materials are "softened" by heating to high temperatures, and are then easily magnetized. Cooling then "traps" the remanent magnetism in a very hard material. The same thing works for rocks and artifacts and is the key to paleomagnetism.

Magnetism of Rocks

Rocks are made up mostly of nonmagnetic materials, but practically all rocks contain impurities of magnetite and hematite. These are oxides of iron and are strongly magnetic. They, with the help of a few related compounds, can give ordinary rocks the ability to record and store a magnetic-intensity vector.

There are many ways a rock can acquire magnetism and many ways it can lose magnetism. To be useful paleomagnetically, a rock must acquire its magnetism at a known and well-defined time, while at the same time erasing any previous record and resisting any new changes. The magnetism acquired must, to be useful, be separable from newer effects and must be a faithful record of the intensity, declination, and inclination at the time of recording.

The main ways of picking up magnetism are called *thermoremanent magnetization* (TRM), *chemical remanent magnetization* (CRM), *detrital remanent magnetization* (DRM), and *viscous remanent magnetization* (VRM). Of these methods, thermoremanent magnetization is the best behaved and the most useful. Let's take a closer look at the techniques for acquiring magnetism.

Thermoremanent magnetism is magnetism locked in a sample by intense heat. Magnetite and hematite at room temperatures are extremely "hard" and have a very long relaxation time. Thus, any magnetism they may have they are likely to keep. New magnetism is difficult to obtain.

But, whenever these materials are heated, a very unusual thing occurs. At a temperature called the Curie temperature (578°C for magnetite), the magnetic domains lose practically all their restraining forces, and the material becomes very "soft." It is then easily magnetized by whatever external field happens to be present. If the rock is allowed to cool with the same field present, the remanent magnetism locked in the rock becomes harder and harder as the temperature decreases, finally becoming quite permanent. The acquired intensity is rather strong and while it may be masked by lower-temperature latter-day magnetizations, it is very difficult to destroy or damage. Reheating the sample beyond the Curie point will, of course, erase the old field record and record a new one.

Other materials have temperatures equivalent to the Curie temperature. These are called the blocking temperature or the Neel temperature, depending on the material. Whenever these temperatures are exceeded, the material is very easy to magnetize. If allowed to cool with the field present, a remanence proportional to the applied field is picked up. The cooled sample is very hard magnetically and a locked-in record remains.

Chemical remanent magnetization is caused by chemical processes that change impurities in the rock from nonmagnetic to magnetic compounds, locking in the field at the time of the chemical change. Sandstone turning red with age is one example of this. Detrital remanent magnetization is caused by fine particles that slowly settle as dust or in water, aligning themselves with the applied field. Neither of these two latter processes is as strong, distinct, or as well-defined as the TRM process. Thus, at present, TRM is far more useful.

Samples with useful TRM come in many forms. Clay is one of the best behaved. Clay is fired by man in the form of pottery, kilns, and firepits, and it is fired by nature by forest fires and underground coal fires. Second best are volcanic lavas, with TRM taking place as the material cools on the surface of the earth or the bottom of the sea. Other materials, while useful paleomagnetically, often give less reliable results, with sediments or badly disturbed formations the poorest of all.

There are other ways magnetism can be picked up and methods by which the recording is either altered or made inherently misleading. Before a meaningful paleomagnetic measurement can be made, these other effects must be taken into account.

Viscous remanent magnetism is soft, modern magnetism acquired as a result of the Earth's modern magnetic field, or it can even be caused by leaving a crowbar or other tool near the sample for a period of time. VRM must be removed before measurement. This is usually done by a demagnetizing process to which the TRM is resistant but the VRM is not, and by making repeated measurements with the sample being stored in different positions for several weeks before each measurement.

Some rocks magnetize more easily in one particular direction, just as a sailboat prefers to go forward even with the wind at an angle. If a rock does this, it possesses *magnetic anisotropy*, and a casual magnetic measurement will "lie" as to the actual field direction. Modern tests must establish the existence of anisotropy in many types of samples. This is often done by remagnetizing and noting any preferred directions of remanent magnetism.

Anisotropic remanent magnetism (ARM) is caused by lightning—which produces such strong fields that it literally blasts a record into the rock that has nothing to do with the Earth's field. For this reason, rock outcroppings, particularly those on the tops of mountains cannot produce reliable paleomagnetic records.

Other problems include the relaxation time for very old work, the linearity of the remanence (usually good because the intensities are rather low), self-reversals (a rare and peculiar way certain samples have of altering their records long after recording), and the need for many samples to average out inconsistencies and produce reliable results.

To be useful, the magnetic intensity and direction of a sample must be measured to ½% and ½ degree accuracy, respectively. Samples are normally taken to a laboratory where this kind of control can be maintained instead of being directly measured in the field. Because of the low levels of magnetism involved and the required accuracy, considerable care and relatively fancy measuring techniques are needed.

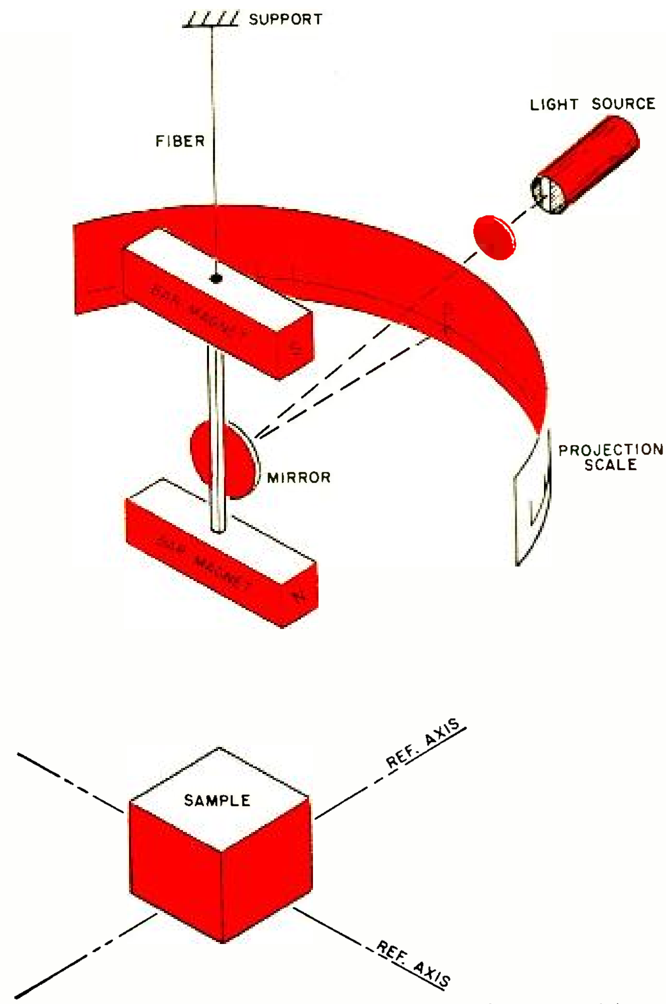


Fig. 3. Astatic magnetometer rotates in proportion to sample's remanent magnetism. Measurement on all three axes yields the total magnetic intensity along with inclination and declination.

An archeologist selects his samples from cultural remains, usually by isolating a small piece of firepit or kiln and, without disturbing its orientation, molds the sample inside a cubical plaster cast several inches on a side. After the plaster has set, its form is removed and the orientation of the sample with respect to horizontal and true north is carefully marked on the plaster surface. Whenever possible, several samples are taken from the same site.

A geologist usually uses a coring drill to obtain his samples. This drills a hollow circle through a rock stratum, leaving a core sample that may later be broken out and taken to the laboratory. Samples start out around an inch in diameter and several inches long; they are broken up into 1-inch-high cylinders before measurement. Once again, the exact sample orientation is carefully noted.

Once in the laboratory, the samples undergo a week-long storage to eliminate any newly acquired VRM. They are then demagnetized at low temperatures by a relatively weak a.c. field that removes the VRM but leaves the TRM. The demagnetization is called magnetic washing, and after the a.c. field is applied it is gradually reduced in intensity until no field remains. To keep the present, modern Earth's field from introducing any bias into the readings, the entire demagnetizer is built inside a Helmholtz coil system. The Helmholtz coil system has currents flowing through it that neutralize the local effects of the present Earth field. After magnetic washing, the sample goes to a magnetometer for measurement.

A magnetometer is an instrument that measures the

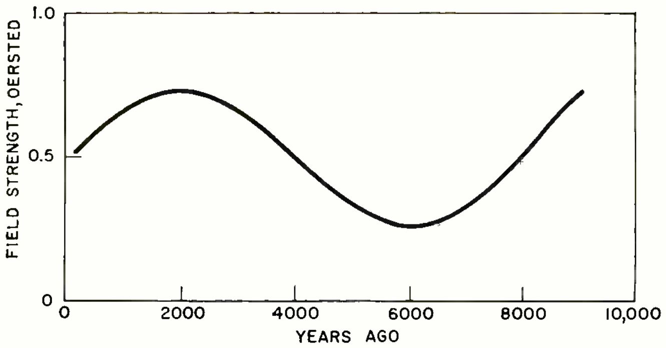


Fig. 4. How the Earth's surface magnetic field strength has varied over the past 9000 years. Note the cyclic variations.

strength of a magnetic field. There are several types. The simplest is called an *astatic magnetometer,* whose operation is diagrammed in Fig. 3.

The astatic magnetometer consists of two opposed permanent magnets supported by a fine fiber. Any torque produced by the Earth's magnetic field on the bottom magnet is canceled by an opposite torque on the upper one. Whenever a sample is brought near the bottom magnet, the magnet system rotates, being attracted to the sample, or away from it, just as a compass seeks magnetic north. Since the lower magnet is closer to the sample, and since the sample's magnetic field falls off with distance, the lower magnet is much more strongly attracted than the top one is repelled. To indicate the amount of rotation, a mirror between the magnets reflects a narrow light beam and projects it on a large scale.

In use, the instrument is zeroed in the absence of a sample. The sample is inserted in a specified direction and the light beam deflection is noted. The sample is then flipped up 90° and remeasured, and then over 90° and measured once again, giving the intensities along each of three axes. By combining the separate vectors geometrically, the magnitude and direction of the locked-in vector are measured directly.

The initial calculation is with respect to the faces of the plaster cube or another test axis. The actual values of inclination or declination are then found by relating the lab orientation and measurement to the field orientation. To allow for different sample sizes, the intensity is usually normalized to either the volume intensity or the density intensity of the sample. This is done by dividing the intensity by either the volume or the density as desired, putting all samples on a similar base so they may be compared.

Various types of magnetometers may be used, including the parastatic, the ballistic, the spinner, the resonance, and the fluxgate, among others. Each has its own advantages and disadvantages. While quite simple and extremely sensitive, the astatic magnetometer needs a field-free area well away from power lines and is quite delicate.

The paleomagnetic measurement does not directly measure the strength of the Earth's magnetic field. It merely measures a rock remanent magnetism that is proportional to the strength of the field at the time it was locked in. This proportionality is determined by the sample size, its magnetic impurities, how the field was recorded, and many other factors. To measure the actual intensity, the sample must be demagnetized, heated to the Curie point, and remagnetized with a known intensity field. Comparing the initial measured intensity against the known modern measurement will give the original intensity in terms of the new field, thus calibrating the sample.

There are many complications with this technique, among which are chemical changes in the sample as it is being heated. There is a detailed and rigorous technique called the *Thellier method,* named after pioneers in paleomagnetic work. The Thellier method demagnetizes and remagnetizes to progressively higher temperatures until the Curie point is reached. By comparing the linearity of each new result, the internal consistency of the sample is measured along with its paleomagnetism.

The Earth's Magnetic Field

Much has been learned about the Earth's magnetic field through paleomagnetism. We know now that the Earth's magnetic field is internally generated, most likely by a magneto-hydrodynamically driven self-excited dynamo effect caused by relative motions within the Earth's molten core. The most likely source of the original dynamo energy is the precession of the earth as it wobbles in orbit once every 25,800 years. We know that tremendous amounts of energy are involved—around 10 billion amperes of core current—and that the internal power generated contributes significantly to the core heating.

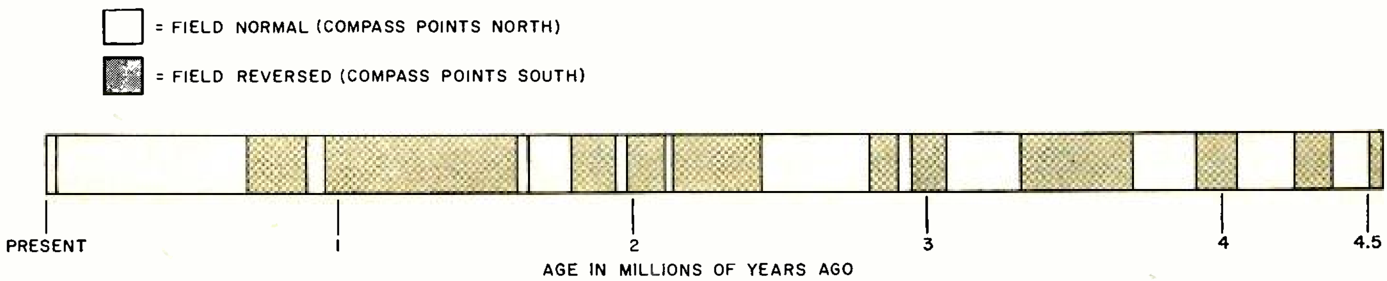
While the total field energy is very high, the surface intensity is rather low, around 0.5 oersted, with localized maxima and minima. We know these maxima and minima, called *isophors,* possess westerly drift in tune with the core motions. We know the shape of the field is mostly that of a dipole (like a bar magnet) now 11½ degrees out of line with true north. We also know there are two important lesser components resulting from various irregularities and internal turbulence. These components are most likely responsible for the self excitation, somewhat akin to the exciting field winding on a generator.

When we turn to the paleomagnetic records, we find great variations in both the direction and the intensity of the field. Fig. 4 shows how the field intensity has varied over the past 9000 years. We see that the intensity is now decreasing from about 1.5 times its present value some 2000 years ago, and that the variation is sinusoidal, and presently goes through a single cycle in 9000 years or so.

If the paleomagnetic record is pushed farther back, we find that the Earth's magnetic field has suddenly *reversed* some 26 times in the last 4.5-million years and probably many times before that. Dates of the known reversals are shown in Fig. 5. Reversals take several thousand years, an extremely short time geologically. The pole position does not change greatly during reversal—the field simply decreases in amplitude, goes through zero, and comes back up the other direction, just like the a.c. power line. During reversal, the other field components prevent a zero field condition, but the intensity does drop below a fifth its normal value during reversals. Either polarity is equally likely over a long time period, and the field has been reversed just about as long as it has been normal.

The Earth's magnetic field is (*Continued on page* 70)

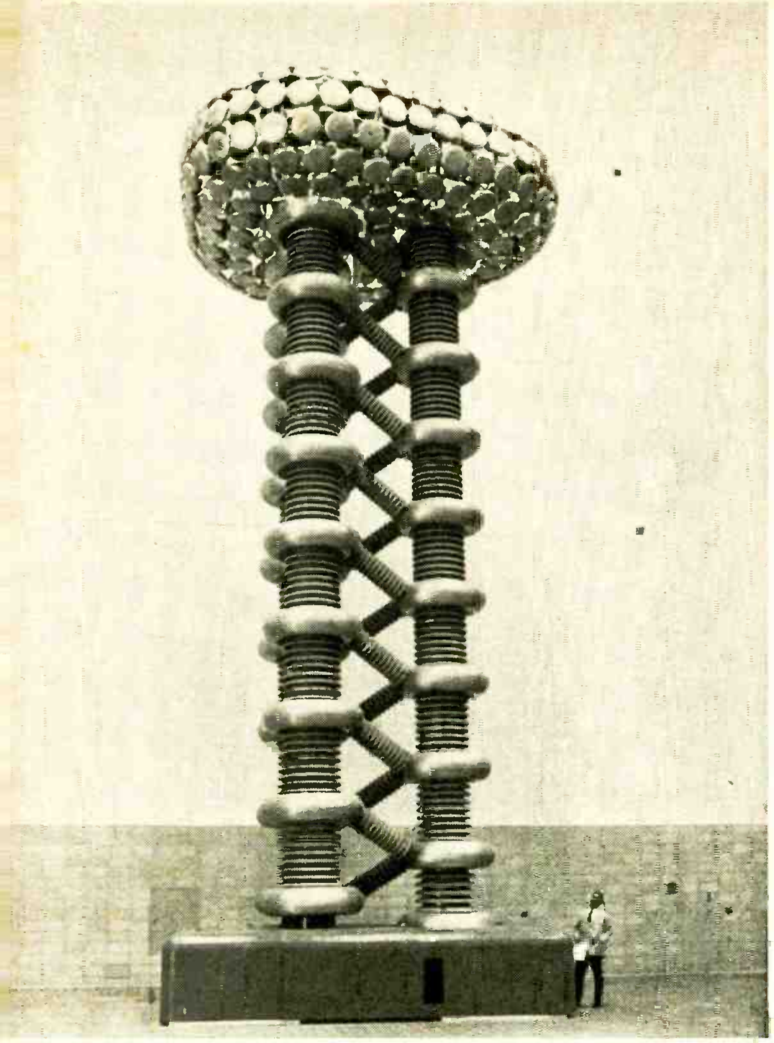
Fig. 5. A history of the Earth's more recent magnetic polarity reversals. Such reversals take several thousand years.



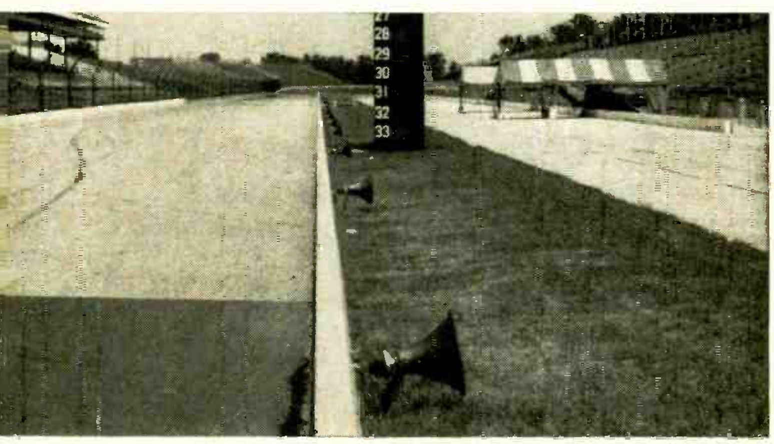
DECIBEL TABLE

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
3.16×10^{-2}	10^{-3}	30	3.16×10	10^{3}
10^{-2}	10^{-4}	40	10^{2}	10^{4}
3.16×10^{-3}	10^{-5}	50	3.16×10^{2}	10^{5}
10^{-3}	10^{-6}	60	10^{3}	10^{6}
3.16×10^{-4}	10^{-7}	70	3.16×10^{3}	10^{7}
10^{-4}	10^{-8}	80	10^{4}	10^{8}
3.16×10^{-5}	10^{-9}	90	3.16×10^{4}	10^{9}
10^{-5}	10^{-10}	100	10^{5}	10^{10}
3.16×10^{-6}	10^{-11}	110	3.16×10^{5}	10^{11}
10^{-6}	10^{-12}	120	10^{6}	10^{12}

RECENT DEVELOPMENTS IN ELECTRONICS



Two-Million Volt Generator for EHV Testing. (Top left) Voltages being used for power distribution in our cities are getting higher and higher. Work is now going on in New York on an underground a.c. power transmission system operating at 345 kV, while on our west coast an above-ground d.c. power system is being built operating at 800 kV between power lines or ±400 kV with respect to ground. (See "D.C. Power Transmission" in our May, 1968 issue.) It is necessary to test the cable and other components to be used in these and other extra-high-voltage (EHV) and ultra-high-voltage (UHV) systems. The Phelps Dodge Corp. has opened an EHV test center for just this purpose. The center will allow the company to test insulated transmission cables with ratings of up to 1200 kV d.c. and up to 1000 kV a.c. The building houses several huge high-voltage generators, one of which is shown here. This unit, a 2000-kV d.c. generator, consists of three 40-foot high oil-filled porcelain elements containing silicon rectifiers, charging capacitors, and voltage dividers. The assembly is on a mobile motor-driven chassis, which also supports a high-voltage transformer and thyristor regulator. The upper electrode is an aluminum polyhedron array which permits various angular connections.



Largest P.A. Installation. (Center) The line of p.a. speaker horns that stretches back as far as the eye can see is only a small part of the giant p.a. installation at Indianapolis Speedway. There are some 302 large horns to cover the big areas as well as additional monitor speakers in the tower and many small monitors in offices and shops throughout the 537-acre area. Power required to run the installation is normally about 10,000 watts. This elaborate sound system operates only during the four qualifying days and two weekends prior to the main racing event, held annually on Memorial Day. Each March the regular annual check of all the equipment begins. Then, in April comes the big job of re-installing all the speakers which are removed after the race each year. During the racing season, the sound equipment is in operation for a continuous 12 hours a day. The sound level has to be high enough so as to compete successfully with the loud high-speed racing engines and yet not be so loud that it drives the spectators out of the stands. All equipment in system is made by University Sound.

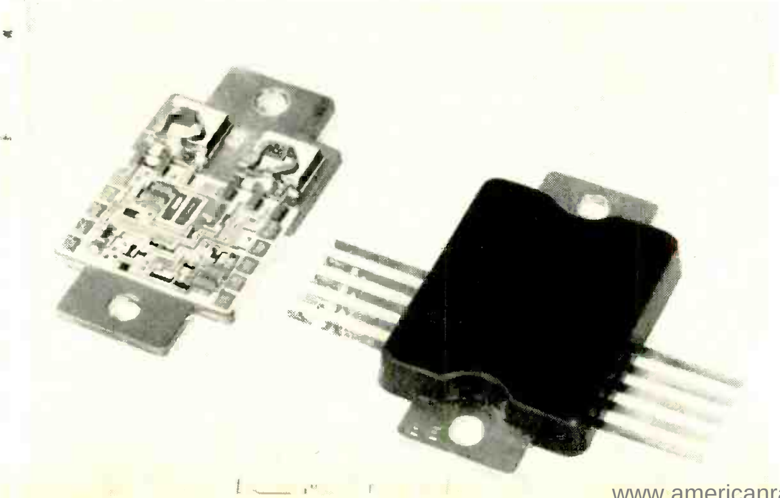
Infrared Analyzers Check Air Pollution. (Below left) Keeping tabs on air pollution is one of our major urban problems. New York City has a fairly elaborate 38-station network that is one of the most advanced in the nation. A portion of this system uses ten infrared analyzers tied into a central computer to provide instantaneous information on carbon monoxide (CO) levels. The CO analyzer, made by Mine Safety Appliances Co., samples the air at each monitoring station. The CO in the sample absorbs infrared energy thus reducing the radiation reaching a detector through the sample beam. The output of the detector is then proportional to the amount of air pollution. The signal from the IR carbon-monoxide analyzer is processed for telemetry and fed over telephone lines to the central station.

Martian Tape Recorder. (Top right) The two Mariner spacecraft slated to orbit Mars in 1970 will each carry one of these tape recorders. Similar units were installed in Mariners VI and VII which should have reached the red planet by the time this appears. The units are reel-to-reel recorders, using 8 tracks, and with the ability to record 180 million bits of TV and scientific data. Five of these small tape recorders are now being built by Lockheed Electronics under a $787,000 contract from the Jet Propulsion Laboratory.

Radome for Giant Jet. (Center) A technician is shown adjusting a nose radome for the Douglas DC-10 giant tri-jet transport. The big plane is scheduled to enter commercial service in 1971. It will carry up to 345 passengers. The reinforced plastic radome, almost 7 ft in diameter, houses a weather-radar antenna that will radiate a beam with 60 kW peak power to cover a 300 nautical mile range. The black neoprene covering protects the nose from erosion by rain and the weather. The dish at left is a transmitting antenna which serves as radar signal source during this testing procedure.

A 100-watt Hybrid Linear. (Below left) In a package not much more than an inch square is a new 100-watt hybrid linear power amplifier. The module contains 11 transistors, 8 diodes, 23 thick-film resistors, and 7 chip capacitors in two sections mounted on a single base plate. With an input of ½ V at 20,000 ohms, the plastic-encapsulated module can deliver a 100-watt output power with 7 amperes peak load current. Designed for such uses as servo amplifiers for motor controls or for high-fidelity audio amplifiers, the device will be available in sample quantities from RCA later this year. A unique load fault protection circuit is built into the module.

Modeling V.l.f. Antennas for Omega. (Below right) This technician is crouching down among the mountains of Trinidad —in model form. The model mountains, actually located at the Westinghouse Georesearch Laboratory in Boulder, Colo., are used to predict the performance of the very long valley-spanning antennas for the Navy's Project Omega. This is a worldwide navigation system using very-low-frequency radio signals. Antennas for these frequencies have to be so long and so high that mountain crests are sometimes used as supports. The model is made of wire mesh stretched over a wooden frame. A dugout beneath the model contains associated electronic testing equipment. Stretching across the valley from peaks on either side are wires of a working, scale-model radio transmitting antenna. A full-size version of the antenna would span a distance of well over a mile. This program has been undertaken to help the Navy select sites for transmitting antennas used for Omega, which is scheduled for full operation in several years.



Automatic Tint Control for COLOR-TV

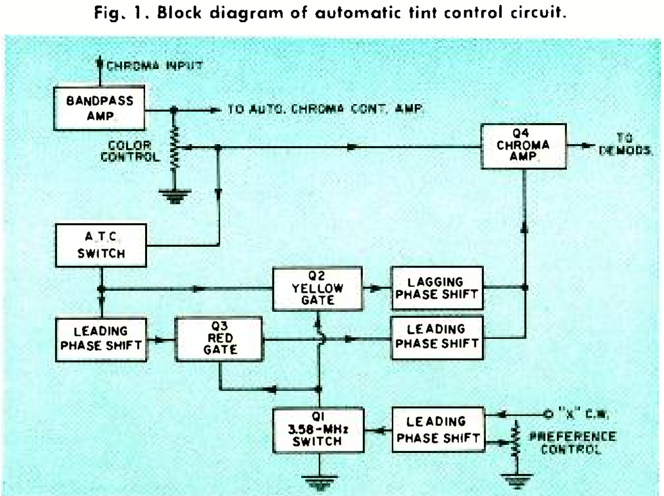
By MILTON S. SNITZER / Technical Editor

Here are details on a new Magnavox circuit that does a good job of minimizing green faces and purple people during color programs.

A properly adjusted color-TV receiver is a joy to behold. But when people's faces turn sickly green or garish purple, the owner of an expensive color set begins to have doubts about his receiver's performance. In a good many cases, however, the fault is not with the receiver but with the transmitting station. The user can tell that the station is at fault if he can get good colors and the proper flesh tones much of the time. True he may have to keep his Color control down a bit so that his colors are not overbright, unnatural, and garish. And he may have to adjust his Tint or Hue control carefully so that skin colors are natural—slightly pink or tan—and not green or purple. After these adjustments are made, the user has every right to expect the colors to stay that way. But let a commercial come on, or let the program director switch cameras (for a closeup, for example), and sometimes the people look as though they came from another planet—with greenish or magenta or purple faces. A new automatic tint control (a.t.c.) circuit in the Fall 1969 *Magnavox* top-of-the-line color sets just introduced does a good job of keeping the flesh tones the proper hue at all times. Hence, the user need not keep readjusting his Tint control every time he changes channels, or when commercials or films come on, or when camera changes take place during a program.

The reason for the hue change is slight changes in phase of the chroma signal as transmitted by the color station. It doesn't take too many degrees of phase change to alter a hue from yellow-orange to red or magenta or to a greenish-yellow. And since flesh tones are familiar to viewers and are used as a reference in setting up their tint or hue controls in the first place, viewers are very sensitive to slight hue changes affecting skin colors. If detergent boxes are not quite the right shade of red or if the sky is not quite the right shade of blue, people are not bothered too much. But everyone can easily recognize green faces and purple people as not being quite right.

Fig. 1. Block diagram of automatic tint control circuit.



Transmitting stations are hard at work to minimize the hue changes that occur when switching cameras or when going to film or video tape. But it requires experienced, careful technicians with a very good color sense to set up all the cameras just exactly right and to make sure that film and video-tape units produce precise skin colors even though the original colors on the film or tape may not be quite proper. At best it's a subjective judgement that must be made by studio technicians and often these adjustments must be made on the spur of the moment when the input signal source is switched during a program. TV stations with lots of experience in transmitting color are doing a pretty good job most of the time in keeping the colors correct during switching. But other stations, especially those newer to color, are transmitting unnatural or incorrect colors at least some of the time.

The New Magnavox Circuit

When we saw the new *Magnavox* a.t.c. in operation, we were quite impressed. We were able to make a direct side-by-side comparison with *Magnavox* receivers without the new circuit, and the difference in flesh tones was quite obvious. The set with the a.t.c. maintained good skin colors consistently while the other receiver showing annoying differences in color. We then switched the automatic tint control "off" and "on" and the extent of the correction was quite obvious. The circuit is able to correct phase errors of up to ±30 degrees of the proper flesh hue. Even without making an A-B test, the constancy of the skin colors was very pleasing with the circuit switched on. No doubt other set manufacturers are working on their own a.t.c. circuits, but the *Magnavox* circuit is the first we know of in actual production receivers.

The receiver with a.t.c. has a three-position front-panel switch marked "Off," "Partial," and "Full" correction, along with a rear-panel control marked "Preference." The user simply switches the a.t.c. to Full and adjusts the Preference control for the shade of flesh tones he prefers. (Most viewers in California, for example, like to see their people a little more suntanned than viewers in New York.) Then the automatic circuit will operate to keep the flesh tones at the preferred setting at all times.

The company recommends that the a.t.c. switch be left in the Partial position for normal viewing. The circuit is still effective over the same ±30 degrees of phase except that the correction voltage produced is about half as large. This prevents too much color compression around the yellow, orange,

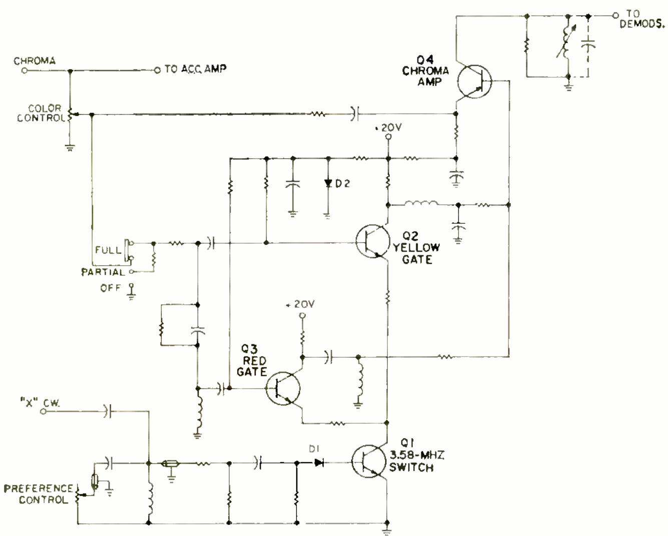


Fig. 2. Schematic of a.t.c. circuit showing two gating and one switching transistor which alter the phase of the chroma signal by applying a correction signal to the base of the Q4 chroma amplifier. The uncorrected chroma signal is applied to the emitter of this transistor, whose output is the vector sum of these two signals. The various LC circuits are for phase-shifting. Diode D1 allows switching transistor Q1 to conduct only during the positive peaks of the c.w. signal, while D2 clamps the base bias voltage of Q2 and Q3 to 0.6 V above ground. This assures that the positive portions of the low-level chroma signals forward-bias the gates during sample time. D.c. voltage for the circuit is derived from cathode of vertical-output tube via resistor and zener (not shown).

and red phases that might reduce the proper color range to be reproduced at these hues. Colors that are more than 30 degrees from orange (which is 57 degrees from burst) are not affected at all by the a.t.c. circuit. This means that most of the pure magentas, blues, cyans, and pure greens are not altered in any way.

The circuit itself consists of four transistors, a pair of diodes, and various *R*, *C*, and *L* components all mounted on a small printed-circuit board in a metal box attached to the tuner mounting assembly. The circuit is located between the bandpass amplifier and the color demodulators (Figs. 1 and 2). The chroma signal, before being demodulated, is a 3.58-MHz sine wave whose amplitude and phase vary in accordance with the saturation and hue of the transmitted scene. This signal is applied to the chroma amplifier. Also applied to this amplifier is a 3.58-MHz correction signal from the a.t.c. circuit. The total output to the demodulators is then the result of the two inputs and is phase-corrected for variations in flesh tones.

In order to make sure that only those hues that influence flesh tones are altered, a pair of gating transistors are used in conjunction with a 3.58-MHz switch. Phase-shifting circuits are used to make sure that gating occurs at exactly the proper phase of the chroma signal. The gates are turned "on" and "off" by the switch which, in turn, is turned "on" and "off" by a phase-shifted X-axis c.w. signal. A yellow chroma signal produces maximum output from the yellow gate and low output from the red gate. A red chroma signal produces maximum output from the red gate and low output from the yellow gate.

The output signal from the yellow gate passes through a phase-shifting network and is applied to the chroma amplifier to correct flesh tones which appear yellowish or greenish. The output from the red gate is phase-shifted in the opposite direction and applied to the chroma amplifier to correct flesh tones which appear reddish or magenta. When the skin colors are correct, the correction signals from both the yellow and red gates are equal and opposite and cancel each other. Therefore, the chroma signal passes through the chroma amplifier unchanged.

The "on" times for the gates are very short since the switch conducts only on the positive peaks of the c.w. signal. When this occurs, both gates are turned on by completing the emitter circuits of Q2 and Q3 through the now conducting switch Q1. While the gates are turned on, the chroma signals applied to the bases of the two gating transistors must also be positive to produce an output from the collector circuits. Chroma signals that affect flesh tones (between yellow and magenta) are positive-going during sample times and hence correction signals are produced. On the other hand, blue, cyan, and green chroma signals are negative-going at this time, so no correction signal is produced for these colors.

Vectorscope Displays

In order to see the effects of the a.t.c. circuit on the output of the color demodulators, a vectorscope display is useful. In this display, the R-Y output of the color set is applied to the vertical-deflection plates of a CRT and the B-Y output is applied to the horizontal-deflection plates. With a color-bar generator applied to the receiver, the usual flower-petal display shown in Fig. 3 appears. Each of the ten petals (plus color-burst petal) corresponds to one of the color bars that appear on the screen of the picture tube of the color set. Note particularly the appearance of the first three bars between zero and 90 degrees on the scope. These are yellow, orange, and red.

Fig. 4 shows what happens with the a.t.c. circuit switched on for full correction. Note how the first three petals have been squeezed together. What happens is that if the flesh tones become yellowish or greenish, the circuit rotates the vector clockwise back toward 57 degrees, which is the proper location for the flesh-tone signals. If the flesh tones become reddish, the circuit rotates the vector counterclockwise back toward 57 degrees.

When partial correction is used, (*Continued on page* 78)

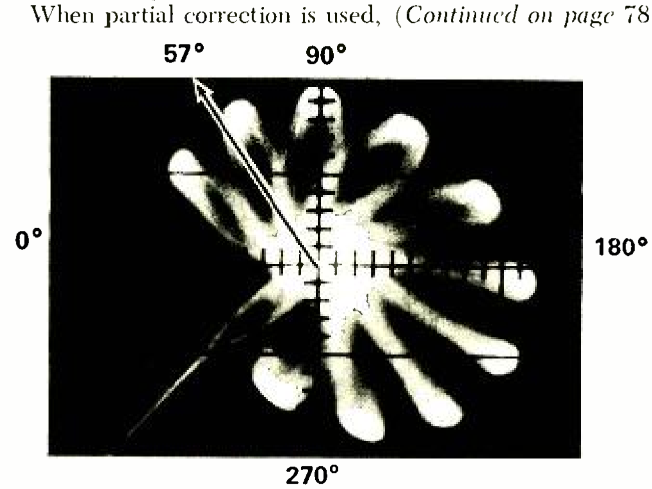
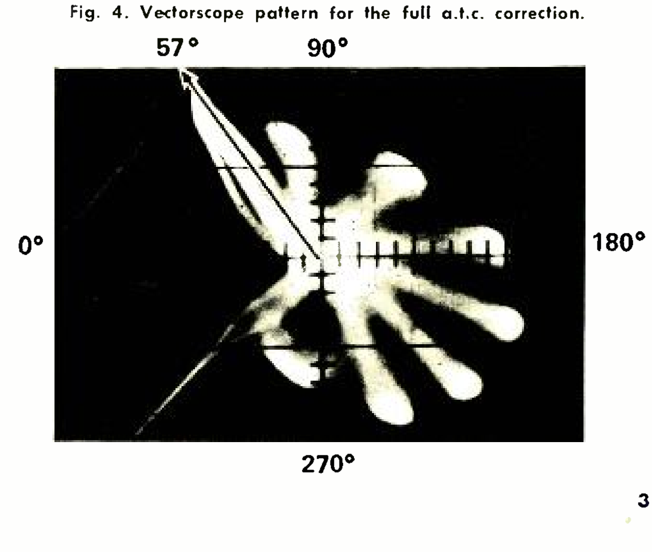


Fig. 3. Vectorscope pattern for normal color-bar display.

Fig. 4. Vectorscope pattern for the full a.t.c. correction.



New Developments in Public-Address Systems

Examples of p.a. amplifiers: (left) Bell Mod-45, (center) Bogen MTX-30B, and (right) University UPL-60T.

By ALFRED ZUCKERMAN / Benjamin Electronic Sound Corp.
Division of Instrument Systems Corp.

Part 1 of a series on modern p.a. sound-system practices focuses on amplifiers, solid-state circuits, and features that are important for best p.a. performance.

THE audio electronics technician frequently finds himself with the responsibility of specifying a public-address system and then installing it. While improvements have been made in microphones and loudspeakers in recent years, their impact has not been as great as the emergence of the transistor p.a. amplifier. Once the technician has made the usual determination regarding power requirements, microphone locations, speaker types, and distribution, he is then faced with the decision . . . shall it be a vacuum-tube amplifier or a transistor type? The decision must not be made only on relative costs, but on factors of performance, features, reliability, and flexibility as well.

Table 1. Various transistor input circuits and characteristics.

INPUT IMPEDANCE	CIRCUIT	USED WITH	RELATIVE COST
100,000 ohms, unbalanced	Common emitter	High-imp. mics, limited low-freq. response	Lowest
500,000 ohms, unbalanced	Common emitter with bootstrap or FET	High-imp. mics, good low-freq. response	Low
Approx. 600 ohms, unbalanced	Common base	Low-imp. mic. at intermediate distances	High
200 or 600 ohms, balanced	Matching transformer into common emitter	Low-imp. mics at great distances with max. immunity from noise & r.f. pickup	Highest

At present, vacuum-tube p.a. amplifiers cost about 25% less than transistor amplifiers. This may account for the fact that the tube amplifier outsells the transistor product by about three to one.

Comparative Characteristics

On the basis of equal expected performance, the transistor amplifier has the following desirable characteristics:

1. Indefinitely long life of the active devices (the transistors).
2. Lower power consumption. In addition, the transistor amplifier is more efficient than the tube amplifier in terms of d.c. power utilization. Because there is less heat generated within the unit, components such as capacitors and resistors are not as severely stressed.
3. Transistors are able to operate more efficiently at lower voltages than tubes. Thus the transistor amplifier may be designed to operate directly from low-voltage d.c. sources such as vehicle batteries.
4. Due to the absence of structurally supported elements within the transistor, it is almost completely devoid of microphonic spurious signals generated within its active elements due to shock or vibration. This characteristic also makes it ideal for mobile use.
5. Audio power is almost instantly available at the throw of a switch, and the system draws power only when in its activated state.
6. Because the transistor amplifier has no cathodes to heat up, a source of a.c. hum at the input and preamplifier stages is eliminated.
7. The transistor is better suited to drive low-impedance loads such as the voice coil of an 8- or 16-ohm loudspeaker.

The tube amplifier does not necessarily come off second best as far as its public-address application is concerned. In its favor are these considerations:

1. Lower initial cost.
2. In the event of the failure of a tube, the amplifier service may be restored almost immediately. Replacement of transistors is usually a more laborious job.
3. The tube amplifier is less susceptible to the catastrophic type of failure that sometimes occurs in transistor amplifiers.
4. The tube amplifier is considerably easier to service on the bench than the transistor amplifier.
5. Despite the fact that the tube amplifier runs hotter than a transistor amplifier of the same output power rating, the tube amplifier is less affected by installations where the ambient temperature is high.

Transistor Input Stages

In the case of tube p.a. amplifiers one has two choices with regard to microphone(s) and input impedances—a high-impedance (usually low-cost) system or a low-impedance (usually high-cost) system.

If the microphone is to be located near the amplifier, the most economical system employs a high-impedance microphone into a high impedance input. The least expensive high-impedance microphone is the crystal or ceramic type which requires a very high impedance load for good low-frequency response. This load (around 500,000 ohms) is available in the tube amplifier by connecting directly into the preamplifier stage grid circuit. If the microphone is to be located some distance from the amplifier, the cost runs higher for two reasons. Low-impedance microphones are generally of the moving-coil variety and require a built-in transformer to provide a 200- or 600-ohm output, optimum for the lowest induced noise in the microphone line. In order to properly couple a low-impedance microphone to the preamplifier input grid, a matching step-up transformer is employed.

In the transistor amplifier a number of input conditions can be obtained, as shown in Table 1.

The type of amplifier will determine, to a great extent, the future integration of modules that may be plugged into the basic amplifier to expand its versatility. Many manufacturers provide such "plug-in" accessories to permit more flexible operation from a basic economy amplifier.

One of the basic plug-in modules is the microphone matching transformer. It is usually designed to plug directly into sockets provided on the chassis. This type of design flexibility permits low-to-high impedance matching while maintaining line balance to ground for minimum noise pickup.

Input volume control from distances as great as 2000 feet is made possible by the use of a plug-in light-sensitive module. The remote station does not control audio volume directly; it simply controls the level of direct current flowing to a lamp in a light-tight enclosure. Within this enclosure is a light-dependent resistor which is tied into the amplifier signal path. The resultant brightness of the lamp in the module changes the resistance of the LDR which acts as a volume control. Despite the fact that the control station is so far away, there is absolutely no extraneous noise pickup as there is complete electrical isolation of the audio signal controlled from the control line. Use of this device permits the operator of the p.a. system to be located with the audience so that he can better judge the proper sound levels that are required.

In some input designs built around expandability, manufacturers have provided both space and receptacles for optional two-channel microphone preamplifiers. It is interesting to note that most of such design features are at the input end of the amplifier, for this is the area of greatest complexity as far as added facilities are concerned.

An example of a group of amplifiers using modular construction to permit up to six additional plug-in input modules is the *Bell P/A Mod Series*. Of particular interest are the microphone input modules using FET's to achieve 1-megohm input impedances. The low-impedance module uses a matching transformer with an electrostatic shield operating into an FET, simulating tube operation. Another interesting use of FET's to achieve results not ordinarily obtainable with other devices is a plug-in volume-limiting module which utilizes, in addition to the FET, an IC operational amplifier.

As with tube amplifiers, it is usual practice to provide high-gain microphone preamplifier stages in order to main-

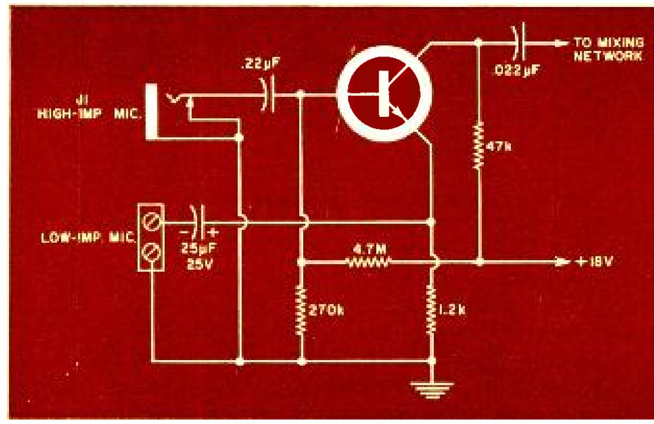


Fig. 1. Multi-impedance microphone preamplifier stage.

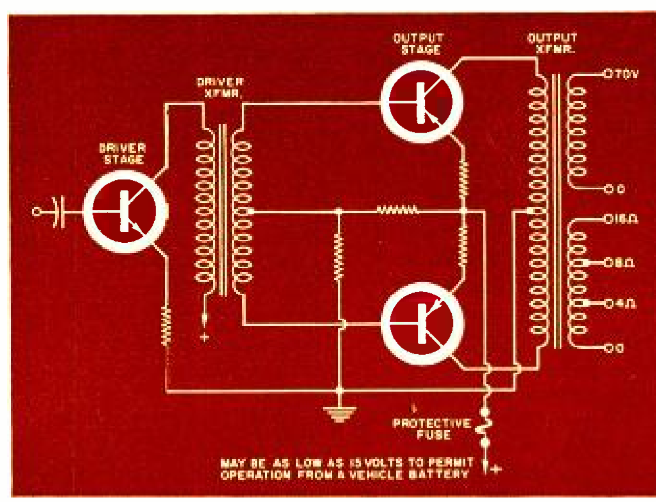
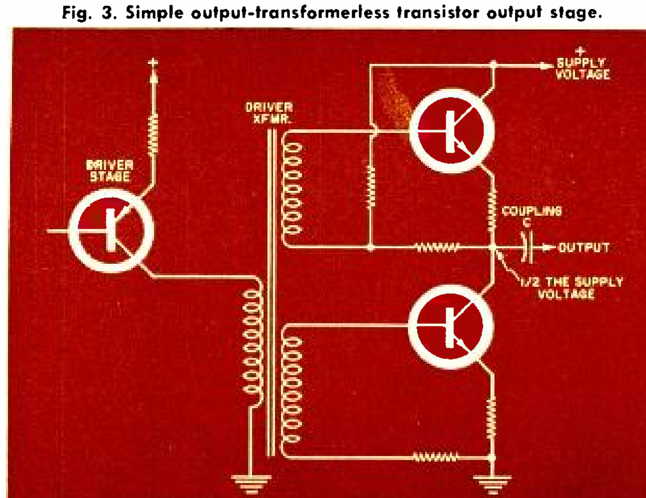


Fig. 2. Basic transistor output stages using two transformers.

Fig. 3. Simple output-transformerless transistor output stage.



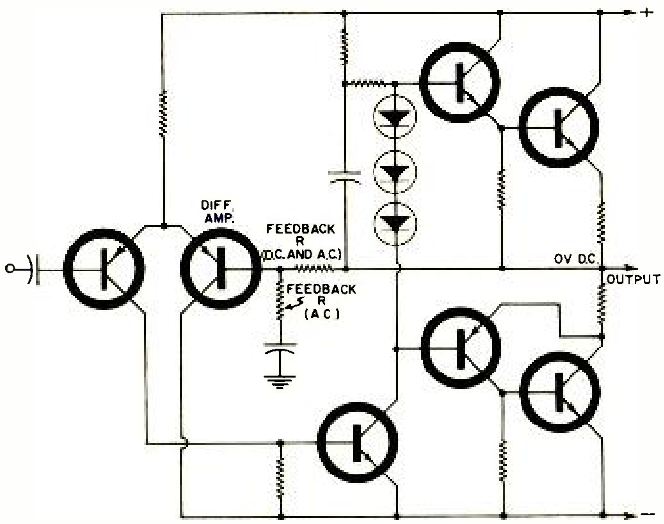


Fig. 4. Output stage that is completely transformerless.

tain a good signal-to-noise ratio by mixing the several inputs at some intermediate level. The proper input impedance is important, not only because of the profound affect it has on microphone performance, but because the relationship of the input impedance (and how it is achieved) to the microphone impedance influences the input signal-to-noise ratio.

The advent of the transistor freed circuits from hum pickup in the input stage. There is still present the "shot" noise effect which requires careful selection of transistor type and proper design of the input stage with regard to collector current in order to eliminate it.

Another factor is the necessity for a wide dynamic range. The input stage must be able to handle a wide range of signal levels without clipping or adding distortion at high levels, or allowing the introduction of spurious noise at low levels. By using a sufficiently high collector supply voltage, large signals can be handled without overload. The effect is that the dynamic range the stage is required to handle will dip down less into the noise level than would be the case if the overload point were lower.

In some amplifiers the 600-ohm and 100,000-ohm unbalanced input impedances are achieved by a simple technique which automatically selects the appropriate impedance, depending on which type of microphone is connected. This is illustrated in Fig. 1 which shows the microphone input stage that is utilized in the *Bogen* CHS-35 p.a. amplifier.

When a high-impedance microphone is employed, it is plugged into *J*1. The stage then operates as a common-emitter amplifier which has a medium input impedance. The emitter resistor is not bypassed. The resulting current feedback helps to raise the input impedance to about 100,000 ohms. If it is desired to operate from a low-impedance (600-ohm) microphone, connection is made instead to the terminal strip. In this mode of operation the base is effectively grounded at signal frequencies by the 0.22-μF capacitor. The signal is fed into the emitter of what has become a common-base amplifier which has low input impedance with high power gain.

The current trend toward lower prices of junction field-effect transistors will be reflected in their increased use in future designs of input and intermediate stages of public-address amplifiers. The use of FET's provides stage input impedances comparable to those of vacuum tubes and will result in designs which are direct analogs of tube designs in terms of input impedance, mixing networks, and tone controls. Since some FET's have better noise characteristics at low frequencies than transistors and are immune to the noise problems of tubes, it is possible to obtain very good input-stage characteristics by using them.

Transistor Output Stages

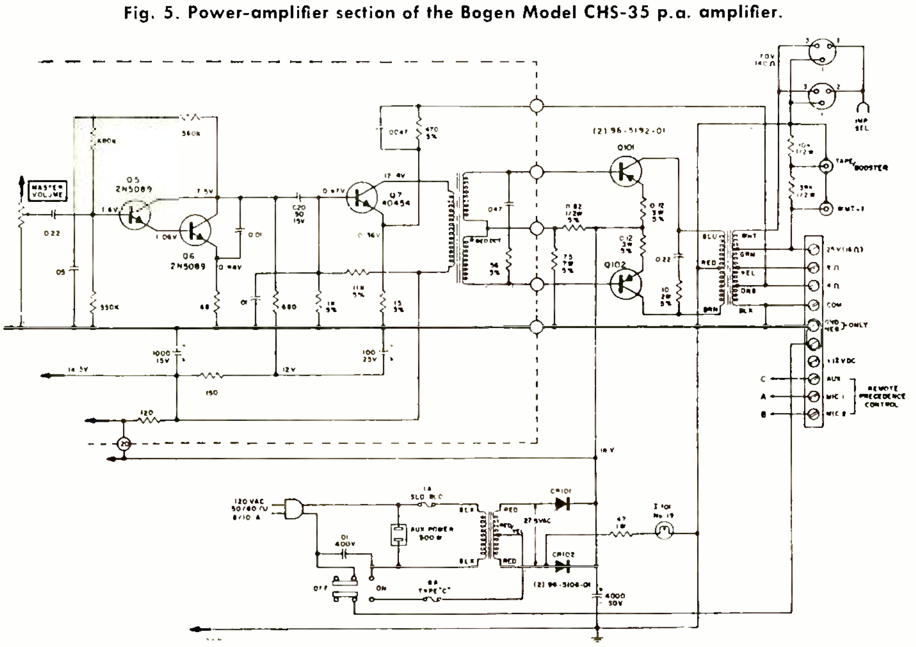
The vacuum-tube amplifiers used today are essentially the same as those used for over thirty years. Transistor amplifiers, on the other hand, are available from different manufacturers in a variety of output-stage circuits. Why is this so?

The earliest transistor amplifiers were analogous to the tube amplifiers in that the transistors were substituted for tubes while retaining the output (and in some cases the driver) transformer. It is interesting to note that most of the transistor amplifiers sold today are still of this type. Fig. 2 shows the basic output stage. The output transformer is essential to the operation of this circuit but imposes a restriction on the output bandwidth of the amplifier. In practice, however, with the exception of those few installations where large amounts of bass power are required, the performance of the amplifier is completely acceptable and is, in fact, better than the performance of most speakers used in distribution systems.

Impetus was given to the development of improved transistor output circuitry by the demands of the hi-fi field. In order to improve the operation with a single speaker, designers took advantage of the inherent low-impedance characteristics of the transistor to develop a practical output-transformerless output stage.

In Fig. 3, even though the transistors are operated in series directly into the low-impedance load without an intervening transformer, phase inversion and input drive are accomplished through the use of a dual-secondary driver transformer. The upper section acts as an emitter-follower into the load on the half cycle that the upper base is driven positive. Current flows from the supply through the capacitor and through the load. On the alternate half cycles the lower section is driven into conduction and the energy stored in the capacitor drives current through the stage half and the load in series. The use of a driver transformer imposes a restriction on the power bandwidth of the stage, but reasonably good results can be obtained with a carefully designed transformer using inexpensive materials.

Fig. 5. Power-amplifier section of the Bogen Model CHS-35 p.a. amplifier.



A more recent development in the field of output-transformerless stages is the circuit shown in Fig. 4. The output transistors are in series, as in the previous circuit, but the power supply consists of both a negative and positive supply in series with a common ground. As a result, the d.c. voltage at the junction of the output transistor circuit is at ground potential, eliminating the need for the output coupling capacitor used in the previous amplifier. Because of the large degree of d.c. inverse feedback used, this point is maintained within a few millivolts of zero voltage over a wide range of temperature and line voltage so that under normal circumstances no more than a few insignificant milliamps of current would flow through the speakers.

Phase inversion is obtained by using a complementary *n-p-n/p-n-p* pair of driver transistors. For signal purposes, the bases of these two drivers are essentially tied together (by the bias diodes) and driven by the pre-driver which, in conjunction with the resistor-capacitor network in the base circuit of the upper section, is able to swing these bases through the wide range of voltage necessary for full output. The differential amplifier provides a convenient means of obtaining separate isolated control points for the input signal and the a.c. and d.c. feedback voltages.

Protective Circuits

If a class-AB tube amplifier were operated into a short-circuited load, either the primary fuse would blow or, more likely, the output tubes would operate beyond rated dissipation and the plates would glow red. Even operation over extended periods would only result in some gas evolving from the plates to the hardly perceptible detriment in operation after the fault was cleared.

Transistors, unfortunately, cannot be abused this way. If the junction temperature exceeds a precisely defined point, the device is ruined catastrophically. Protection must be provided to prevent this if a short circuit develops. There are two schools of thought as to how best to accomplish this type of protection.

One group contends that if a fast-acting fuse or circuit breaker is used, it will open up and protect the transistors before the junction temperature rises to a damaging level. The reason this is possible is that the rugged, relatively "slow" (having poor high-frequency gain) transistors usually used in the center-tapped transformer circuit, when effectively coupled to massive heat sinks, have a thermal ballistic characteristic that is long enough to permit the fuse to open before enough energy is pumped into the transistor to raise the junction temperature to an unsafe level when a short occurs in the load.

The other group, in order to achieve better high-frequency power output, utilizes "faster" transistors which use smaller chips and do not have as favorable a thermal configuration and therefore require faster-acting protection. In general, a fuse is not fast enough to provide the needed protection. Instead, a circuit which causes the high output current under short-circuit conditions to activate fast-acting solid-state switches is used to cut the drive signal instantly. These protective devices will be dealt with later in this article.

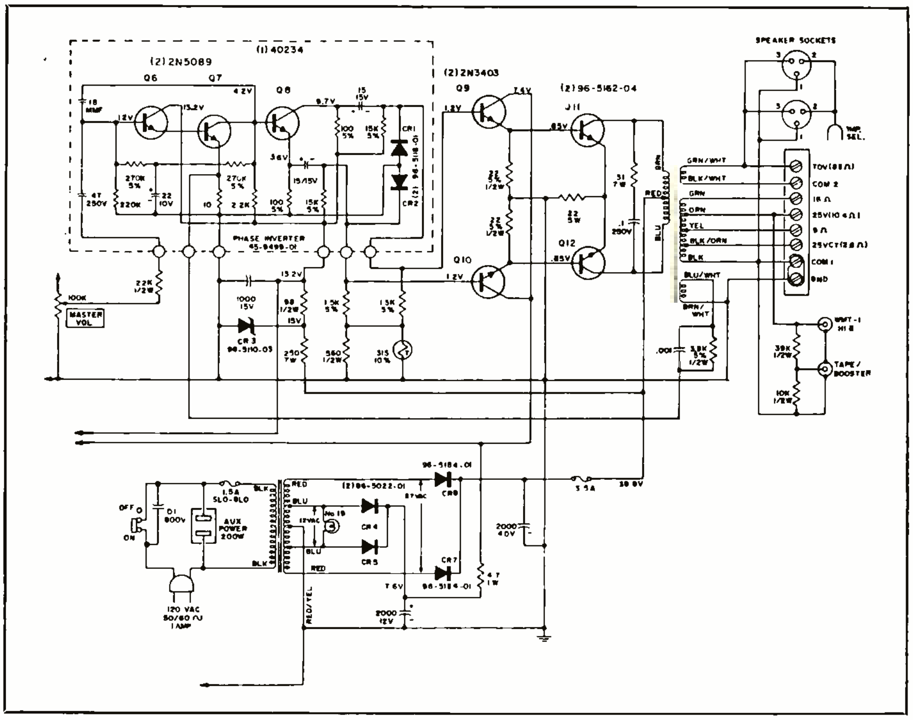


Fig. 6. The power-amplifier section of the Bogen Model MTA-60 p.a. amplifier.

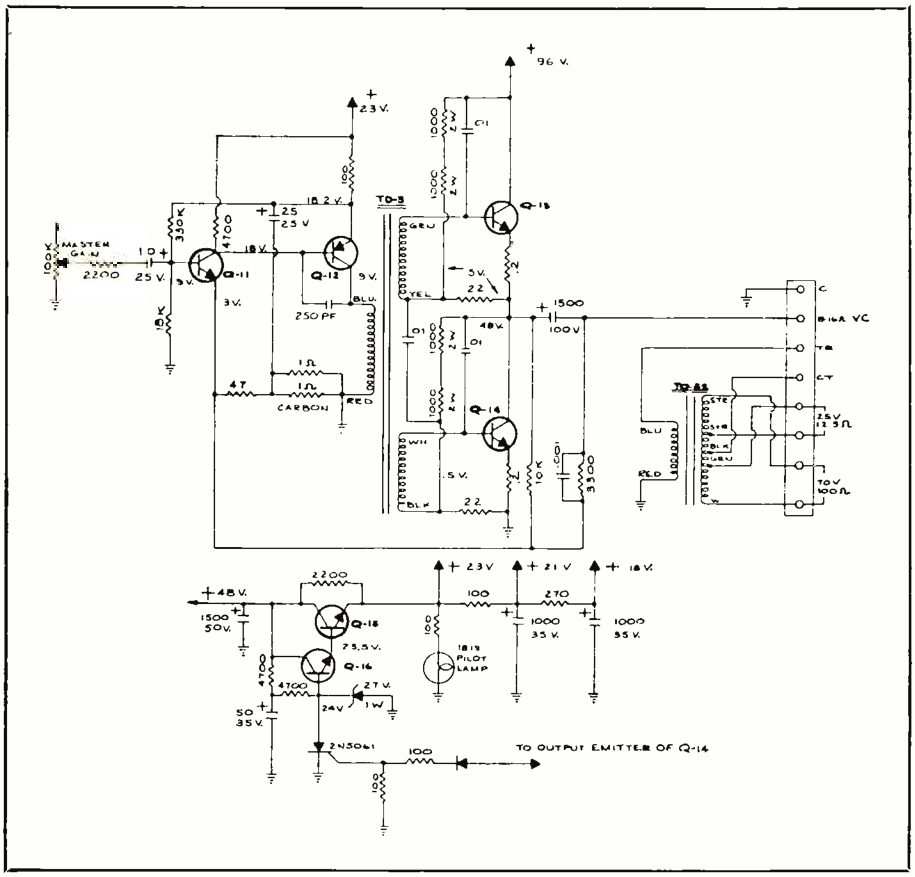


Fig. 7. Power-amplifier portion of the Grommes-Precision Model G-76 amplifier.

The center-tapped transformer-terminated output stage selected for analysis first is that used in the *Bogen* Model CHS-35, a 35-watt p.a. amplifier (Fig. 5).

To achieve high efficiency the output stage is operated in class AB with only a small amount of forward bias to eliminate crossover distortion. This bias is derived from a series resistive network across the d.c. supply. The low voltage at the junction of these two resistors is applied to both bases of Q101 *and* Q102 by feeding it into the center tap of the driver transformer secondary. Thermal stability is accomplished by the use of emitter resistors as well as the low d.c. resistance between the base and emitter of the output transistors afforded by the driver transformer's secondary winding.

The output transistors, germanium *p-n-p* devices, are operated into a center-tapped output transformer which reflects the proper low impedance from the load circuit. The output transformer secondary windings provide 4-, 8-, and 16-ohm output impedance taps as well as a 25- and 70-volt output taps. This array of impedance and voltages makes for a flexible, easy-to-use load arrangement.

Since a short circuit in the load network causes a rise in collector current of only the two output transistors, Q101 and Q102, and since these devices are rugged units, it is possible to protect them from destructively high temperatures under abnormal loads by simply fusing the d.c. supply lead with a 6-ampere fast-acting fuse. Since the built-in power supply delivers only 18 volts d.c., it is possible to operate the amplifier from a 12- to 15-volt vehicle battery system by a simple reconnection at the terminal strip.

The output transformer is essential to the operation of the amplifier and is utilized for all of the output taps. Unless somewhat more costly output and driver transformers are used, the frequency response, and particularly the low-frequency power capability, is limited. Similarly, the combined phase shifts of the two transformers limit the amount of stable inverse feedback that can be applied to reduce distortion and to flatten frequency response. Despite these limitations, this type of amplifier is widely used and has a history of providing satisfactory, reliable service.

A variation of this configuration substitutes a split-load phase inverter and additional directly coupled power gain in the form of a Darlington configuration (Q9 and Q11 as well as Q10 and Q12) for the driver transformer (Fig. 6). This circuit is exemplified by the *Bogen* Model MTA-60, a 60-watt amplifier. Elimination of the driver transformer permits more inverse feedback, resulting in better frequency response and lower distortion.

Other Circuit Examples

The *Grommes-Precision* Model G-76, a 50-watt p.a. amplifier (Fig. 7) is an example of a transformer-driven, series-output stage. Two class-AB-operated *n-p-n* transistors, Q13 and Q14, are connected in series from the d.c. supply to ground. The junction of the two is connected to the load through a 1500-μF capacitor. The individual secondary windings of the driver transformer are connected between the base and emitter of each output transistor in such a phase relationship that Q13 conducts current from the supply to the load for one half of the drive cycle and Q14 conducts current from the charged coupling capacitor to ground through the load on the other half of the drive cycle. The combined current through the load is a replica of the signal voltage across the primary of the driver transformer.

Forward bias is obtained by returning the driver-transformer secondaries to the junctions of the 1000-ohm and 22-ohm resistors in each half of the stage. Inverse feedback is taken back to the emitter of Q11 from two points, before and after the output coupling capacitor. If the full amount of feedback were taken after the capacitor, the phase shift at low frequencies would cause instability.

Operation into a low-impedance load of from 4 to 16 ohms is possible with maximum fidelity characteristics by direct connection to the amplifier output only. The frequency at which output power would be halved by the output capacitor is 30 Hz for a 4-ohm load. For operation into other impedances (25- and 70-volt constant-voltage lines), the autotransformer is connected to the output. This results in some deterioration of response and power bandwidth as compared to the direct connection but is a moderate compromise to make in order to achieve the flexibility of a multi-impedance output.

Output transistor protection is provided by a fast-acting latching circuit using a silicon controlled rectifier. When an abnormal load condition causes the emitter current of Q14 to rise to a high value, the drop across the 0.2-ohm emitter resistor drives current through the diode and the two 100-ohm voltage-divider resistors. The junction of these resistors drives the gate of an SCR, which is normally in a non-conducting condition. Whenever the voltage at the gate exceeds a critical "trigger" voltage (on the order of ½ volt) the SCR is turned on. The current which otherwise flowed through the zener diode to maintain its voltage at 27 volts is then diverted through the SCR with the result that the voltage at the input base of the Darlington pair, used as the series regulator for all of the stages before the power stage, is rapidly lowered to about 2 volts. This, in effect, cuts off the d.c. voltage to the driver stage, which has no storage capacitor in the supply circuit, in about 100 microseconds. Switching off the drive to the output stage, this rapidly prevents excessive current from raising the junction temperature to damaging levels. Since an SCR, once in the conducting mode, cannot be turned off except by reducing the current through it to zero, the system is restored to operation after the fault is cleared by turning the power switch "off" for about 5 seconds and then "on" again.

The quasi-complementary, (*Continued on page* 75)

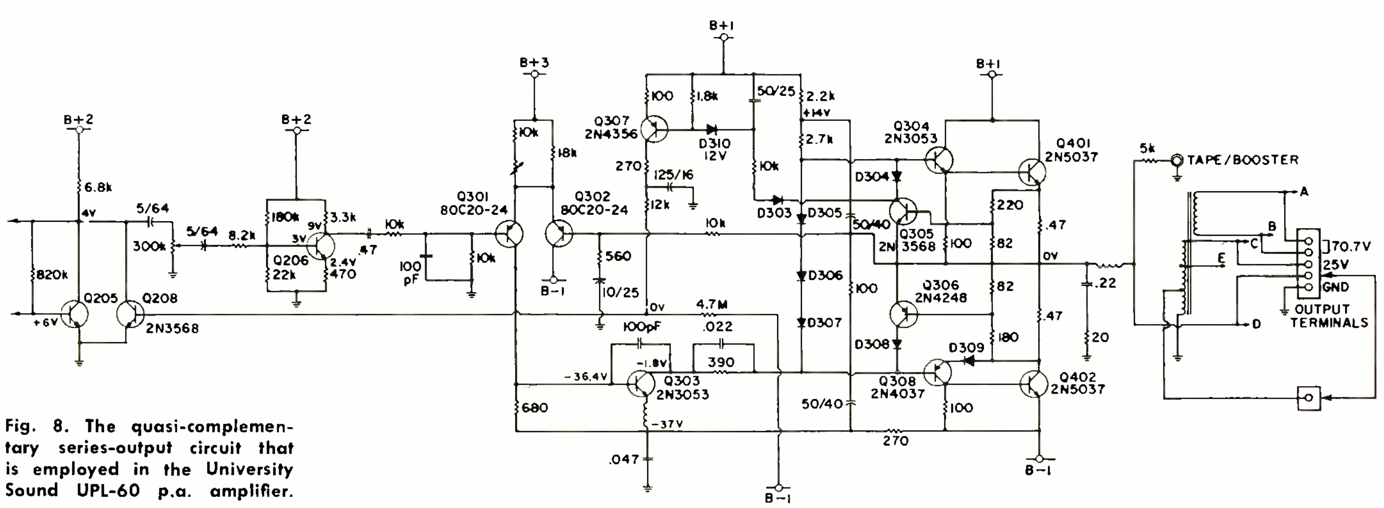


Fig. 8. The quasi-complementary series-output circuit that is employed in the University Sound UPL-60 p.a. amplifier.

The SOLID-STATE INDUCTOR

By DAVID L. HEISERMAN

By combining the Hall effect with integrated circuit technology, a solid-state device with inductive reactance has made its appearance.

CONVENTIONAL thinking about inductors seems to rule out any possibility of developing solid-state versions of inductive devices. Dr. S. Kataoka and his co-workers at the *Tanashi Electrotechnical Laboratory* in Tokyo, however, departed from conventional thinking recently and produced what may be the first practical approach to truly solid-state inductors.

Semiconductor Hall-effect devices have been playing an increasingly important role in electronics technology for over a decade. Dr. Kataoka and his staff took advantage of some little-used Hall-effect phenomena to develop their new device.

The Hall Effect

Fig. 1 shows the basic experimental arrangement for demonstrating the Hall effect. A current, I_i, from a constant-current source passes lengthwise through a thin slice of semiconductor material such as indium antimonide (*InSb*). A magnetic field, *B*, at right angles to the input current bends the current carriers toward one edge of the Hall device. With an excess of charge carriers thus gathering on one edge, a potential difference, V_h, develops between the edges. This potential is the Hall voltage, and is given by the equation: $V_h = KI_iB \sin \theta$; where *K* is the Hall constant, and θ is the angle between the input current and the magnetic field. The Hall constant depends upon the density and mobility of the current carriers, and the thickness of the Hall device. If the magnetic field is fixed and at right-angles to the input current, the Hall output voltage is proportional to the input current. Likewise, holding the input current constant and changing the strength of the magnetic field varies the Hall output voltage accordingly. The latter effect is employed in the design of Hall-effect gaussmeters.

Fig. 2 shows the equivalent circuit for a Hall device with a very large impedance connected across the output terminals. The input impedance of a Hall device with a large output load can be approximated by the simple relationship: $Z_i + R1$. Used in this way, the input impedance of the Hall device is simply the inherent longitudinal resistance of the Hall material. Most present-day Hall devices are used in this mode.

Short-circuiting the output terminals or making the load impedance very low, however, produces quite a different input impedance (Fig. 3). Making Z_e very small makes the input impedance approximate: $Z_i = R1 + K^2B^2/R2$. With the Hall output terminals short-circuited, then, the input impedance rises and responds to the square of the magnetic field strength. Such a device is used as a magnetoresistance—an effect just now becoming popular in research and development laboratories.

Hall Devices with A. C. Inputs

Fig. 4A shows the phase relationships between *I1*, V_h, *I2*, and *V1* for a Hall device with a purely resistive load. Taking the constant-current input as a reference phase, the figure shows that V_h is in phase with *I1*. The Hall current developed by V_h is also in phase with the input as is the resulting voltage across the input terminals of the Hall device. Since the voltage across the device, *V1*, is in phase with the input current, the resistively loaded Hall device appears to be a purely resistive load to its associated current source.

If the external load is purely capacitive, on the other hand, the current through the external load will lead the Hall voltage by 90°. The result of this phase shift, as shown in Fig. 4B, is that the voltage across the input terminals leads the input current by 90°. Thus, with a capacitor across the output terminals, a Hall device appears inductive to the current source.

On the other hand, connecting an inductor across the output terminals, as shown in Fig. 4C, makes the Hall device appear capacitive to the input current source.

The Kataoka SSI

Once it was established that a (*Continued on page 66*)

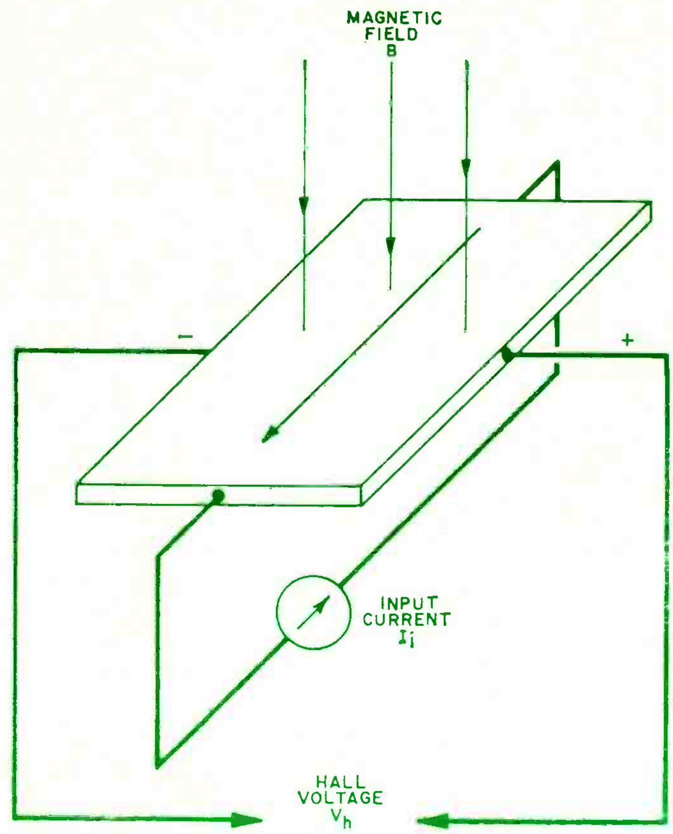
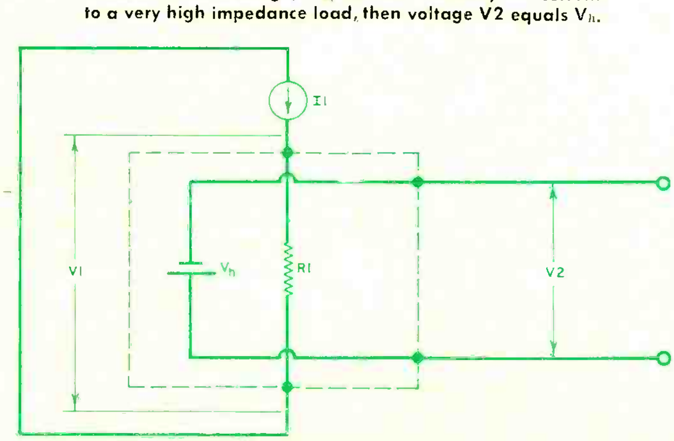


Fig. 1. Current flows lengthwise through a thin slice of semiconductor material. A magnetic field cuts the flow of current carriers at right angles and creates a Hall voltage along the edges of the semiconductor material as shown.

Fig. 2. Equivalent circuit of unloaded Hall device. In the case of a Hall-effect device with very large impedance (or open circuit) across output terminals, the longitudinal voltage across the Hall material, V1, is simply the input current times the intrinsic d. c. resistance of the material, R1. Since the Hall voltage, V_h, delivers virtually no current to a very high impedance load, then voltage V2 equals V_h.



Multichannel Recording for Creating the "NEW SOUND"

By RON WICKERSHAM/Engineer, Pacific Recording Studios

Some of the new groups are using 16-track recorders in their mastering sessions, which allows for more experimentation and greater flexibility. Here are some of the techniques being used by a major recording studio.

UNTIL recently, most rock music was recorded on 4- or 8-track master audio recorders using half-inch or one-inch-wide tape. With the availability of a 16-track machine, *Pacific Recording* decided to get one. We have been using the 16-track machine since last December in both studio and remote master recording sessions.

Today's "new sound" uses recording techniques vastly different from those used by master recording studios in the days of Glenn Miller and Tommy Dorsey. Since The Beatles began experimenting with multichannel recording in the early 1960's, popular rock groups have followed suit and the result is that most major recording studios have obtained, or are in the process of getting, recorders with at least 16-track capability.

Today, the recording room is no longer the heart of a recording studio. The control room is where the action is. Contemporary sounds are obtained through experimentation. Groups record feedback and the bloops and bleeps of life outside the studio in the hope of finding the right sound that they can ride to a hit tune. The control room is the "creation room" and recording a master tape is like making a layer cake. You record a layer of sound—the rhythm—on one track, the vocals on another layer, add instrument solos on another, and the chorus on still another layer. Up to 16 tracks can be used to make a single two-track stereo recording. After all the layers are recorded, group members and technicians gather in the control room for the mix-down session. Then the creative work begins. We vary the volume of different tracks to change the mood of the music. The sound that is first recorded is called "dry sound," which has no depth or echo. We add to this by reverberating (echoing) selected tracks to give a certain feel. The distinctive sound associated with many of today's groups is actually created more by the engineer than by the musicians. This is known as "composing" with a machine. This has been made possible by the availability of the 16-channel recorder which allows more time for experimentation and introspection—the main ingredients of increased quality.

However, the one drawback to this method of composing is that as emphasis is placed on recording techniques and electronic effects, many groups record way-out sounds that cannot be reproduced during a live performance. Consequently, their fans expect a certain "sound" which the group cannot deliver at a live concert or on television.

Multichannel Recording

The multichannel recording technique is the recording of each instrument, or group of instruments, vocals, and electronic effects, on separate channels located side-by-side on a wide (usually two-inch) tape. At the mix-down session, each channel of the master recording is equalized, positioned to the left or right, and balanced to make the stereo tape from which phonograph discs and tape copies will be made.

Jerry Garcia (center) and members of the "Grateful Dead" tune their instruments in preparation for a master "session" with the Ampex MM-1000-16 recorder/reproducer in background. This multitrack recorder allows groups to record a session on as many as 16 channels, including mixing, until they get just the right sound. Multitrack recording is meeting more demanding needs of today's "new-sound" groups.

Techniques that are impossible in direct recording, such as a vocalist singing along with himself (doubling), a musician playing two or more instruments, and adding parts involving performers who were not present at the original recording session, are routine with multitrack recordings. In addition, instruments which record poorly when played in concert with the loud electric instruments, are added later in a quiet studio. The performer wears headphones and keeps in time with the originally recorded music which is played from the sections corresponding to the tracks previously recorded. Thus perfect synchronization is assured.

Each channel is an original recording and not a second-generation dub as in the sound-on-sound technique, which results in a gradual deterioration in the quality of the original tracks as each new track is added. In multitrack recording, the normal reproduce head is used when listening to recorded takes since the highest quality reproduction is obtained this way.

With four-channel equipment there was little complaint in switching from the normal play to the sel-sync modes. But. as the number of channels increases, it becomes more difficult to operate the widely spaced controls on the individual electronic modules. The multichannel recorder incorporates a relay-operated sel-sync system to allow selection of the mode from a central control panel or from a remote location. A "Record/Non-Record" sel-sync lever switch and a "Master Play" sel-sync push-button switch are grouped at the right of the main control panel and duplicated at the remote-control position.

Typical operation is to select the channel(s) to be recorded and then operate the "Master" sel-sync push-button. The track is recorded and when the tape is rewound for listening, the "Master Play" button is depressed and the tape is monitored through the reproduce head. If it is decided to re-do the track, the "Master" sel-sync push-button is the only control which need be operated to record.

A bonus feature of the sel-sync control in the multichannel recorder is evident when it is necessary to re-record a portion of a track. For example, a vocalist may wish to re-record the second verse but keep the first verse already on the track. The channel is selected for record and the "Master" sel-sync push-button depressed, but only the "Play" mode is activated. The vocalist hears the first verse through the headphones and, at the appropriate time, the engineer pushes the "Record" button and the channel goes into "Record" for the second verse. Previously, three separate switches had to be operated which required some fancy fingering to get the job done if the timing were close.

With a relay-operated sel-sync system, the setup of the tape machine can be incorporated into the control console. and separate switches will not be required. Recording will then be a matter of assigning the desired microphone channel to the desired output channel and operating the "Record" button on the transport.

Early problems in multichannel recording were related to the tape transport. As the tape becomes wider (from ¼ inch to 2 inches), the problem of guiding it past the heads accurately and without damaging the edges of the tape becomes increasingly more difficult. Simply making the motor shafts longer and putting a wider headstack on a small machine is asking for trouble in the guiding department.

Disappointments in the operation of transports come from insufficient distance between guiding points and small rotating surfaces on the capstan which cause tape slippage and slow acceleration of the tape to the 15 in/s normally selected for master recording. The *Ampex* approach (the MM-1000-16, built around the *Ampex* two-inch video tape recorder transport and improved AG-440-type electronics modified for remote sel-sync operation), which was to select a large, proven, two-inch transport, appears to be a good one. In addition, the transport base is 4 inches thick and sturdy to ensure long-term mechanical alignment; the capstan is ¾ inch in diameter and accelerates the tape to 15 in/s in less than 0.5 second.

The tape timer is a useful device, also borrowed from the video-tape realm. It is highly accurate and reads the reel position in hours, minutes, and seconds directly at 15 in/s. Leadering the tape to locate the beginnings of songs is no longer required. Just place a piece of splicing tape near the beginning of a reel and each time the tape is loaded on the machine set the counter to zero and indicate on the take sheet the elapsed time to the selection.

The band-type brakes are released for tape threading by pulling the left-hand guide outward at about a 45° angle where a switch activates the brake solenoids. The arm is of the automatic shut-off type in case of tape runout or breakage. The reel idler is of the excellent fluid-damped type. The tape comes in front of the guide, between the play head and the capstan, and behind the guide ahead of the erase head. Improper threading will result in no erasure in one case or scratching the tape in the other.

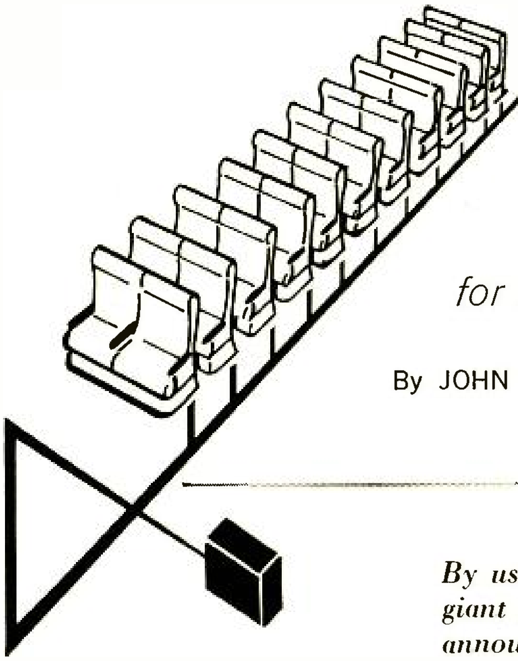
At the left of the control panel is the tape-speed indicator for 7½ or 15 in/s in the standard machine, with 15 and 30 in/s options available at extra cost. A "Remote/Local" switch assigns control and locks out the local or remote position not selected, preventing accidental operation. The tape lifters are automatic but can be manually overridden by a momentary contact switch to scan (listen to) the tape in fast reeling or to lift the tape from the heads in the "Play" or "Record" modes.

The tape motion is controlled in the center of the panel by push-buttons arranged in a "T" configuration. A motion sensor, located under the left-hand reel, allows pushing the "Play" button while in the fast mode. The tape is stopped and then automatically goes into "Play." The "Record" button is interlocked and requires simultaneous depression of "Record" and "Play," even if the machine is already in "Play."

One-Inch Tape

While the transport was designed for two-inch tape, provisions have been made for accommodating one-inch tape. One-inch rotary guides are located to the left of the reel idler, a one-inch head stack assembly is installed, and a one-inch guide controls the output of the tape timer. Unlike other transports accommodating two tape widths, the tape is raised to the center of the tape path by a ½-inch spacer which sets under and over each tape reel and guides are designed to place the tape in the center of the pinch roller. This avoids the skewing common to machines (*Continued on page* 77)

Author and guitarist Jerry Garcia listen to one of sixteen available tracks recorded on the multitrack recorder/reproducer, following a recording session of the "Grateful Dead." The recorder allows Garcia and other members of the group to record individually, and at different times, and later the tracks are mixed for the master tape. This technique permits a wide variety of special effects which identify the group.



Multiplexing Audio Entertainment *for the* Boeing Superjet

By JOHN W. PARTRIDGE/Vice President, ISC/Telephonics

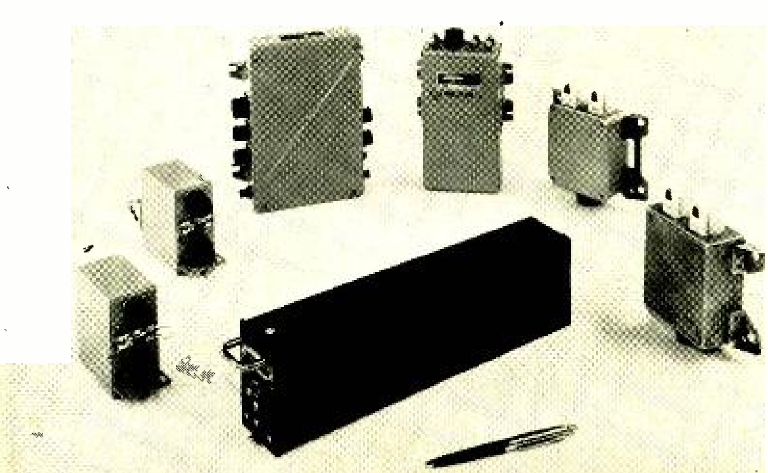
By use of time-division multiplexing, passengers in the new giant jet will be able to enjoy 14 channels of audio and one announcement channel, all carried to them over single coax.

TIME-DIVISION multiplexing makes it possible to transmit a number of different messages simultaneously over one wire. This is accomplished by the continuous sequential sampling of each message, sending the interleaved samples over a single coaxial wire to a receiving point, and reconstructing the samples into complete messages.

In today's ever-growing aviation industry, multiplexing can be used for any number of tasks. The *Boeing Company* is using a multiplexing system developed by *ISC/Telephonics*, a division of *Instrument Systems Corporation*, to provide passenger entertainment and service functions in its new 747 superjet. The system will reproduce high-quality music and audio information for the passengers without imposing the prohibitive weight and maintenance limitations that would normally occur in an aircraft that carries in excess of 360 passengers.

Using time-division multiplexing, the system transmits many channels of high-quality stereo sound and movie soundtrack to each passenger through the single wire. The systems on the 747 supply, to each seat, ten channels of music, four movie soundtracks, a passenger-announcement channel which overrides the entertainment selected, an attendant call capability, control of individual reading lamps, and the capability of expanding to additional control functions.

The seven units that make up the entertainment and passenger-service system are main multiplexer (center) and (clockwise from lower left) two types of seat electronic units, zone submultiplexer, column timer/decoder, and two overhead service units.



Similar systems are being proposed to *Lockheed* for the L-1011 Tristar jet, and to airlines for fleets in use today. Since the system features only the single coaxial wire and not large bundles of wire as in previous systems, extensive modification of the aircraft is unnecessary. Greater flexibility in seat configurations is also possible because the single wire can be run within the standard seat tracks.

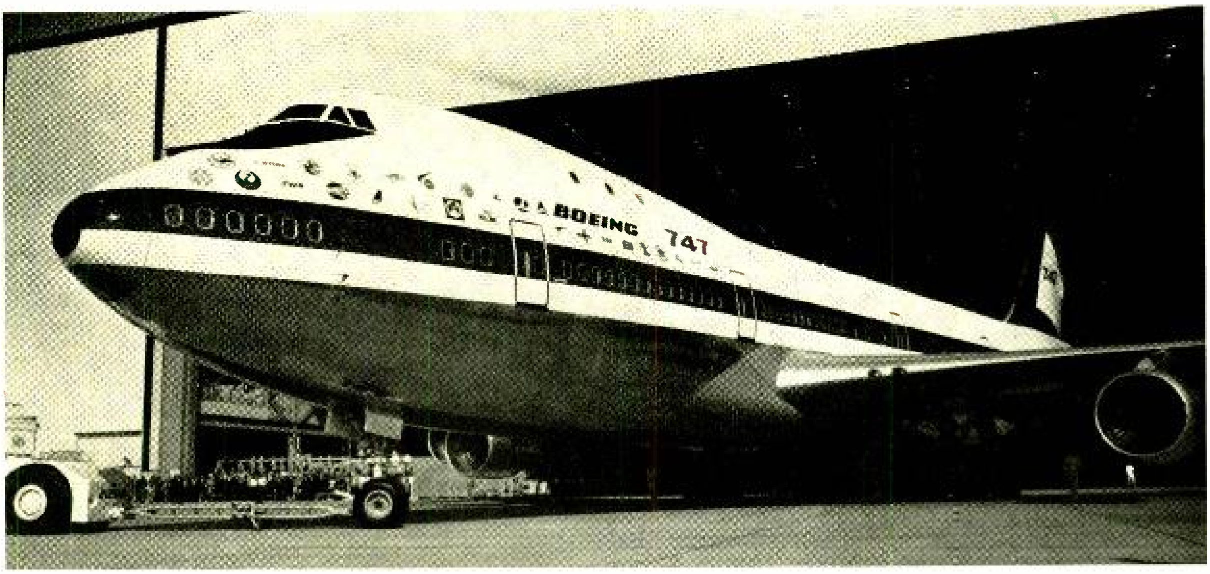
Extensive use of microcircuitry has permitted the elimination of hundreds of pounds of weight with an inherent improvement in performance, reliability, and maintainability, providing an over-all lower cost of ownership for the operating airlines.

In the present system, ten of the fifteen audio channels originate from a ten-channel tape reproducer. These are supplied to a main multiplexer which samples the channels sequentially and sends the interleaved information over the single wire to the zone submultiplexers in the aircraft passenger areas. Typically, there are five separate areas in the aircraft. At each zone submultiplexer, five additional channels are interleaved and the total fifteen channels are transmitted again *via* the single wire to each column of seats within the zone. The addition of channels at the zone level allows each zone to have its own audio entertainment (movie, TV) and individual zone attendant capability (see Fig. 1).

In this system, each audio program channel is sampled and reconstructed at a rate of approximately 25,000 times each second. This cannot be detected by the human ear; what the passenger hears is an extremely faithful reproduction of the original audio.

Passenger Service System

The passenger service system operates in a similar fashion. Each seat is periodically interrogated to determine the position of the attendant call and reading lamp switches located on separate seat control units. If the switch has been operated since the last interrogation (very small part of a second), a signal is placed on the line which causes the appropriate action to be taken (the reading lamp to be illuminated or extinguished, or the attendant call chime and lamp to be operated).



The new 747 superjet is shown being pulled from its main manufacturing building. The plane is 231-ft long (the 707's length is only 153 ft) and will carry 360 to 370 passengers.

The principle utilized here is the assignment of a certain brief period of time to each seat group. The same clock circuitry used for the audio entertainment provides this time division and ensures that a command from an individual seat switch is applied only to the circuit corresponding to that seat. There are time slots for the two or three seats in each particular seat group. Each seat is provided with time slots into which commands can be inserted. The process of advancing from seat-to-seat and from seat group-to-seat group is a function of the timing system and is completely automatic. Although a timing system of this type is responsible for some delay between passenger actuation of a switch and the occurrence of the appropriate action, the delay is at most a fraction of a second and cannot be noticed by the passenger.

Multiple-Chip Microelectronics

Dual in-line microcircuit packages are not being used in the seat electronics boxes because of the development of a new high-density package. Each of these packages is the equivalent of 20 dual in-line IC's. Containing a number of separate chips, the packages measures about 1" by 1.2". However, by 1970, newer packages are expected to be available which will contain a single chip with the equivalent of 200-250 active elements.

The system also uses four different MOS (metal oxide semiconductor) microcircuits containing the equivalent of several hundred transistors each. The multiplexing function is performed by one of these circuits, which is located in the main multiplexer box and in each of the six zone submultiplexers. The circuit has 350 transistors and 80 gates in a chip that measures only 100 x 125 mils.

The microcircuit which demultiplexes the signals (*i.e.*, sorts out only the requested channel from the coaxial cable) has 424 transistors and 115 logic gates on a similarly sized chip. One of these microcircuits is in each seat box and samples the channel selection switches in each group of seats. It retains this information and does the demultiplexing of the incoming signals for either two or four seats, depending on the particular seat configuration.

Also in the seat box is another MOS circuit which does the passenger-service encoding. Yet another MOS is in the overhead unit which demultiplexes the passenger-service instructions.

For a better understanding of the system, refer to Fig. 2. Let us assume that we desired to send the messages shown before the microphones at the left over one wire to the speakers shown at the right. Assume further that the position of both the transmitting and receiving switches are changed one position after each number in each message. In succession, the outputs of all receivers would be ". . . 0-7-3-6-1-8-4-7-2-9-5-8- . . ." However, the output of receiver speaker A would be ". . . 0-1-2 . . ." and of receiver B, ". . . 7-8-9 . . ." or exactly the original message.

This vastly simplified example demonstrates the principle involved in time-division multiplexing. In practice, the encoding end (multiplexer) samples each channel at such a high rate that the receiving end (demultiplexer) can reconstitute the signal and filter out the discontinuities without any discernible loss of signal or distortion. Each short burst, representing a tiny segment of one of the input signals, is transmitted down the cable to the receiving end, followed by a small portion of the input from the next channel to be transmitted. This process continues until each of the inputs has been sampled once. The process then repeats itself with the first input signal and so on.

The receiving end of the (*Continued on page* 76)

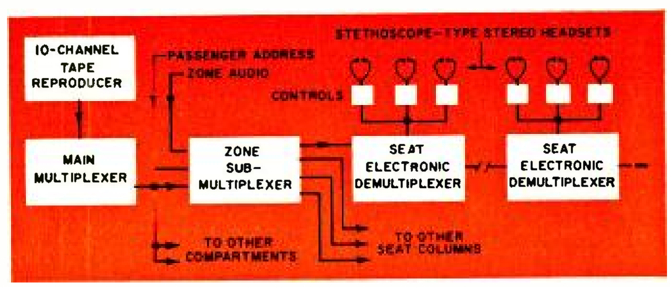
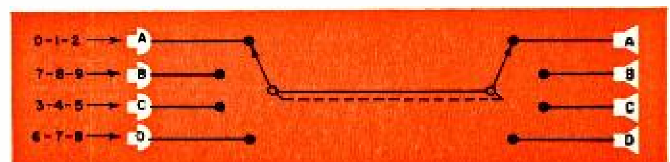


Fig. 1. Block diagram of portion of the multiplexing system.

Fig. 2. Simplified examples showing principle of operation.



Low-Cost D.C.-Voltage Calibrator

By L. H. GARNER

Here is a maintenance-free circuit that can provide highly accurate and stable reference voltages for calibration of test equipment.

WITH the increasing proliferation of solid-state equipment, both industrial and commercial, the proper calibration of test equipment takes on a new level of importance. To the service technician as well as the design engineer, the measurement of low-level voltage differences usually indicates whether or not a circuit is operating properly. As an example of this, Fig. 1 illustrates a typical transconductance curve for a silicon transistor. It is evident by looking at this curve that a small change in the base-emitter voltage produces a large change in the collector current (this difference is smaller in germanium transistors). This logarithmic characteristic is actually typical of any silicon diode, although the absolute values will vary slightly due to type of construction and relative doping levels. The important point here is the fact that a small ΔV_{BE} produces a large ΔI_C; the absolute value of this V_{BE} will usually mean the difference between a low-distortion or high-distortion amplifier, or whether a transistor is operating in a linear or saturation region. Looking at Fig. 1, considering the 25° C curve, a V_{BE} change from 0.60 V to 0.67 V will change the collector current from 100 μA to 1 mA. This means that it is very important to be able to measure a voltage change of only 70 millivolts, with the absolute value being equally important. In order to achieve this end, a very simple but very accurate voltage calibrator was constructed, as shown in Fig. 2.

This circuit is just about as simple as you can get. The power transformer is a low-cost, low-current unit with a 40-V secondary feeding a molded-bridge assembly and a single filter capacitor. Since the current drain is a constant, no further filtering is needed, although the filtering may seem to be minimal. The d.c. voltage from the filter (approximately 56 V) is applied to the anode of the 1N5297 constant-current diode in series with a string of ±1% precision resistors mounted on a selector switch. This diode supplies a current of 1.0 mA and sets the voltage reference points at the output taps.

The basic 1N5297 device has a 10% tolerance as purchased and, as such, may have to be selected for the 1.0-mA level. As an alternate to this, Fig. 3A illustrates another method of obtaining the constant current. In this circuit, a general-purpose JFET is connected as a variable current source. The FET shown is merely an example of one which may be used; the basic criteria for the selected device are that the minimum I_{DSS} is in excess of 1.0 mA and that the maximum pinch-off is 5 volts. If this approach is taken, the accuracy of the circuit will be equal to the ±1% of the resistor string ± the accuracy of the instrument used in the initial calibration. Having performed a series of tests on the current-source diodes for over 1000 hours, it can be stated that the stability of these devices is nothing short of remarkable. Stability of the reference device is, after all, what determines the stability of the circuit in which it is used.

Referring to Fig. 3B, the resistor values in the string were altered to provide the voltage ratios normally found in commercial v.t.v.m.'s. In Fig. 3C, the resistor values reflect voltages found on many commercial v.o.m.'s; the actual voltages required are dependent on the instrument to be calibrated and are easily selected by the builder.

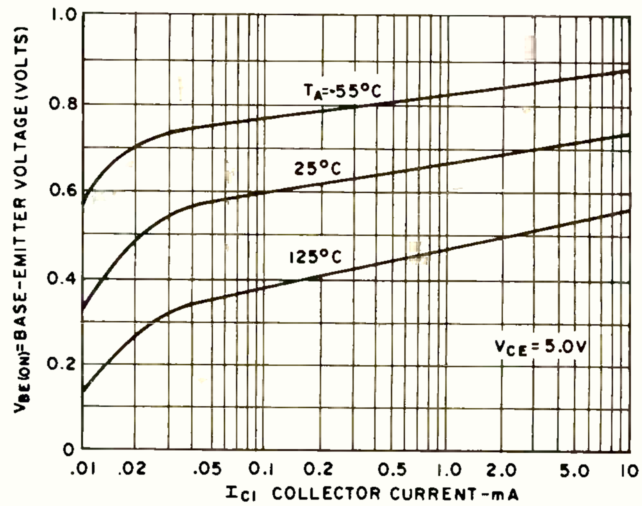


Fig. 1. Typical transconductance curve for a silicon transistor.

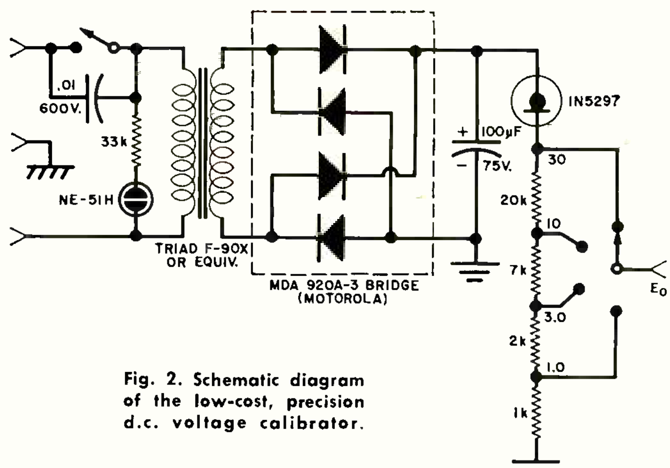
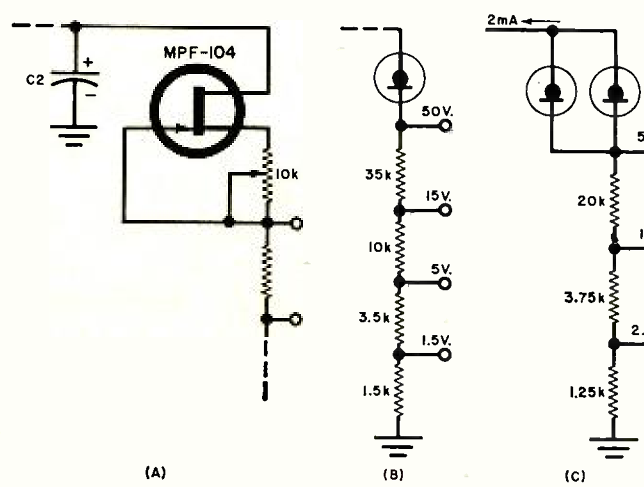


Fig. 2. Schematic diagram of the low-cost, precision d.c. voltage calibrator.

Fig. 3. Variations of calibrator circuit for using a general-purpose JFET for alternate constant-current source (A) and different voltage-divider networks for obtaining the voltage ratios found in commercial v.t.v.m.'s (B) and v.o.m.'s (C).



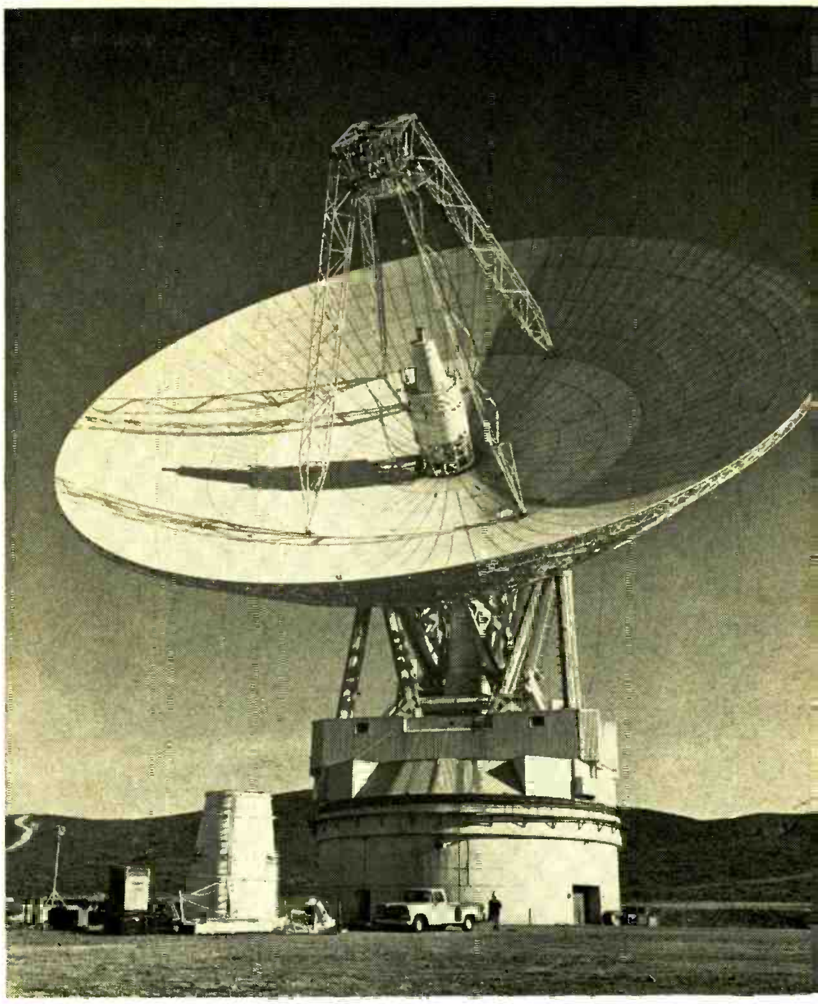
As this circuit technique shows, a very simple and highly accurate and stable voltage calibrator may be built with a minimum of components. The current-source stability of the FET diode is such that no voltage regulator or reference elements (zener diodes) is required. The author's calibrator has been in use for over a year with v.o.m.'s, v.t.v.m.'s, and d.c. oscilloscopes, and its accuracy is still within the repeatability of the test equipment and, as such, has not required any periodic maintenance or recalibration. ▲

Mariner Spacecraft

Explorers of Mars

By FRED W. HOLDER
Bendix Field Engineering Corp.

Mariners VI and VII, launched early this year, are adding to our knowledge of the distant red planet to which we may some day travel. Here is what the scientific packages were designed to accomplish.



This 210-ft antenna at Goldstone, Calif. is used to communicate with the Mariner spacecraft and other deep-space probes.

ON November 28, 1964, an Atlas/Agena rocket roared off the pad at Cape Kennedy, Florida. The 575-pound Mariner IV spacecraft was on its way. Its mission: To gather scientific information on the red-orange planet, Mars. Eight months and 325,000,000 miles later Mariner IV was within 6118 miles of the Martian surface. On July 15, 1965, Mariner slewed its TV camera into position and snapped 21 pictures of Mars. A breakthrough had been achieved. The Mariner photographs showed surface features as small as two miles across. Even the most powerful telescopes and the most favorable atmospheric conditions on Earth have never yielded such high-resolution pictures of the Martian surface; their best resolution shows surface features 100 miles across.

Early this year, two more Mariner spacecraft (Fig. 1), propelled by the powerful Atlas/Centaur rocket, were hurled into space. Their mission: To fly within 2000 miles of the Martian surface and to further the exploration begun by Mariner IV. These spacecraft, designated Mariners VI and VII, were launched in February and March, one month apart. Mariner VI will journey 226,000,000 miles to take close-up TV pictures of the equatorial region of Mars on July 30, 1969. Mariner VII, on the other hand, will travel a somewhat shorter distance and just five days later, on August 4, 1969, will photograph the polar region of Mars (Fig. 2).

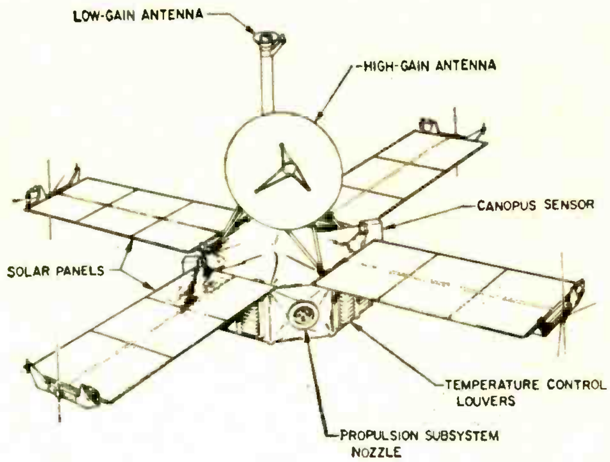
Such lengthy journeys through the bitter cold vacuum of space pose several problems which the designers must solve if the spacecraft's passenger, the scientific data package, is to reach its destination. In this article we will investigate some of these problems, see what the scientific package may accomplish, and what NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California has planned for the future.

Power Generation

The Mariner IV spacecraft needed almost 200 watts of electrical power to operate its functional components over the 1,534,000,000 mile journey, which officially ended on December 20, 1967. This power was furnished by 70 square feet of solar-panel area containing 28,224 solar cells. When Mariner was in the vicinity of the Earth, these panels generated about 700 watts of electrical power. As Mariner approached Mars, the output from the solar panels was reduced to 300 watts, leaving a good margin of power in case of solar-cell damage.

The electrical systems of Mariners VI and VII require a maximum of about 388 watts at the time of Mars encounter. The power is supplied by 83 square feet of solar-panel area which contains only 17,472 photovoltaic solar cells. At Earth distances from the Sun, these solar panels produce about 800 watts of power, but as the spacecraft approaches Mars, the power capability decreases to 449 watts, leaving an ade-

Picture of Martian surface sent to Earth by Mariner IV (1965).



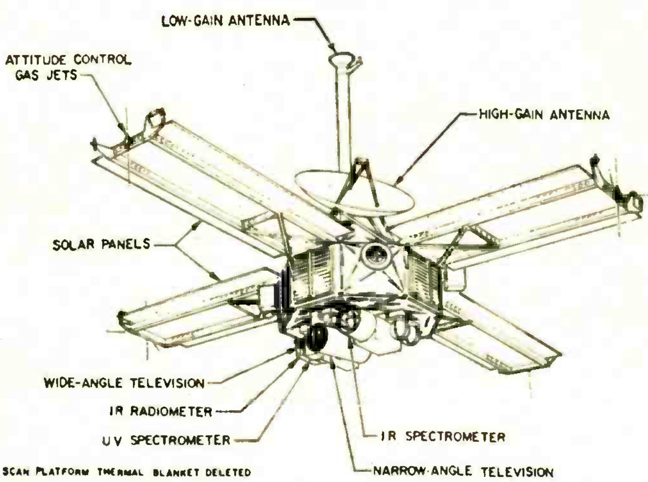
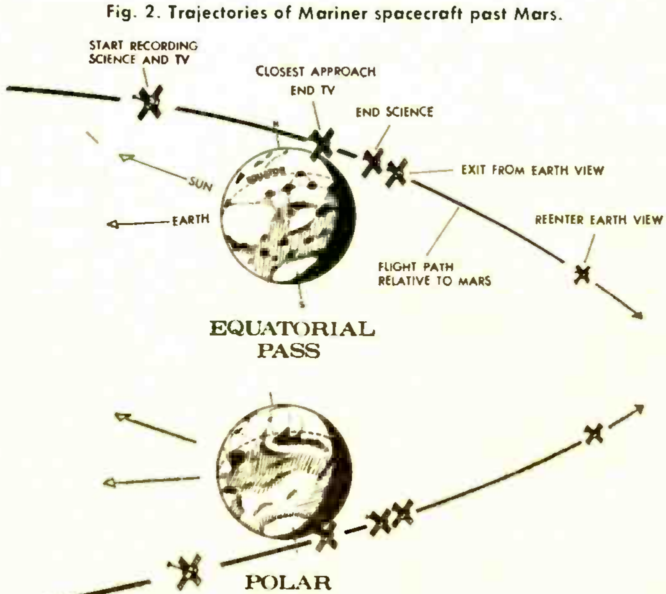


Fig. 1. Spacecraft used for Mariner VI and VII missions.

quate margin in case of degradation caused by solar flares.

Each spacecraft carries a rechargeable, silver-zinc battery that is a sealed unit containing 18 silver-zinc cells. This battery has a minimum capacity of 1200 watt-hours at launch. This capability is reduced to about 900 watt-hours at Mars encounter. Power from the solar cells is directed to the battery to keep it in a state of full charge so that it may be used during Mars encounter as an emergency backup power source.

Fig. 2. Trajectories of Mariner spacecraft past Mars.



Each spacecraft carries two power regulators to provide a redundancy factor. If one regulator should fail, it is automatically removed from the line and the second regulator is switched in to assume the full load of the spacecraft. Also, should an out-of-tolerance voltage condition exist in the main regulator, the standby regulator takes its place in the line.

The primary power distributed to most of the spacecraft systems is a 2400-Hz square wave. However, the gyro spin motors use a 400-Hz three-phase current. The infrared spectrometer and the scanning motor are supplied with a 400-Hz single-phase current. The transmitter amplifier tube, battery charger, and temperature-control heaters use the unregulated d.c. power from the solar panels or from the battery.

Temperature Control

An object in space will be warmed on the side facing the Sun's rays and cooled by its own radiation into the black sky around it on the side away from the Sun. If the object is not rotating, the sunny side may be several hundred degrees hotter than the shady side. And an object at Earth distances from the Sun may be 125° F warmer than it would be at Mars distance. The Mariner spacecraft and its electronic components couldn't tolerate these adverse conditions. Therefore, it was necessary for the engineers to devise methods of maintaining certain temperature limits within which the electronic components could operate properly.

Heating by direct sunlight on the Mariner spacecraft is minimized by the use of a thermal shield of aluminized Teflon on the sunny side. The side away from the Sun is also covered with a thermal shield to prevent rapid loss of heat to the cold of dark space.

The temperature is controlled in the spacecraft's six electronic compartments by the opening and closing of polished metal louvers that are actuated by coiled bimetal strips. These strips act as spiral-bound springs that expand and contract as they heat and cool. This mechanical action is calibrated to provide an operating range from fully closed at 55° F to fully opened at 90° F. Each pair of louvers operates independently on its own local temperature, as determined by the internal power dissipation within the compartment.

Other elements of the spacecraft are temperature controlled by means of paint patterns and polished metal surfaces. For example, the high-gain antenna dish, which is dependent upon the Sun for its surface heat, is painted green to keep it at or near room temperature during planet encounter. At Earth distances from the Sun, the antenna dish is at its upper thermal limits.

Communications

Broadcasting continuously at 2300 MHz with 10 watts of power, the radio subsystem in Mariner IV provided a communications link over which scientific and equipment performance data was returned to Earth at a rate of 8⅓ bits per second for most of the flight. As Mariner approached Mars, it took 12 minutes for these radio signals to travel the 134,000,000 miles back to Earth. The signal reaching the big 85-foot antennas on Earth was 10^{-19} watt, a bit faint for conventional receivers. For example, the average home TV set receives a signal of about 10^{-7} watt.

All communications between the Mariner spacecraft and the Earth is in digital form. Command signals transmitted to the spacecraft are decoded, translated from binary form into electrical impulses, and routed to the proper destination within the spacecraft. Data gathered in the spacecraft is converted to digital form for transmission back to Earth. In Mariner IV, two transmission rates were available: 33⅓ and 8⅓ bits per second. Early in the Mariner IV flight, the spacecraft was switched to the 8⅓ bits-per-second rate. Mariners VI and VII have five different data rates for transmission: the engineering channel has 8⅓ and 33⅓ bits per second at any time, the science channel has 66⅔ bits per second during encounter and 270 bits per second during data storage playback, and a high-rate science channel at 16,200 bits per second. This latter science channel can be used only when the 210-foot antenna at Goldstone, California is available to receive data.

Unless Mariners VI and VII are receiving uplink signals, they transmit a frequency of 2195 MHz, which originates within the spacecraft transmitter. The transmitter consists of two redundant exciters and two redundant radio-frequency power amplifiers in any combination. However, only one exciter-amplifier combination will operate at any one time. Both amplifiers on each spacecraft employ traveling-wave tubes. They are capable of operating at 10 watts or 20 watts output and can transmit through either the high-gain or low-gain antenna.

The S-band receiver used in Mariners VI and VII operates continuously during the mission at a frequency of about 2115 MHz. The receivers in the two Mariners operate at slightly different frequencies. These receivers are used with the low-gain omnidirectional antenna only and receive the uplink command and ranging signals from the ground stations of the Deep Space Network.

Television

A brief review of the TV subsystem in the Mariner IV spacecraft provides a basis for comparing the systems used in Mariners VI and VII. In Mariner IV, a 12-inch focal length telescope with a 1-degree field of view brought the image to a vidicon tube having a 0.22-square-inch faceplate. The image was scanned in 200 lines of 200 dots or picture elements each. The TV camera converted the scanning image to a digital signal of 240,000 bits per picture. The digital picture data was recorded on a two-track, ¼-inch magnetic tape loop 300 feet long which was capable of recording a little more than 21 pictures. Each of the 40,000 elements in a picture was converted to a six-bit binary number (64 possible numbers) representing picture shading from pure white (binary 000000) to jet black (binary 111111). It took more than eight hours to transmit each picture back to Earth at a rate of 8⅓ bits per second. The bits were transmitted as pulses which were present (1) or absent (0).

The binary numbers representing picture elements were fed into the computers at NASA's Space Flight Operations Facility at Jet Propulsion Laboratory. The computers processed the data so it could be fed into a digital photographic processor. In one method used, this processor converted each number to an appropriately shaded dot. The dots were then projected in sequence (200 dots per line for a total of 200 lines per picture) onto a cathode-ray tube. Each completed picture was photographed by a 35-mm camera.

Mariners VI and VII each carry two cameras. Camera A is similar to the camera on Mariner IV, except that it has been equipped with a wide-angle lens and covers an area 12 to 15 times larger than the Mariner IV camera. It has approximately the same resolution—two miles. The resolution of camera A is one-tenth that of camera B, and its photographs cover an area 100 times larger on the surface of Mars. The best resolution for camera B is expected to be about 900 feet, compared with two miles for the Mariner IV camera.

The vidicon tubes in the TV cameras of Mariners VI and VII operate in a manner similar to that used in Mariner IV, except that the electronic beam scans 665,280 points on the picture image. As in Mariner IV, each point is converted to a shading number and recorded on a digital tape recorder. Each picture will be represented by 3.9 million bits of information. Transmission of the picture data back to Earth is in binary form. Once the information is received at the Space Flight Operations Facility, it is converted to electrical pulses, representative of the pattern of light and dark elements of the original image on the vidicon tube. These pulses will intensify a beam of light as it is swept across a 70-mm negative to expose it at 665,280 points to recreate the original image.

The standard approach plan programmed in the on-board computer in each spacecraft provides for 50 approach pictures. Whether or not this plan can be implemented is dependent upon the availability of the 210-foot antenna at Goldstone, which will allow transmission of these pictures to Earth at 16,200 bits per second before the flyby. If the "big dish" is not available, an alternate approach will be used in which eight approach pictures will be taken for transmission to Earth after the flyby.

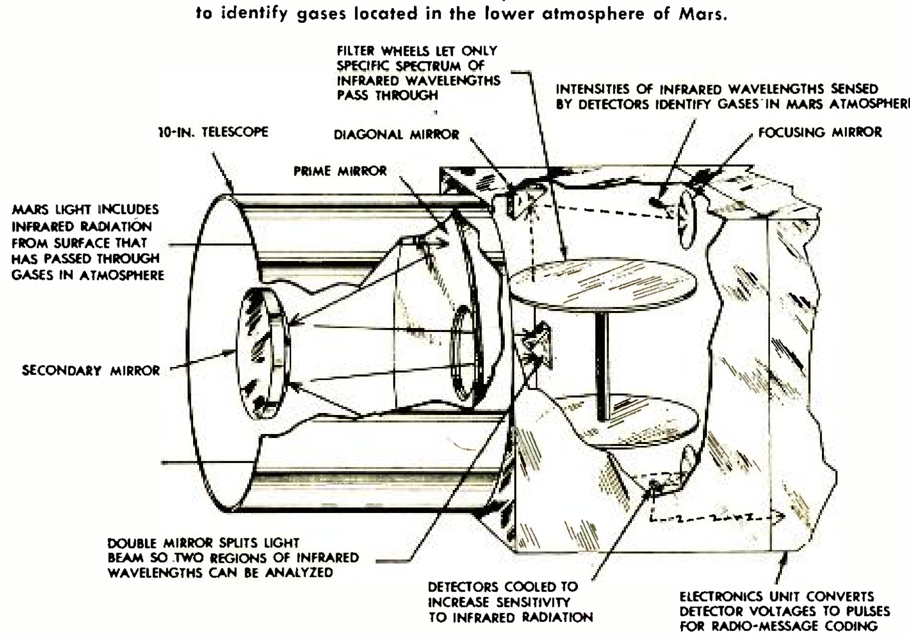
As the spacecraft fly by Mars, they are each scheduled to take a series of 24 close-up pictures of the surface at a closing range of from approximately 6000 to 2000 miles from the surface. Red, green, and blue filters will be used on camera A to delineate color differences, while a yellow filter will be used on camera B to reduce haze.

The approach pictures are expected to give scientists the first detailed pictures of features previously studied from Earth. These photographs may serve to locate haze, clouds, or dust storms and allow studies of changes during the time each series is made and during the five-day interval between the two spacecraft. The television pictures may allow scientists to detect any moist areas on the Martian surface. The innermost of Mars two moons, Phobos, might appear in one of the approach series.

Other Scientific Experiments

The scientific payload of Mariner IV was made up of six devices besides the television subsystems: (1) a helium magnetometer to measure planetary and interplanetary magnetic fields; (2) a solar plasma probe to measure the quality rate and energy of positive ions "solar wind"; (3) an ionization chamber and Geiger-Mueller tube to measure the ionization caused by charged particles; (4) a trapped-radiation detector to measure the Earth's Van Allan belt and to check for similar formations around Mars; (5) a cosmic-ray telescope to detect protons and *alpha* particles; and (6) a cosmic-dust detector that is employed in order to measure mo-

Fig. 3. Details on the infrared spectrometer that is used to identify gases located in the lower atmosphere of Mars.



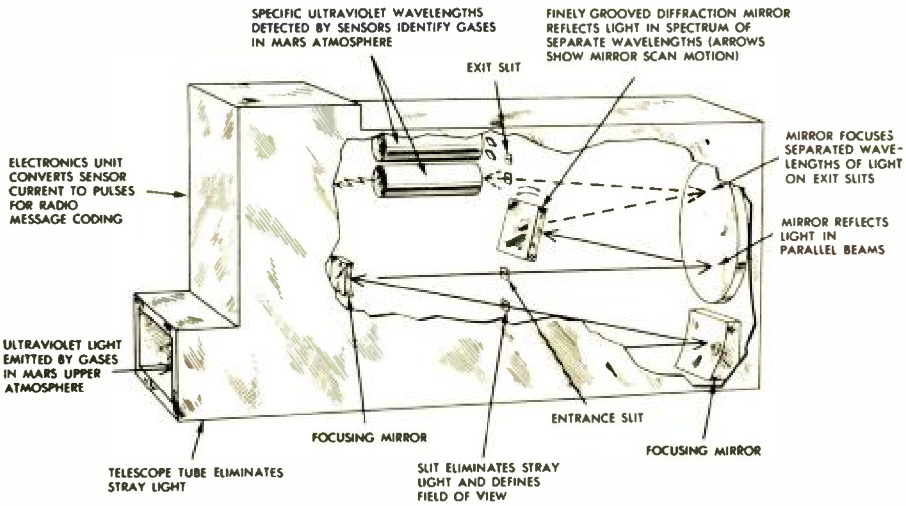


Fig. 4. Details on the ultraviolet spectrometer that is used to identify the gases located in the upper atmosphere of Mars.

mentum, direction, and the number of hits from cosmic dust.

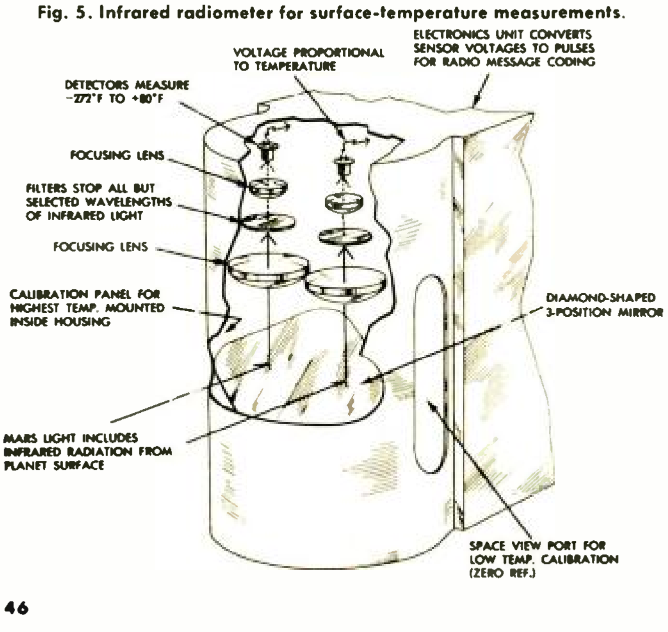
In addition to the TV subsystem, Mariners VI and VII carry an infrared spectrometer, an ultraviolet spectrometer, and an infrared radiometer to be used to explore the surface and atmosphere of Mars. These devices are designed to yield data on the physical, chemical, and thermal properties of the planet. They will probe the surface and atmosphere of Mars in the visible and near-visible portions of the electromagnetic spectrum, from the infrared region through the visible portion of the ultraviolet region. The S-band occultation experiment, which requires no special equipment other than the spacecraft's radio, will provide new values for atmospheric pressure and density, and electron density in the Martian atmosphere.

The infrared spectrometer (Fig. 3) will detect infrared radiation in the 1.9 to 14.3-micron region. It will allow detection of water, carbon dioxide, methane, ethylene, and acetylene, if present. The presence of organic molecules would provide evidence of the existence of either past or present life on Mars. This detection, however, would not be conclusive.

The ultraviolet spectrometer (Fig. 4) identifies different species (molecules, atoms, and ions) by the wavelengths of light they absorb or emit. Each species absorbs the energy of light (which is composed of a number of different wavelengths) at one or more wavelengths and re-radiates the absorbed light at the same or longer wavelengths. An atom, for example, re-radiates the wavelength it absorbs. The spectrometer can detect certain wavelengths and thus identify the species. This device uses two photomultiplier tubes as detectors. Each of these tubes is sensitive to different regions of the spectrum. One tube responds to the 1100 to 2150 angstrom region, the other from 1500 to 4350 angstroms.

The infrared radiometer (Fig. 5) is boresighted with the television cameras to allow correlation of surface temperatures with terrain features and clouds. This provides a map of the surface, relating temperature variations to surface features. The unit uses two antimony-bismuth, five-junction thermopile detectors to provide 30 readings every 63 seconds. Twenty-seven of these readings will be of planetary temperatures, two of them will be calibration readings, and the remaining reading will be an engineering measurement on the instrument itself. One of the detectors covers the 8 to 12-micron range; the other covers the 18 to 25-micron range. Filters are used to determine the wavelengths actually reaching the detectors. If frozen water exists on Mars, there is a possibility of detecting localized moist areas on the surface. This would require a higher surface temperature in the area, which would be detectable. The experiment may also determine if the bright rim seen on the craters in the Mariner IV photographs of Mars are remnants of carbon dioxide or water ices.

Fig. 5. Infrared radiometer for surface-temperature measurements.



Future Missions

Two more missions to further explore Mars are in the planning stage. The first of these missions is scheduled for 1971 when two Mariner spacecraft will orbit the planet for three months. The first spacecraft will orbit at an inclination of 60 degrees to the planet's equator. This orbit would permit it to examine about 70 percent of the Martian surface. The second spacecraft would then be placed in the near-polar orbit, inclined 80 degrees to the planet's equator. This orbit will permit examination of the Mars polar caps and provide high-resolution coverage of selected areas. It will also permit oblique views of broad areas of the planet's surface and possibly an examination of the planet's two moons, Phobos and Deimos.

In 1973, NASA plans to send two spacecraft to Mars. Designated Project Viking, the two spacecraft will be launched in mid-1973, about ten days apart. Each spacecraft will consist of a Surveyor-type soft-lander mated with a Mariner 1971 class Mars orbiter. The Mars orbiter will provide power and communications support to the landers during the cruise period.

Upon arrival at Mars, the orbiter propulsion system will be used to place the orbiters and landers into a Mars orbit. After reconnaissance of potential landing sites by the orbiters, the landers will be detached and will soft-land, using the techniques developed for Surveyor and the Apollo Lunar Module. The orbiters will then provide broad-area surveillance in support of the landers, in the same way that the Lunar Orbiter and Surveyor spacecraft worked as a team in exploring the Moon.

The exploration of Mars began 3½ centuries ago when Galileo distinguished the disc of Mars with the first astronomical telescope. Such exploration has continued through the centuries with ever-increasing sophistication, with larger and more powerful telescopes and more sophisticated photographic equipment, to the missions of Mariners IV, VI, and VII. We can only hope that the data provided by the Mariners of 1971 and 1973, as well as those in the present series, will give us an even more comprehensive picture of the red planet. ▲

New TV Front-Ends

By FOREST H. BELT / Contributing Editor

Here's up-to-date information on new TV tuners which use diode or varactor tuning, detented u.h.f. operation, and integrated circuits.

THIS is a year of improved television tuners, particularly those used in color receivers. You can already see some of the innovations; others are due shortly; while a few are promised for the near future. No one except the tuner manufacturers can be sure what's coming when, or who'll have it, and they're understandably reticent about revealing which set manufacturer will use which tuner. Set builders who design their own tuners don't want to spring their surprises too soon for competitive reasons. Secrecy notwithstanding, there are at least three "hot" tuner subjects: diode or varactor tuning, detented u.h.f., and integrated-circuit tuners.

Tuning R. F. Stages with Voltage

A controversial topic right now is diode tuning. That's the idea of using varactors—voltage-variable capacitor diodes to tune the r.f. and oscillator stages in tuners. This argument has continued for several years, ever since diode tuners appeared in European TV sets. One side says that diode tuners are too expensive for U.S. television and that today's varactor diodes aren't good enough. The other side says that getting designs into receivers will bring the prices down; while the diode manufacturers insist their products are capable of handling America's crowded TV channels.

There are some difficulties with diode tuners, as European designers found out. One problem was developing varactors that could handle the frequency spread. Another was finding varactors with consistent enough characteristics for this application.

Nevertheless, European set-makers managed. With varactor diodes carefully matched in trios, they came out with varactor tuners for both v.h.f. and u.h.f. The v.h.f. unit in Fig. 1 is typical of European models while the u.h.f. version is shown in Fig. 2.

With diode-tuning comes simplified ways of bandswitching and tuning. It takes only one variable d.c. voltage to tune all three varactors in the two tuners. Switched channel tuning is simple and Figs. 3, 4, and 5 show three ways.

An adjustable potentiometer is the accepted way to tune varactors to different frequencies. Fig. 3 does it that way, applying the voltage through sections of a push-button switch. This is how a number of the solid-state-tuned European receivers do it. If rotary selection is preferred, as presently used in American sets, a detented multi-position switch works the same, as Fig. 4 shows.

Another possibility is shown in Fig. 5. The various voltages are developed incrementally across a divider. Adjusting this setup is critical. You have to start with the bottom pot and adjust each one in order. The least voltage produces the highest capacitance, which tunes the bottom-most channel. So alignment has to progress from the lowest-frequency channel through the topmost.

U.S. set makers have wanted to avoid the added cost of all-solid-state tuning. A partial approach is the automatic fine tuning (a.f.t.) that holds color-set tuners on frequency. A varactor diode in the tuner oscillator is controlled by a d.c. voltage fed back from a discriminator at the output of the third i.f. stage. Any drift from the normal 45.75-MHz picture i.f. produces a correction voltage that changes the varactor capacitance and re-tunes the oscillator in the TV front-end.

One of Our Own

Costs notwithstanding, *Standard-Kollsman* has two varac-

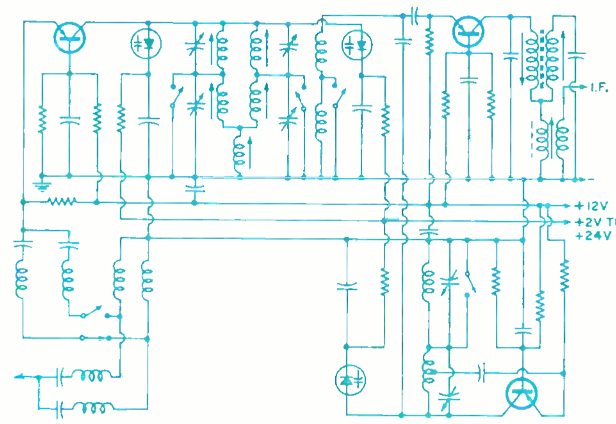


Fig. 1. Method of using diode tuning for a v.h.f. TV tuner. This one and the one in Fig. 2 are from European TV sets.

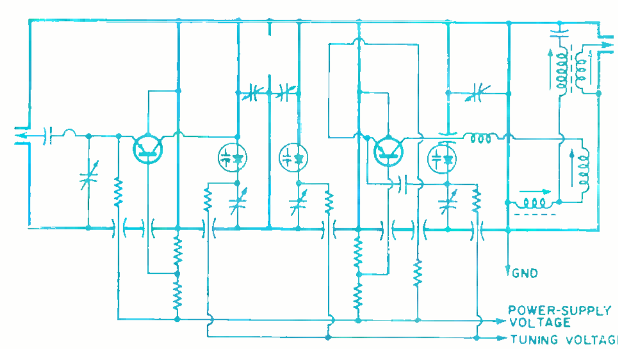
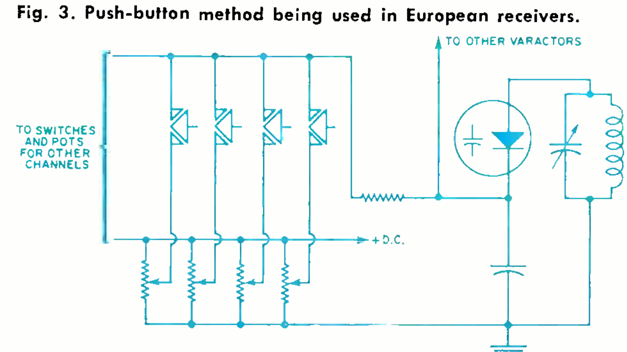


Fig. 2. U.h.f. tuner that has varactor-diodes for tuning. They are used in quarter-wave resonant coaxial tuning lines.

Fig. 3. Push-button method being used in European receivers.



tor-tuned units—one for v.h.f. and one for u.h.f. They have been designated by the tuner manufacturer as an "all-channel package."

But diode tuning isn't the only unique feature of the *S-K* unit. All-channel switching—from v.h.f. to u.h.f. and back—is handled by solid-state switching diodes instead of big mechanical switches. It takes special diodes, with very low forward resistances, and the ones in the *Standard-Kollsman* tuner measure less than 1 ohm in the forward direction, yet have very high back resistance.

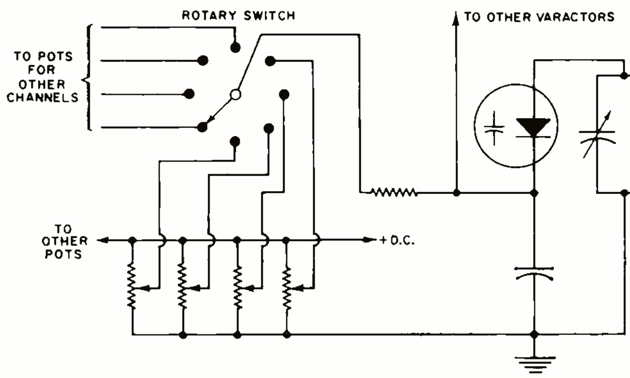


Fig. 4. Detented rotary motion is what U.S. viewers are used to.

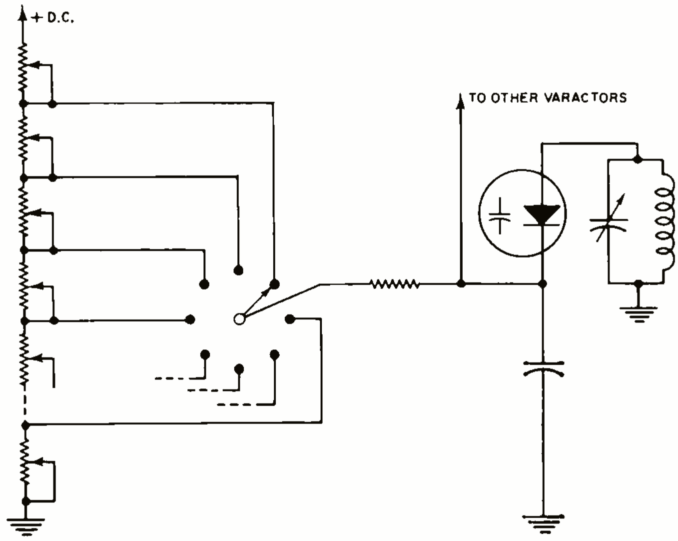
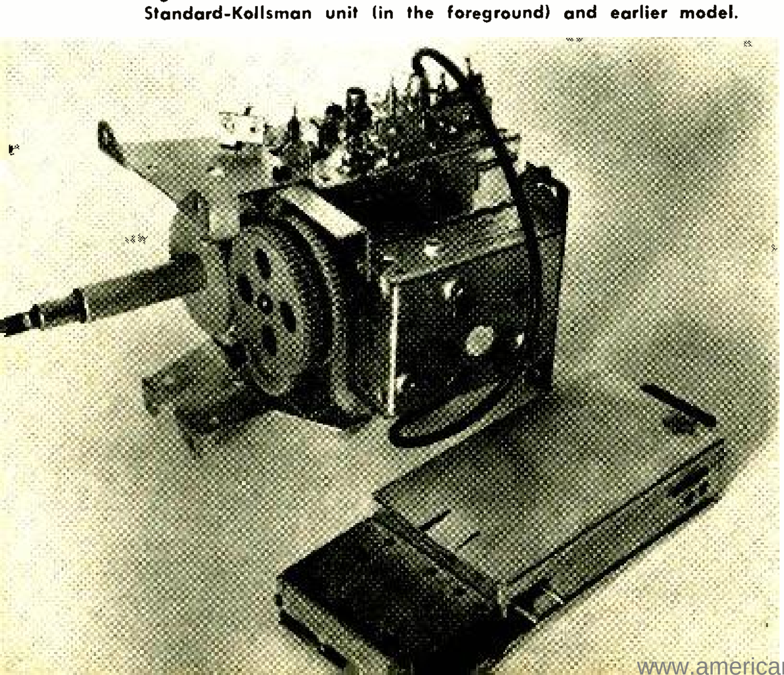


Fig. 5. Another method of applying the tuning voltage required.

Fig. 6. First all-channel tuner of U.S. manufacture: New Standard-Kollsman unit (in the foreground) and earlier model.



The all-channel tuner package is compared in Fig. 6 with its predecessor, a recent-model u.h.f. and v.h.f. tuner assembly. The compactness and simplicity of the new unit are apparent.

Tuning is with variable d.c. voltages, bandswitching is by voltage, too—eliminating the big drums and rotary switches commonly associated with tuners. The manner is ingenious (and patented). The diagram of Fig. 7 shows how bandswitching and tuning can both be accomplished through a single d.c. connection.

Imagine the slider of *R3* at the negative end. The negative voltage applied through *R1* makes *D1* a short circuit. *C1* is a large-value blocking capacitor and does *not* tune *T1*.

At the same time, *R2* carries the negative voltage to *D2*. The reverse bias makes *D2* act as a capacitor, *C2* is large enough so that *D2* is placed effectively across the secondary winding of *T2*. The low r.f. reactance of *C1* connects the tuned circuit, *D2-T2*, to the output lead.

If the slider of *R3* is moved toward the center of the control, less negative voltage is applied to *D2*. That changes its capacitance, and varies the resonant frequency of the *D2-T2* tuned circuit. *D1* remains shorted as long as the voltage is negative.

As the slider of *R3* is moved past center, the voltage applied through *R1* and *R2* becomes positive. *D2* becomes a shorting diode and *D1* the controlled varactor. Varying the value of the positive voltage applied to *D1* alters the resonant frequency of the tuned circuit. *C2* acts as ground return for the now-active *D1-T1* tuned circuit.

R1, *R2*, and *C3* decouple the resonant signal circuit from *R3*, while *C4* and *C5* decouple the voltage-control circuit from the power-supply source.

Any number of these tuned circuits can be controlled from a single pot. In the *Standard-Kollsman* tuner, which has three transistors, there are three of these bandswitched tuned-circuit groups: one precedes the r.f. amplifier, one precedes the mixer, and one tunes the oscillator. The output of the mixer is, of course, fixed-tuned at the i.f.

Prices for all-electronic u.h.f./v.h.f. tuners are higher than for mechanical types, but savings in mechanisms may offset much of the basic cost increase. Controls—simple things that they are—can be mounted away from the tuner, connected only by the voltage wire.

A detented switch for this tuner could be an 18- or 24-position unit, covering 12 v.h.f. channels and the rest for u.h.f. Presetting is as easy as turning a voltage pot for each channel selected; v.h.f. could even be operated from a voltage divider with only two or three trimmer pots. An even simpler system involves one potentiometer, with a detent wheel slipped over the shaft. However, the pot would need a peculiar curve and diode tolerances would be very critical.

RCA is known to be working to get its diode-switched tuner completed and into production for its fall line. At press time we haven't been able to get too many details, but understand that the v.h.f. tuner is remotely operated from a push-button transmitter. Four digital IC's in the tuner activate diode-switched circuits in the transistor mixer, oscillator, and r.f. stages. The u.h.f. tuner is a motor-driven signal-seeking unit.

Mechanical details of the controls each set manufacturer will use are probably the least certain factor in the whole diode-tuning picture. Whether some try continuous tuning or all stick to detented forms of tuning, diode tuning is doing more than just simplify tuners electronically.

A Tuner for All Channels

The Federal Communications Commission has been generating a little heat by threatening to rule that u.h.f. tuners must tune as simply as v.h.f. One general interpretation is that u.h.f. must be detented for snap-snap-snap tuning, but that may not be the only way.

Fig. 8 shows a little tuner the *Selectronics Division* of *Oak*

Electro/Netics calls its "Mark IV." You can see from the photo how small it is. It measures 1⅛" x 3½" x 4" and weighs only 15 ounces. But size is not its most important characteristic. It is the first truly all-channel tuner for U.S. TV sets. By bandswitching in a unique fashion, it covers—in three bands—the entire v.h.f. and u.h.f. television spectrum.

This *Oak* tuner shoots holes in the theory that detented tuning is the only way to achieve "parity." It is a continuous tuner with u.h.f. and v.h.f. tuned exactly alike and with the same knob. Fig. 9 shows the tuner in a receiver. The big knob in the center selects which band: low v.h.f., high v.h.f. or u.h.f., then the outer ring tunes a slide-rule dial for the desired channel.

However, there may be a matter of customer preference. Continuous tuning for v.h.f. channels was discarded almost 20 years ago in favor of positive-action tuners. Customers today complain about continuous tuning in u.h.f. tuners, which is partly the reason why the FCC took the particular stand it did.

Oak points out that it has developed a detented drive mechanism for the Mark IV. It allows for 12 preset v.h.f. and 12 preset u.h.f. channels. It's more complicated and costly than the continuous arrangement, but is likely to be the type of system preferred by U.S. customers.

The insides of the *Oak* tuner are unusual and the manner of bandswitching is unique. The tuner is in two sections, separated by a thin metal grounded shield wall. Two lines from the tuning-capacitor stator are in a hole in the shield wall, extending from the u.h.f. compartment into the v.h.f. compartment. Each line has two flexible leaves.

When the bandswitch is turned to a u.h.f. position, a plastic cam comes up between the two flexible leaves of each tuning line and spreads them apart. The lines touch the opening in the shield wall through which they pass, grounding them at that point along their length. The four points of contact convert them to a pair of tuned quarter-wave lines at u.h.f. When the bandswitch is in a v.h.f. position, the tuning-stator leaves are contacted by the rotor blades of a special switch section. The former u.h.f.-tuned lines now become a tuning capacitor which tunes the v.h.f. coils mounted on the switch.

There's a big difference between the drive ratios needed for u.h.f. and v.h.f. A mechanism coupled to the bandswitch changes the value of the drive ratio from 4:1 for v.h.f. to 16:1 on u.h.f.

The Mark IV has three transistors—r.f. amplifier, oscillator, and mixer. All three stages work for all three bands. That means there's a tuned stage of u.h.f. amplification, and the chance to reduce crosstalk—where u.h.f. locals are strong—by application of a.g.c. to the r.f. stage. Image rejection in the Mark IV is better than 60 dB on u.h.f.

And "Snap-Snap" U.H.F.

The pressure from the FCC is having its effect. Two tuner makers—*Sarkes Tarzian* and *Zenith*—now offer detented u.h.f. The mechanical arrangements of both tuners bear a marked resemblance.

The *S-T* tuner is shown in Fig. 10. A part you can't see in the picture is a round, flat drum, about 4 inches in diameter and ⅝-inch deep. Arranged around the outside of the drum, at 60-degree intervals, are six gears mounted on shafts that protrude from inside. The drum and what's inside it are why this unit is important. The tuner itself isn't radically different from previous *Sarkes Tarzian* u.h.f. tuners, but, because of the drum, any six u.h.f. channels can be programmed and then selected—snap-snap-snap, just like that.

In operation, the main selector knob rotates the flat drum 60 degrees at a time, for six stops. At any stop, when you push in the knob, the small gear near the tuner engages one of the gear wheels on the drum. The inner mechanism of the drum contacts the tuning capacitor in the tuner. You tune in the desired u.h.f. station, and when you release the knob, its

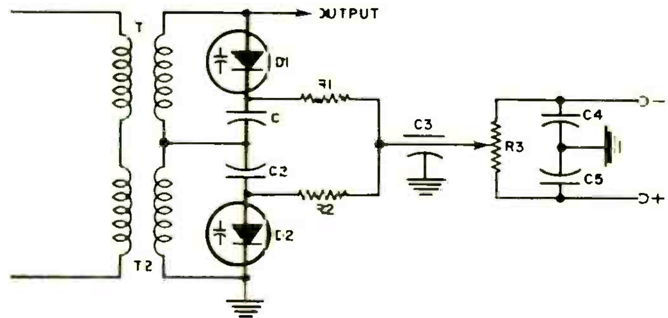


Fig. 7. The (patented) principle of diode bandswitching and tuning that uses only one d.c. voltage source and one control.

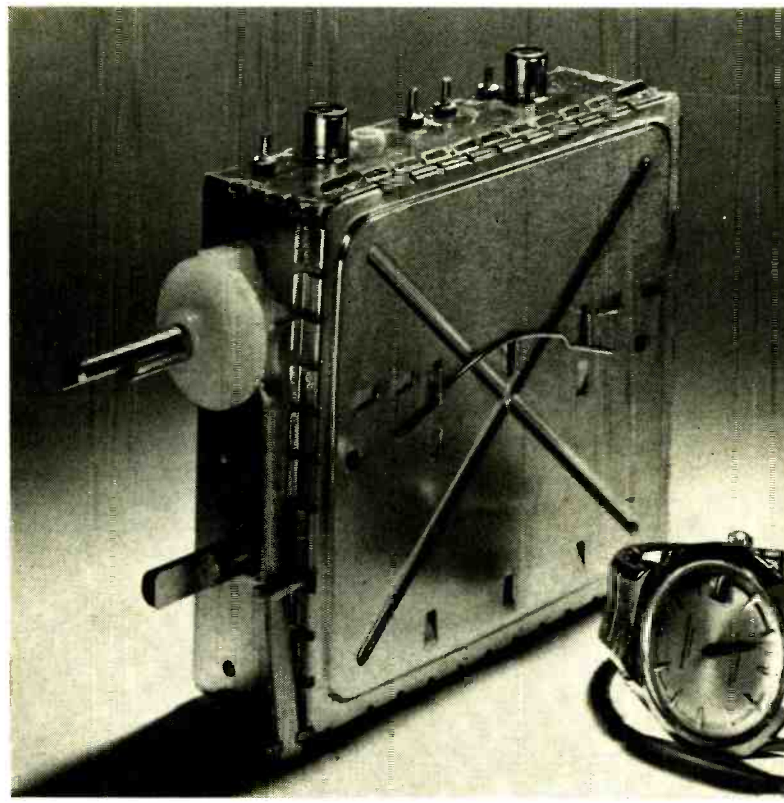


Fig. 8. All-channel Oak tuner is first to use special mechano-electronic switching to put u.h.f. and v.h.f. in one unit.

Fig. 9. All-channel tuner in receiver using a continuous tuning arrangement and slide-rule dials for all three bands.

shaft springs it back out to the channel-select position. However, whenever you return the drum to that stop, it positions the tuning capacitor to the same channel you tuned in manually.

Something else you can't see in the picture is an indicator bar that's on top of some versions. The drum also presets the bar on the slide-rule dial to whatever channel you have tuned. The same tuner mechanism can be used with other indicator systems.

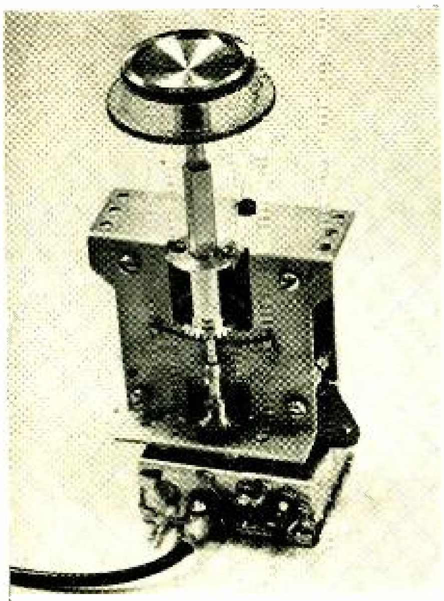


Fig. 10. Sarkes Tarzian tuner for detented u.h.f. It meets general concept of FCC insistence that u.h.f. tuning be easy.

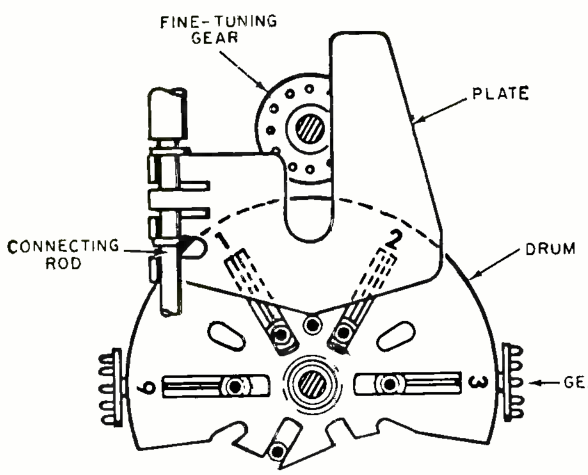
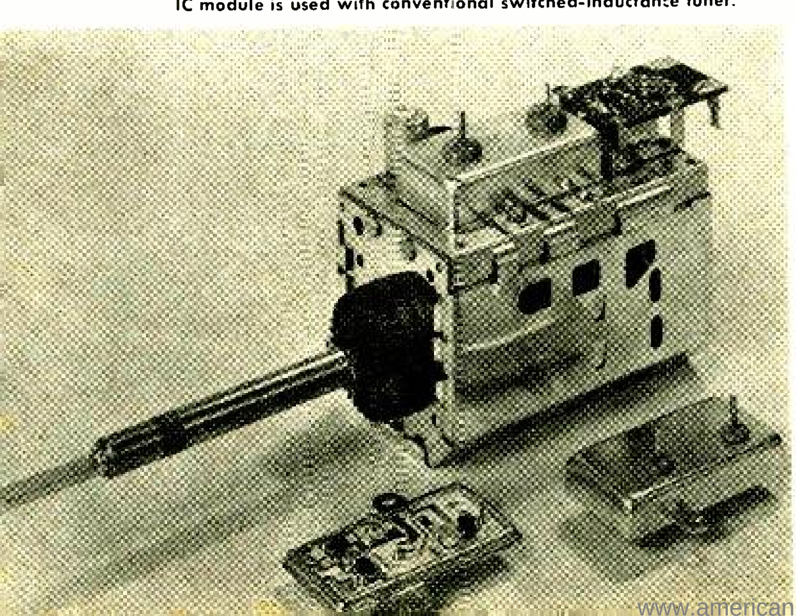


Fig. 11. Drum of Zenith Ultramatic one-knob u/v tuning system is similar to S-T unit. Related mechanism is in production.

Fig. 12. Integrated-circuit module in new Oak v.h.f. tuner. IC module is used with conventional switched-inductance tuner.



All on One Knob

The mechanism of the *Zenith* detented u.h.f. tuner, called "Ultramatic," is very similar in basic appearance. It has a drum, which has six wheels mounted around the outside on shafts that protrude radially. Fig. 11 gives you an idea how the drum and gears look. These gears are right-angle-drive gears, which accounts for their rather unusual construction.

The wheel at the top of the sketch is connected to the fine-tuning knob and shaft. To preset a u.h.f. channel, the drum is first rotated from the "park" position (shown) by the channel-selector knob. At u.h.f. channel A (shown as 1 in the diagram), the protruding gear is in position to mesh with the fine-tuning gear wheel.

The fine-tuning knob is pushed in to engage the gears, and the desired u.h.f. station is tuned in with the knob. What happens is that the wheel on the drum turns a worm gear that moves a sliding tab closer to or farther from the center or hub of the drum. The large flat blade, with the coupling rod at its left, rests on this sliding indexing tab. The blade, coupled to the variable capacitor in the u.h.f. tuner, moves up or down to wherever you set the tab. So you merely turn the fine-tuning knob until the station you want on that stop is tuned in. Then whenever you return the drum to that stop, the capacitor inside the u.h.f. tuner will take up the same position and tune in the station you have preset.

A complex gearing system makes it possible to tune the Ultramatic assembly to any one of the 12 v.h.f. channels (on a v.h.f. tuner) or to any one of six preset u.h.f. channels. All this is done with one set of channel-selector and fine-tuning knobs. Two dials on the front of the set indicate v.h.f. channels by number and u.h.f. channels by letter; labels let the installing dealer put the right u.h.f. channel numbers at each dial stop.

RCA has had a preset detented u.h.f. tuner for two years, on some of its top-line sets. The system has a 24-channel detented selector, with each position having a range of about five u.h.f. channels for presetting. With the 70-channel u.h.f. band divided into 3-channel groups, the *RCA* tuner covers every u.h.f. channel. Channels that are closer together than three channels apart are not likely to be in use in the same locality.

Both the *RCA* and *Zenith* systems can be readily adapted to remote control. The *Sarkes Tarzian* unit can probably be mounted into a mechanism that permits one-motor channel selection, but the company hasn't announced any such system.

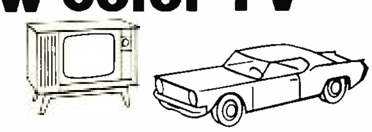
Integration Affects Tuners

There's something else interesting from *Oak*. It's the first TV tuner to use an integrated circuit—the IC module is used with a conventional switched-inductance tuner, as you can see from Fig. 12. The tuner is only for v.h.f., but it's likely a u.h.f. IC module will follow soon. *Oak* spokesmen don't anticipate going to diode tuning any time soon; yet it's easy to imagine what a compact and easily serviced tuner would result from wedding an IC thick-film module to varactor switching and tuning. Add another innovation of *Oak's*—printed inductances—and an epitome of tuner construction and design seems apparent.

By the time we're ready for 1971 models, we may see an IC module that contains the stages for a u.h.f./v.h.f. all-channel, all-electronic tuner. The whole package may be tucked away on the chassis like a big resistor, tuned from the front panel by a few lighted push-buttons that let you select your channel number as you change a station on your car radio. The technology for it already exists and its cost is plummeting weekly. ▲

How would you like a nice new color TV?

How would you like a nice new color TV and a new car?



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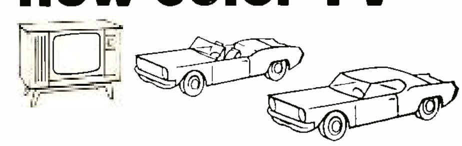

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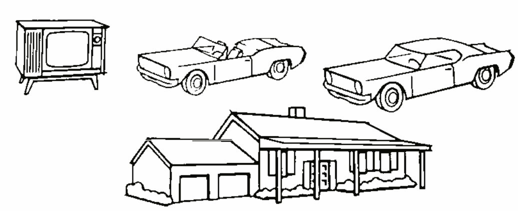


YOU WOULD?

Then turn the page and read a story that could start you on the road to getting them...

"CIE training helped pay for my new house," says Eugene Frost of Columbus, Ohio

Gene Frost was "stuck" in low-pay TV repair work. Then two co-workers suggested he take a CIE home study course in electronics. Today he's living in a new house, owns two cars and a color TV set, and holds an important technical job at North American Aviation. If you'd like to get ahead the way he did, read his inspiring story here.

IF YOU LIKE ELECTRONICS—and are trapped in a dull, low-paying job—the story of Eugene Frost's success can open your eyes to a good way to get ahead.

Back in 1957, Gene Frost was stalled in a low-pay TV repair job. Before that, he'd driven a cab, repaired washers, rebuilt electric motors, and been a furnace salesman. He'd turned to TV service work in hopes of a better future—but soon found he was stymied there too.

"I'd had lots of TV training," Frost recalls today, "including numerous factory schools and a semester of advanced TV at a college in Dayton. But even so, I was stuck at $1.50 an hour."

Gene Frost's wife recalls those days all too well. "We were living in a rented double," she says, "at $25 a month. And there were no modern conveniences."

"We were driving a six-year-old car," adds Mr. Frost, "but we had no choice. No matter what I did, there seemed to be no way to get ahead."

Learns of CIE

Then one day at the shop, Frost got to talking with two fellow workers who were taking CIE courses . . . preparing for better jobs by studying electronics at home in their spare time. "They were so well satisfied," Mr. Frost relates, "that I decided to try the course myself."

He was not disappointed. "The lessons," he declares, "were wonderful—well presented and easy to understand. And I liked the relationship with my instructor. He made notes on the work I sent in, giving me a clear explanation of the areas where I had problems. It was even better than taking a course in person because I had plenty of time to read over his comments."

Studies at Night

"While taking the course from CIE," Mr. Frost continues, "I kept right on with my regular job and studied at night. After graduating, I went on with my TV repair work while looking for an opening where I could put my new training to use."

His opportunity wasn't long in coming. With his CIE training, he qualified for his 2nd Class FCC License, and soon afterward passed the entrance examination at North American Aviation. "You can imagine how I felt," says Mr. Frost. "My new job paid $228 a month more!"

Currently, Mr. Frost reports, he's an inspector of major electronic systems, checking the work of as many as 18 men. "I don't lift anything heavier than a pencil," he says. "It's pleasant work and work that I feel is important."

Changes Standard of Living

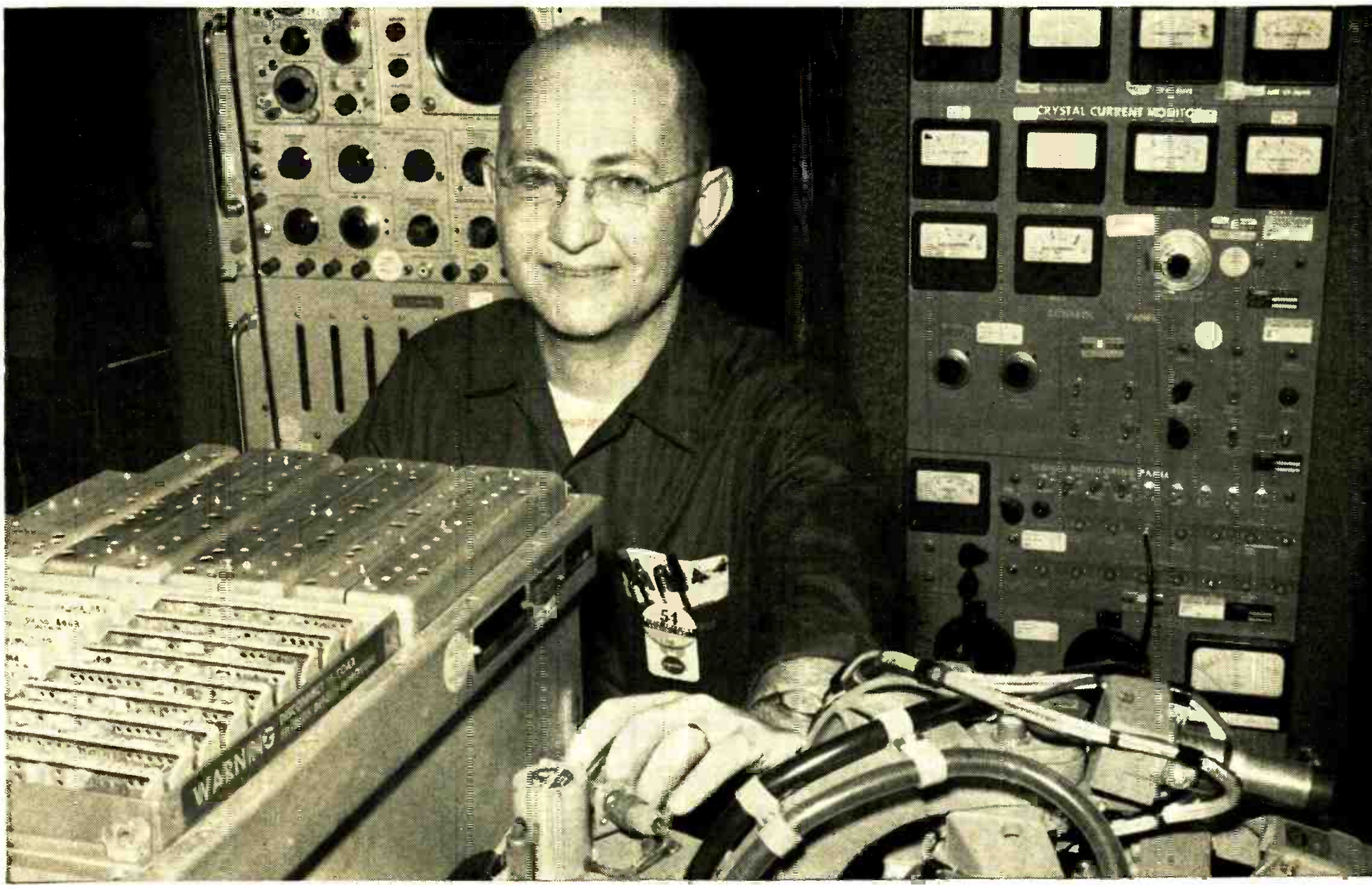
Gene Frost's wife shares his enthusiasm. "CIE training has changed our standard of living completely," she says.

"Our new house is just one example," chimes in Mr. Frost. "We also have a color TV and two good cars instead of one old one. Now we can get out and enjoy life. Last summer we took a 5,000 mile trip through the West in our new air-conditioned Pontiac."

"No doubt about it," Gene Frost concludes. "My CIE electronics course has really paid off. Every minute and every dollar I spent on it was worth it."

Why Training is Important

Gene Frost has discovered what many others never learn until it is too late: that to get ahead in electronics today, you need to know more than soldering connections, testing circuits, and



replacing components. You need to really know the fundamentals.

Without such knowledge, you're limited to "thinking with your hands" ... learning by taking things apart and putting them back together. You can never hope to be anything more than a serviceman. And in this kind of work, your pay will stay low because you're competing with every home handyman and part-time basement tinkerer.

But for men with training in the fundamentals of electronics, there are no such limitations. They think with their heads, not their hands. They're qualified for assignments that are far beyond the capacity of the "screwdriver and pliers" repairman.

The future for trained technicians is bright indeed. Thousands of men are desperately needed in virtually every field of electronics, from 2-way mobile radio to computer testing and troubleshooting. And with demands like this, salaries have skyrocketed. Many technicians earn $8,000, $10,000, $12,000 or more a year.

How can you get the training you need to cash in on this booming demand? Gene Frost found the answer in CIE. And so can you.

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Deciding if a piece of electronic equipment should be repaired or not often involves technician's honesty and technical ability.

FIX IT OR JUNK IT?

AS usual, the September weather had turned hot to welcome the kids back to school. Vacation time was over; new programs were coming on the air; and people were wanting their summer-weary TV sets put into shape for the fall season. All day Mac and Barney had been steadily chipping away at the array of portable sets stacked on the receiving bench; but finally Mac tossed his test prods on the bench, worked his weary shoulders back and forth a couple of times, and took his pipe from a shirt pocket. That was Barney's clue to stop work, too, and to get himself a cold drink from the battered but faithful refrigerator in a corner of the service shop.

"You know, Mac," he said to his employer as he rotated the frosty bottle between his palms, "it's getting harder and harder for anyone in our line of work to 'get away from it all.' Time was when an electronics technician could take his fishing rod, his .22 rifle, or his hunting dog and head for the open country and give his mind a complete vacation from all thoughts of tubes or transistors—but no more."

"Why do you say that?"

"Because of some harrowing experiences I've had lately. Last week I was fishing for bluegills over at Lake Schaeffer and not doing too hot, but the joker next to me kept moving around a few yards at a time and dragging in the fish with disgusting frequency. I finally broke down and asked what bait he was using and found he was using catalpa worms just as I was; but he was *also* using a little green box that turned out to be one of those sonar fish finders. That was why he was moving every few minutes; he was simply staying with the school of bluegills.

"The weekend before I went crow-hunting. I noticed the crows seemed to like the woods across the field from where I was, and I could hear a regular crow caucus going on over there. Imagine my disgust when I sneaked over and found another hunter using what he termed 'an electronic game caller.' It was actually a transistorized 45 r/min phonograph with a husky amplifier working into a 25-watt speaker. The whole thing weighed nine pounds. He was using a crow-calling record, of course, but he told me the manufacturer also sold records for calling fox, coyote, duck, goose, raccoon, wildcat, hawk, turkey, moose, deer, quail, and squirrel."

"I'll bet making those records took some doing," Mac commented.

"Yeah," Barney said with a grin. "I hadn't thought of that. Anyway, I somehow didn't feel it was quite cricket for me to hang around and shoot his crows, although he invited me to do so; so I started home, and on the way I ran across a hound dog acting most peculiarly. Twice I saw him take off after a rabbit, but each time he came to a screeching halt and started whining and shaking his head. When I found the owner a quarter-mile down the road sitting on a high knoll and holding what looked like a walkie-talkie, I learned the reason. He was using an Electronic Dog Trainer to break his coon dog of chasing rabbits. The animal was wearing a light, waterproof unit on his collar that gave him a light shock when the owner actuated the hand-held transmitter. The guy told me the trainer would work up to a half mile and was dandy for curing dogs of biting, chasing cars and bicycles, or even barking excessively. He claimed only a few treatments were necessary to convert an ill-behaved dog into a canine gentleman; then the collar unit could be removed—at least until the dog developed another bad habit you wanted to break him of."

"You've convinced me there's no getting away from electronics," Mac said, "but now, if you don't mind, I'd like to talk to you about something a little closer to home. I mean the problem of having to decide whether we should fix a piece of electronic gear that comes into the shop or advise the owner to junk it. That problem is becoming hairier by the day."

"How's that, Boss?"

"A lot of factors bear on the problem. A big one is the fact that there is a widening gap between manufacturing and service costs. In the electronic industry, it's a lot easier to automate manufacturing than service; and the only way to hold down costs these days is to eliminate human labor as much as possible. Printed and integrated circuits help the manufacturer do just that; so we end up having a highly trained person working on a cheaply produced piece of equipment."

"Yeah, and don't forget the very techniques that make automation possible render the finished product more difficult and tedious to service. No wonder it's often as cheap to buy a new transistorized radio as it is to have the old one repaired."

"That's right," Mac agreed. "I'm sure most of us would rather service a roomy hand-wired chassis than one of those crowded printed-circuit jobs, but service on these older sets is expensive, too, because of the exorbitant prices on the obsolescent tubes they use. I firmly believe the Golden Age of the a.c.-d.c. receiver was reached with the five- and six-tube sets using 12SA7, 12SK7, 12SQ7, 35Z5, and 50L6 tubes. Cabinets then were often wood and large enough to accommodate a decent-sized speaker, to give good ventilation, and to permit the use of a large loop antenna. The chassis was not crowded, and Rube Goldberg dial cord arrangements were the exception instead of the rule. The sets were easy to service, and the fact many of them are still working beautifully is a tribute to their simple, straightforward design and manufacture. But the prices of the tubes they use have been jacked up and up until today retubing one of these receivers costs more than the whole set did originally."

"Lots of these older sets are owned by retired people or others having a low income," Barney observed. "If you tell one of these that he should junk his set, that may mean he will have to do without a radio altogether. Seventy percent of the people drawing Social Security have no other income. On the other hand, some workers in the building trades have boosted their wages until they make more in a day than the person on social security gets in a month. Unless the affluent person has a sentimental attachment to his old radio—and such an attachment is by no means unusual—he will be quite willing to discard his old receiver and buy a new one. The rapidly widening gap between personal incomes has to be considered in suggesting what is to be done about a piece of defective electronic gear."

"Ethics and motives also get into the picture," Mac said.

If you already own an earlier Dual automatic turntable, you're equipped to really appreciate the new Dual 1209.

Because the 1209, just like your present Dual, offers flawless tracking and smooth, quiet performance that will be yours for years to come.

All Duals are made that way. And all recent ones have such exclusive features as pitch control that lets you "tune" your records by a semitone. No wonder so many hi-fi professionals use Duals in their personal stereo component systems.

But the 1209 does have some new refinements of more than passing interest:

Its motor combines high starting torque with dead-accurate synchronous speed. Its anti-skating system is separately calibrated for elliptical and conical stylus types.

The tonearm counterbalance has a click-stop for every hundredth-gram adjustment. The cue control is farther front, for greater convenience. And the styling is very clean.

These refinements aren't likely to seduce you away from your present Dual. They're not intended to. But if you don't already own a Dual, perhaps it's time you talked with somebody who does.

And whether or not you own a Dual now, you might enjoy a look at our literature about the 1209, at $119.50, and about other Duals from $79.50.

United Audio Products, Inc., 120 So. Columbus Ave., Mount Vernon, New York 10553. Dual

The people most likely to appreciate the new Dual 1209 are the least likely to need one.

"Take the case of the service-dealer. There's always a temptation for him to encourage his customer to discard his old receiver and buy a new one, even though the old set could be repaired at a reasonable cost. Customers sense this. They often complain to us, when they bring in the receiver the service-dealer said was not worth fixing, 'That guy was a lot more interested in selling me a new TV than he was in repairing my old set.'

"Let's not forget that cuts both ways," Barney warned. "The service shop owner who does not sell radios or TV sets may be just as tempted to encourage his customer to put a lot of money into repairs when that money would be better spent on a new receiver. Saying 'junk it' in this case not only means losing a lucrative service charge at the moment, but it may well mean the future loss of the customer altogether to the dealer who sells him a new receiver."

"The competence of the service technician also plays a large part in this fix-it-junk-it advice," Mac explained. "If the technician is a poor one, he is at loss when he encounters anything really difficult in troubleshooting or servicing. Rather than admit his ignorance, he is likely to tell the customer the receiver is beyond repair. All he gets out of this is his estimate charge, but he also manages to conceal his incompetence. That often is worth a lot to him. Oddly enough, some technicians unconsciously use this dodge to conceal their incompetence from themselves. They rationalize their way into believing an astonishing number of radios and TV sets are 'not worth fixing.' I call these fellows 'coroner technicians' because they spend a large part of their time pronouncing equipment too dead to revive."

"The ones who lie to themselves like that are bad enough," Barney offered, "but the fellows I can't stomach are the ones who, when they can't fix a set, go ahead and gimmick it up so that any other technician who may try to fix it will have an almost impossible job. I've heard them boast, 'If I can't repair it, I fix it so no one else can!'"

"Fortunately there are not many of those, and even the Twelve Disciples contained a Judas," Mac said philosophically; "but I think I've made my point that trying to decide whether a set is worth fixing these days is not easy, no matter how honest and ethical you try to be. Personally, I try to take into consideration the age of the receiver, its original cost, its general condition and appearance, the cost of restoring it to like-new performance, the cost of an equivalent replacement, and the probable importance of the set to the owner. This last item includes such matters as any sentimental value the receiver may have for the owner and whether or not he can afford to buy a replacement. If I don't think he can, I hesitate a long time before telling him the set should be junked. It's surprising how much a good technician can do toward keeping an old set going with a minimum of cost if he really tries, and in the case of some poor old person trying to hold body and soul together with a meager Social Security check, I'm willing to try."

"Uh-huh," Barney said softly. "I've seen you try so hard you didn't even get fully paid for the parts you put into the set. You just charged enough so the poor customer could keep his self respect. You're a traitor to your Scots ancestry, Mr. McGregor! But let me tell you *my* formula for deciding whether to fix or junk:

"I say to myself, 'Barney, you handsome Irish devil—that's the way I always talk to myself when we're alone together—do you really know what's wrong with this set and precisely how to repair it? If it were your receiver, would you be willing to pay what you are going to charge the customer to have it fixed?' If I can answer both of these questions in the affirmative, I go ahead and repair it. If I have to say 'No' to that last question, I tell the owner I do not think the set is worth repairing but that I am perfectly willing to repair it if he wants me to. And do you know what? In a surprising number of cases, he tells me to go ahead. Then I'm glad I did a thorough job of troubleshooting before I gave him an estimate and my advice." ▲

COMPUTER-CONTROLLED BAGGAGE HANDLING

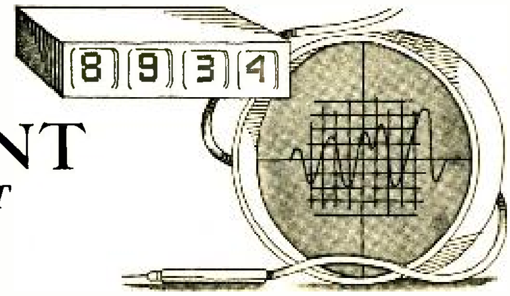
NOW, thanks to computer technology and electronics, the problem of claiming your baggage at the airport terminal may actually take less time than it takes to fly from New York to Chicago by jet, thanks to the new Telecar Baggage System developed by Docutel Corp. of Texas.

The new system transports baggage in individual cars, 36 inches long, 32 inches wide, and 26 inches high. These cars, of rugged thermoplastic construction and powered by linear motors, travel on two aluminum rails at speeds of up to 15 miles per hour.

Each car contains an escort memory that electronically ties the baggage and destination to the car. The memory, in conjunction with central and local controls, directs the Telecar to appropriate functional areas throughout the system.

In using the system, a passenger arriving at the airport goes directly to a check-in station and places his bags in a Telecar. By inserting a baggage claim stub into a terminal he sends the car to the proper loading gate. If the flight has not been called, the car goes to a holding area to await the call. Deplaning passengers claiming baggage insert their claim checks into readers at the desired location and the Telecar brings the luggage swiftly and automatically. A computer keeps track of all these transactions. ▲

TEST EQUIPMENT
PRODUCT REPORT



Triplett Model 310-FET V.O.M.

For a copy of manufacturer's brochure, circle No. 29 on Reader Service Card.

THE incorporation of field-effect transistors into a v.o.m. in order to obtain a high input impedance is not new. But most manufacturers of test equipment have not taken advantage of the size-reduction possibilities afforded. *Triplett* has done just that with its new Model 310-FET.

Superficially, the new meter resembles the company's Model 310, which has been out for some time. This is a handy, compact v.o.m. measuring only 2¾" × 4¼" × 1⅛" that could readily slip into a shirt pocket. The previous instrument is fairly conventional except for its small size, with an input sensitivity of 20,000 ohms/volt on d.c. and 5000 ohms/volt on a.c. Price of the unit is around $44.

The Model 310-FET is the solid-state version of this pocket-sized meter. For an additional $26, you get a v.o.m. with a 10-megohm input resistance on all d.c. voltage ranges, sensitivity about ten times greater than the conventional bench-type v.t.v.m. in the 0.3-volt range, and resistance readings to 5000 megohms.

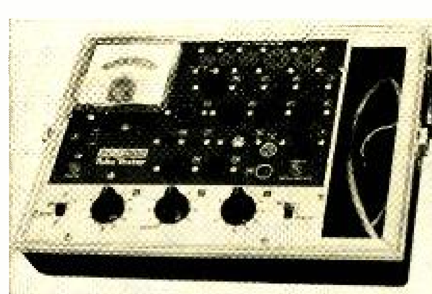
The little unit has a thumb switch on the side for polarity reversal and a single selector switch on the front for choice of test and range. On one position of this switch the condition of the 7-V battery that powers the FET bridge circuit can be checked. The condition of the 1½-V battery in the ohms-measuring circuit is checked merely by being able to zero-adjust the meter. If you are interested in measuring large values of a.c. current without having to open the circuit, you can attach an a.c. clamp-on meter adapter.

The meter has six d.c. voltage ranges (from 0.3 V to 600 V full-scale), five a.c. voltage ranges (from 3 V to 600 V full-scale), two d.c. current ranges (1.2 μA and 120 μA full-scale), and four resistance ranges. Accuracy is 3 percent on d.c. and 4 percent on a.c. A taut-band meter movement is employed.

The hand-sized Model 310-FET, which weighs a mere 14 ounces, is available for $70. ▲

Eico Model 635 Tube Tester

For a copy of manufacturer's brochure, circle No. 30 on Reader Service Card.



ALTHOUGH much of our consumer electronics equipment is now solid-state, there are still plenty of tubes in use in black-and-white and color-TV sets and in the older radios and hi-fi equipment. Hence, new tube testers continue to come from the various test-equipment manufacturers. One of the latest we have seen is the new *Eico* Model 635. This is a very lightweight, highly portable tester that is still versatile enough to check just about any tube in present-day or older equipment.

The plastic luggage-type carrying case measures only 12½ by 9 by 4 inches deep and the entire instrument weighs just 4½ pounds. With this tube checker tucked under your arm and the little v.o.m. described above in your shirt pocket, you have a good start in trouble-shooting any piece of gear using tubes.

The top five red sockets on the unit are pin straighteners while the remaining sixteen sockets are for testing just about any presently used tube type, including nuvistors, compactrons, 9-pin novars and neonovals, 10-pin miniatures, and 12-pin duodecars. The usual grid-leakage and shorts tests are performed along with the standard emission test. Total cathode current is read on a 3-in meter.

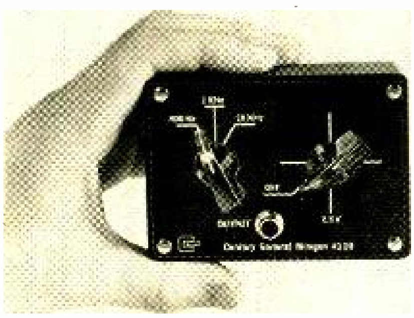
Setup and use of the tester is quite simple, although we were a little surprised to find the tube sockets lettered from right to left and the operating controls numbered from right to left rather than the usual left to right.

Tucked away in a compartment at the right is an adapter cable for use in testing picture tubes. The instrument checks standard 8- and 12-pin 110-degree black-and-white TV picture tubes for emission and shorts.

The Model 635 is available as a kit at $45 or factory-wired at $70. ▲

Century General Model 4110 Audio Generator

For a copy of manufacturer's brochure, circle No. 31 on Reader Service Card.



WE seem to be celebrating pocket test equipment month in this issue's test-equipment column. You can almost be a walking test lab with the *Triplett* 310-FET in your shirt pocket, the *Eico* 635 tube tester under your arm, and now the *Century General* Model 4110 audio generator in another pocket.

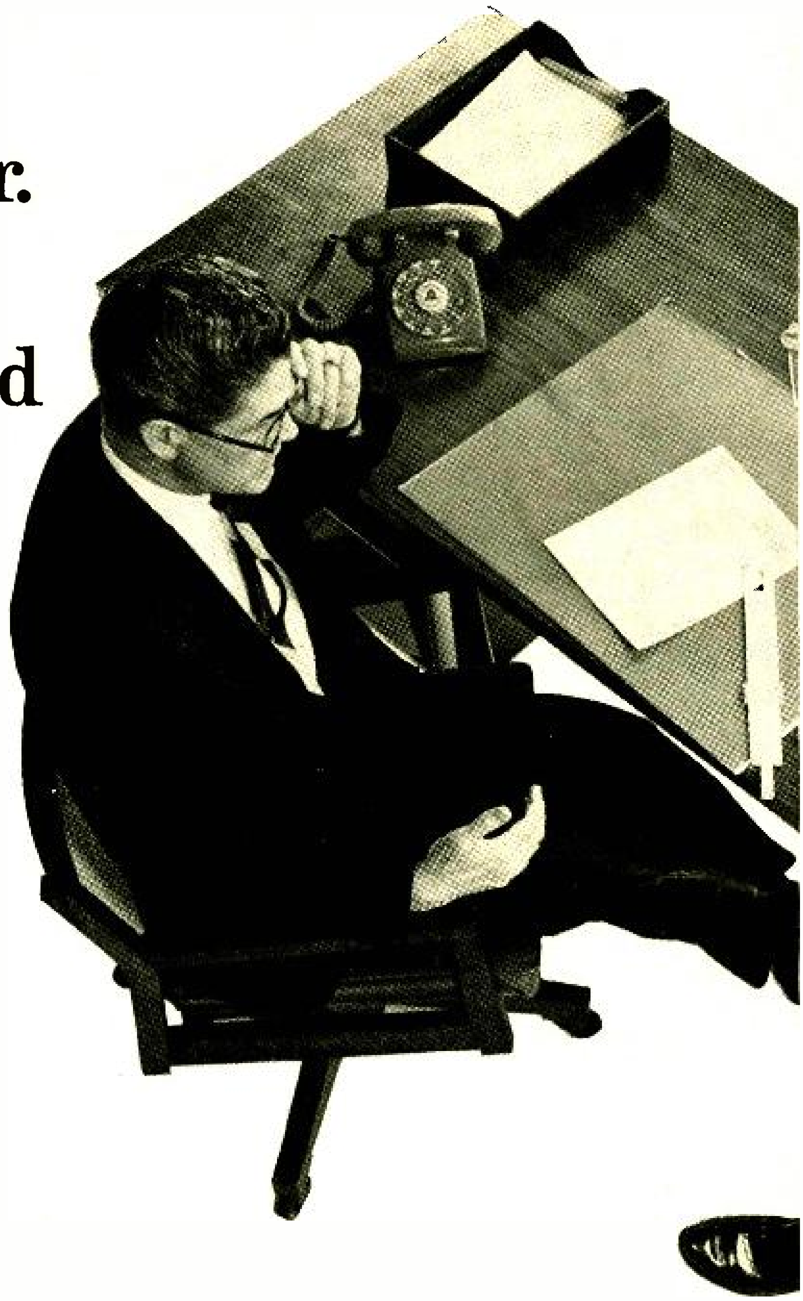
This generator, which measures only 4 in by $2\frac{7}{8}$ in by $1\frac{5}{8}$ in deep and weighs a mere $7\frac{1}{2}$ ounces, supplies three fixed audio test tones for checking out and signal-tracing hi-fi and p.a. equipment as well as the audio sections of radios and TV sets.

The device consists of a single-transistor oscillator with three different capacitance values switched in to produce the three fixed output frequencies. An output level control is provided. The circuit is powered by a 9-V transistor battery.

The three frequencies marked on the front panel are 400, 1000, and 10,000 Hz while the maximum output level is given as 2.5 volts. These are all nominal values. The unit we checked out produced fairly good sine waves at 420 Hz at an output of 2.65 V maximum, 1010 Hz at an output of 2.85 V maximum, and 8900 Hz at an output of 3.5 V maximum. Battery current drain was 12 mA at the three frequencies.

Price of the little plastic-cased generator is $15 with probe and battery. ▲

"He's a good worker. I'd promote him right now if he had more education in electronics."



Could they be talking about you?

You'll miss a lot of opportunities if you try to get along in the electronics industry without an advanced education. Many doors will be closed to you, and no amount of hard work will open them.

But you can build a rewarding career if you supplement your experience with specialized knowledge of one of the key areas of electronics. As a specialist, you will enjoy security, excellent pay, and the kind of future you want for yourself and your family.

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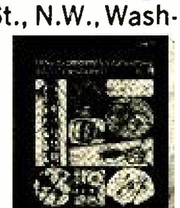

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Solid-State Inductor

(*Continued from page* 37)

Hall device could simulate an inductor by connecting a capacitor across its output terminals, Kataoka carried the circuit idea one step further and integrated the capacitor into the Hall-effect device. The Kataoka SSI (solid-state inductor) consists of two thin slabs of *InSb*—one of the *p*-type and the other of the *n*-type—separated by a thin layer of a metal oxide dielectric. With a permanent magnet fixed to the device, the two slabs of *InSb* act as plates of a capacitor, and the voltage across the input terminals leads the input current, as illustrated earlier in Fig. 4B.

Of course the metal-oxide capacitor is not perfect, and the internal resistance and Hall constant tend to limit the "Q" of the SSI. One of Dr. Kataoka's early inductors has a nominal inductance of 570 μH, and a "Q" factor of 0.37 at 1 kHz. By conventional choke standards this is, indeed, a poor inductor. Dr. Kataoka is quick to point out, however, that future improvements in design will soon increase the SSI performance to the point that it may become a major breakthrough in integrated-circuit technology. ▲

Editor's Note: For readers who are interested in further information on the Hall effect and on instruments that utilize this effect for magnetic measurements, refer to the article "The Hall Effect" by John R. Collins which appeared in our April, 1963 issue.

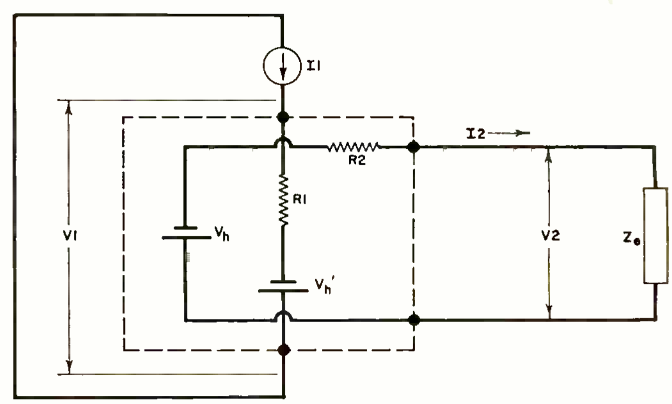
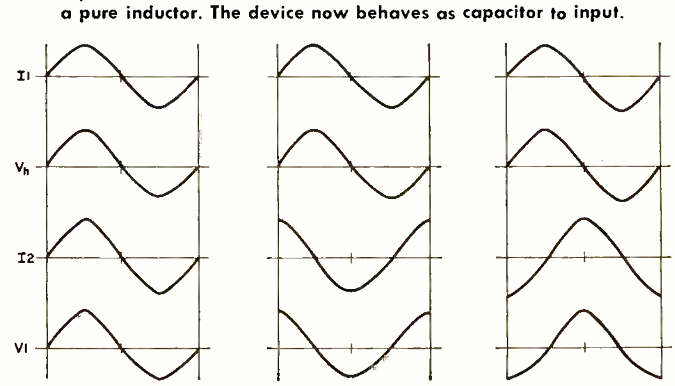


Fig. 3. Equivalent circuit of loaded Hall device. When loaded with a fairly low impedance, Z_e, a Hall current I2 flows through the intrinsic transverse resistance, R2, and the external circuit. Since this current is subjected to the same Hall phenomenon as I1, the Hall current creates a secondary Hall voltage, V'_h, that tends to oppose input current.

Fig. 4. Phase relations between voltages and currents in a. c.-operated Hall device. In (A) the device is resistively loaded and all waveforms are in phase. In (B) a pure capacitance has been connected across the output terminals. The Hall current, I2, leads its source voltage, V_h, by 90 degrees. This voltage lag is reflected in the secondary Hall voltage which is mainly responsible for the V1 potential. As shown, the voltage across the input of the device leads the applied current by 90 degrees—just like an inductor. In (C) the device has been loaded with a pure inductor. The device now behaves as capacitor to input.



New Messenger 124 full-function, 23-channel base station. $289.95

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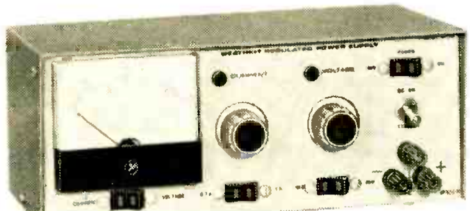

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NEW Heathkit Color Bar-Dot Generator... Advanced Integrated Circuitry Produces 12 Patterns Plus Clear Raster, Eliminates Divider Chain Instability Forever

The new IG-28 is the signal source for all color and B&W TV servicing. No other instrument at any price will give as much stable, versatile TV servicing capability. Its solid-state circuitry produces dots, cross hatch, vertical and horizontal bars, color bars, and shading bars in the familiar 9x9 display . . . plus exclusive Heath 3x3 display of all these patterns . . . plus a clear raster that lets you adjust purity without upsetting AGC adjustment. Fifteen J-K Flip-Flops and associated gates count down from a crystal controlled oscillator, eliminating divider chain instability and adjustments. And for time-saving convenience the IG-28 has variable front panel tuning for channels 2 through 6. Plus & minus going video signals at the turn of a front panel control . . . for sync, in-circuit video or chroma problems, use the front panel sync output. Two front panel AC outlets for test gear, TV set, etc. Built-in gun shorting circuits and grid jacks too. Add any service-type scope with horizontal input and you have vectorscope display capability as well. Fast, enjoyable circuit board-wiring harness construction. You can't beat the Heathkit IG-28 for versatility or value . . . put it on your bench now. 8 lbs.

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Tunes both narrow and wide band signals between 154-174 MHz . . . for police, fire, most any emergency service. Exceptional sensitivity and selectivity, will outperform other portable receivers. Smart compact styling, portable or fixed station capability with accessory AC power supply, variable tuning plus single channel crystal control, collapsible whip antenna, adjustable squelch control, easy circuit board construction. The new GR-88 receiver is an added safety precaution every family should have . . . get yours today! 5 lbs.

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Tunes 108 through 136 MHz for monitoring commercial and private aircraft broadcasts, airport control towers, and many other aircraft related signals. Same exceptional features as the GR-88 above. The perfect receiver for aviation enthusiasts. 5 lbs. **GRA-88-1**, Accessory AC Power Supply. . .**$7.95***

NEW Heathkit Deluxe Radio-Controlled Screw-Drive Garage Door Opener Semi-Kit

The next best thing to a personal doorman. The "wireless" factory assembled transmitter operates up to 150 feet away. Just push the button and your garage door opens and the light turns on . . . and stays on until you're safely inside your home. The giant 7 ft. screw mechanism coupled with the ¼ HP motor mean real power and reliability and the adjustable spring-tension clutch automatically reverses the door when it meets any obstruction . . . extra safety for kids, pets, bikes, even car tops. Assembles completely without soldering in just one evening. Easy, fast installation on any 7′ overhead track (and jamb & pivot doors with accessory adapter). Order yours now. 66 lbs.

Adapter arm for jamb & pivot doors, Model GDA-209-2, **$7.95***

From The Leader HEATHKIT®

NEW Heathkit Ultra-Deluxe "681" Color TV With AFT . . . Power Channel Selection & Opt. RCA Hi-Lite Matrix Tube

The new Heathkit GR-681 is the world's most advanced Color TV with more built-in features than any other set on the market. Automatic Fine Tuning on all 83 channels . . . power push button VHF channel selection, built-in cable-type remote control . . . or you can add the optional GRA-681-6 Wireless Remote Control any time . . . plus the built-in self-servicing aids that are standard on all Heathkit color TV's. Other features include high & low AC taps to insure that the picture transmitted exactly fits the "681" screen, automatic degaussing, 2-speed transistor UHF tuner, hi-fi sound output, two VHF antenna inputs, top quality American brand color tube with 2-year warranty. With optional new RCA Matrix picture tube that doubles the brightness, **Model GR-681MX** only **$535.00.**

GRA-295-4, Mediterranean Cabinet shown **$124.95***

Heathkit "295" Color TV

With Optional RCA Matrix Tube . . . with the same high performance features and built-in servicing facilities as GR-681 above . . . less AFT, VHF power tuning and built-in cable-type remote control. You can add the optional GRA-295-6 Wireless Remote Control at any time. New optional RCA Matrix tube doubles the brightness, **Model GR-295MX, $485.00.**

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Both the GR-681 and GR-295 fit into the same Heath factory assembled cabinets; not shown Early American style at $109.95*

NEW Deluxe Heathkit "581" Color TV With AFT

The new Heathkit GR-581 will add a new dimension to your TV viewing. Brings you color pictures so beautiful, so natural, so real . . . puts professional motion picture quality right into your living room. Has the same high performance features and exclusive self-servicing facilities as the GR-681, except with 227 sq. inch viewing area, and without power VHF tuning or built-in cable-type remote control. The optional GRA-227-6 Wireless Remote Control can be added any time you wish. And like all Heathkit Color TV's you have a choice of different installations . . . mount it in a wall, your own custom cabinet, your favorite B&W TV cabinet, or any one of the Heath factory assembled cabinets.

GRA-227-2, Mediterranean Oak Cabinet shown **$109.95***

Heathkit "227" Color TV

Same as the GR-581 above, but without Automatic Fine Tuning . . . same superlative performance, same remarkable color picture quality, same built-in servicing aids. Like all Heathkit Color TV's you can add optional Wireless Remote Control at any time (GRA-227-6). And the new Table Model TV Cabinet and roll around Cart is an economical way to house your "227" . . . just roll it anywhere, its rich appearance will enhance any room decor.

GRS-227-5, New Cart and Cabinet combo shown **$54.95***

Both the GR-581 and GR-227 fit into the same Heath factory assembled cabinets; not shown, Contemporary cabinet $64.95*

NEW Heathkit Deluxe "481" Color TV With AFT

The new Heathkit GR-481 has all the same high performance features and exclusive self-servicing aids as the new GR-581, but with a smaller tube size . . . 180 sq. inches. And like all Heathkit Color TV's it's easy to assemble . . . no experience needed. The famous Heathkit Color TV Manual guides you every step of the way with simple to understand instructions, giant fold-out pictorials . . . even lets you do your own servicing for savings of over $200 throughout the life of your set. If you want a deluxe color TV at a budget price the new Heathkit GR-481 is for you.

GRA-180-1, Contemporary Walnut Cabinet shown **$49.95***

Heathkit "180" Color TV

Feature for feature the Heathkit "180" is your best buy in color TV viewing . . . has all the superlative performance characteristics of the GR-481, but less Automatic Fine Tuning. For extra savings, extra beauty and convenience, add the table model cabinet and mobile cart. Get the value-packed GR-180 today.

GRS-180-5, Table Model Cabinet & Cart combo **$42.50***

Both the GR-481 and GR-180 fit the same Heath factory assembled cabinets; GRA-180-2, Early American Cabinet $94.95*.

Add the Comfort And Convenience Of Full Color Wireless Remote Control To Any Rectangular Tube Heathkit Color TV . . . New Or Old!

Kit GRA-681-6, for Heathkit GR-681 Color TV's **$64.95***
Kit GRA-295-6, for Heathkit GR-295 & GR-25 TV's **$69.95***
Kit GRA-227-6, for Heathkit GR-581; GR-481 & GR-180 Color TV's **$69.95***

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Paleomagnetism

(*Continued from page 26*)

an effective shield against outer space *gamma* radiation. During a reversal, much of this shielding is lost. It was once thought that the increase in *gamma* radiation would directly cause mutations of organisms with both extinction and creation of new species. This has been generally discounted on the basis of lower atmosphere shielding and other effects. What the *gamma* radiation increase does accomplish is profound climatic changes through changes in upper atmosphere ionization levels and shifts in weather patterns. The results are definite changes in habitat. There is some evidence to back up major extinctions with reversals, again through the paleomagnetic record.

Geology Applications

The layered or stratigraphic ordering in a thick sequence of geological deposits can be uniquely positioned through the presence and length of the reversals, sort of a "tree-ring" dating technique of use to the geologist. Given suitable calibration, absolute ages of widely separable deposits may be determined.

Early magnetic surveys indicated strange anomalies in the middle of each major ocean, very straight areas with wildly varying inclinations and declinations on either side. Closer inspection has indicated that these are not anomalies at all, but are an exactly defined, symmetrical record of the reversals in the past as newer and newer material is forced up the middle from the depths of the earth. This concept is called *sea-floor spreading*, and all the major oceans expand by an inch or so per year. Earthquakes seem to be somehow related to this spreading process.

Should two samples of the same age, in close proximity, give different values of declination or inclination, we can conclude that one has moved with respect to the other after the TRM had been picked up. Tracing these motions tells much about the origins of the earth and land-building processes. The motions may be local, wide-area, or world-wide.

Local rock and formation movements help explain faulting, erosion, mountain building, and related phenomena. Wide area motions allow the explanation and dating of major landform separations, such as the opening of the Gulf of California, or Madagascar becoming an island.

World-wide motions go under the name of *continental drift*. The original theory was based on the assumption that South America ought to "fit" into the notch in Africa. Paleomagnetic variations were the first to support this theory. Paleogeologists have postulated the existence of two super-continents, Gondwanaland to the south and Laurasia to the north, which broke up some 60 million years ago. Within the last year, a tremendous amount of independent support for this theory has evolved, including more paleomagnetic measurements, correlation of deposits in Africa and South America, mathematical fitting together of continental shelves, and satellite techniques. The amount of motion produced by sea-floor spreading provides a creditable driving force for the drifting.

Wholesale shifts in the positions of the magnetic poles in the distant past have also been observed. This is the theory of *polar wandering*, another major study area of paleogeology. Again, principal and initial support for this theory is based on paleomagnetism.

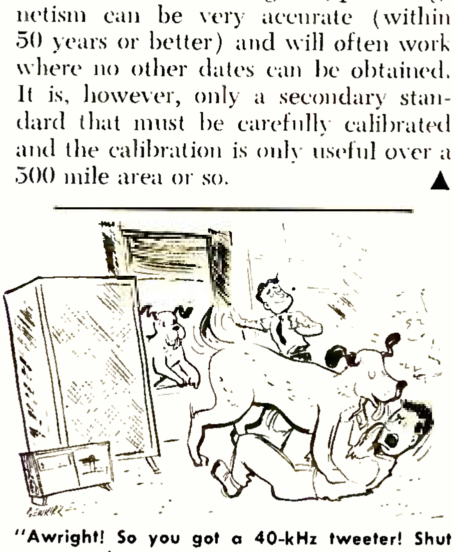
Archeology Applications

Archeologists use paleomagnetism as a support science, to gain cultural information, and as an absolute dating tool. Since the time scale in archeomagnetism is typically less than 10,000 years, the continents can be assumed to be stationary and the field can be assumed to be free from reversals.

As a support science, paleomagnetism can explain some substantial inaccuracies in the carbon-14 dating technique, particularly a 750-year error some 4000 years ago. The errors are thought to be caused by *gamma* radiation variations and a correction curve now exists which can greatly increase the accuracy of the C-14 process.

Cultural information is gleaned from paleomagnetism in special instances. The inclination and declination of the magnetic field of rocks in a road can sometimes be traced to a particular quarry. Tradeware pottery can often be traced to its origin if the pot can be assumed to have been fired right-side up. Other stone, materials, and cultural sources may sometimes be located by this technique.

As an absolute dating tool, paleomagnetism can be very accurate (within 50 years or better) and will often work where no other dates can be obtained. It is, however, only a secondary standard that must be carefully calibrated and the calibration is only useful over a 300 mile area or so. ▲



"Awright! So you got a 40-kHz tweeter! Shut the window or CUT IT OFF!"

DECIBELS WITHOUT LOGS

By WILLIAM G. MILLER/Industrial Electronics Corp.

A simple method of solving decibel problems in seconds mentally without using charts, tables, or slide rules.

DECIBEL problems can be solved easily without the use of algebraic expressions, log tables, slide rules, or nomograms. As a matter of fact, with a little practice, you should be able to make accurate mental calculations.

To begin with, it is necessary to memorize two key numbers and their associated dB figures. The key number will tell you what to do to the *power* value when its related dB figure is used.

1. For 10 dB, the key number is *10*.
2. For 3 dB, the key number is 2.

This means that for an increase or a +10-dB change, our power level would be *multiplied by 10* and for a decrease or — 10-dB change, we would *divide by 10*.

Similarly, a +3-dB change would then indicate that we *multiply the power level* by 2 and a −3-dB change would mean that we must *divide by 2*.

While it is quite easy to see how an amplifier with a 3-dB gain will double the input power, it may be more difficult to realize that an amplifier with a 57-dB gain will have double the power output of an amplifier with a 54-dB gain (both referred to the same 0-dB level).

The power is doubled for *every* 3-dB gain and halved for *every* 3-dB loss. This means that we had to double the power 18 times to get to 54 dB and once more to get to 57 dB.

By way of another example, an antenna with a 30-dB gain can deliver only one tenth the signal power of an antenna with a 40-dB gain. Note that the power is multiplied by 10 for *every* 10-dB gain and divided by 10 for *every* 10-dB loss.

The antenna reference level was multipled by 10 four times to get to 40 dB and then divided by 10 (−10 dB) to get back down to 30 dB.

Up to this point, we have been using the 10-dB and 3-dB figures separately, but they can be used together to form many combinations.

Problem 1: Increase 4 watts by 13 dB.

Solution: First increase the level by 10 of the 13 dB (to 40 watts). Now increase it by the remaining 3 dB (double the 40 watts).

Answer: 80 watts.

Problem 2: Increase 4 watts by 7 dB.

Solution: First increase the level by 10 dB (40 watts), then subtract 3 dB by dividing by 2.

Answer: 20 watts.

Many combinations of 3 and 10 can be used to arrive at the decibel figure you want and different combinations can be used to achieve the same answer.

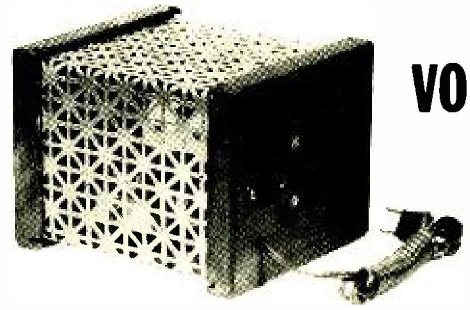
Technicians who are familiar with powers of ten can pick up even more speed when it is considered that each 10-dB change means that the decimal point is moved one place.

Problem: Attenuate 6 watts by −33 dB.

Solution: Move the decimal point 3 places to the left and halve the result.

Answer: 0.003 watt.

Voltage and current ratios can also be expressed in decibels but the decibel figure associated with the key number is doubled. 1. For 20 dB the key number is *10*. 2. For 6-dB the key number is 2. The same method as described above can then be used for voltage and current ratios. ▲



VOLTAGE REGULATOR For Enlarger Lamp

By ROBERT A. WOLFF

EVERY time an amateur photographer turns on his high-intensity enlarger lamps, he runs the risk of having exposures ruined by variations in lamp brilliance. However, if he uses a solid-state constant-voltage power supply as an energy source, he assures himself of constant light output irrespective of voltage variations.

One of the niceties of a solid-state power supply is that it's easy to build. Parts are inexpensive and available at most electronics supply stores, and only a modicum of specialized electronics know-how is needed. The unit discussed in this article is one which any amateur electronics man can construct.

The transformerless solid-state package, shown in photo, weighs less than two pounds. It can deliver a constant 120-volt d.c. output to a 75-watt enlarging lamp or photoflood, irrespective of line-voltage variations which range from 100 to 140 volts. The unit can also be used with 150-watt enlarger lamps if the enlarging process does not exceed the normal exposure periods.

The constant-voltage supply shown in Fig. 1 is basically a conventional series voltage regulator driven by a full-wave line-voltage rectifier. Advantage is taken of the rectifier's capability of producing an output voltage equal to the peak value of the a.c. line, or about 170 volts. (Under low-line conditions, for example, 100 V a.c., the rectified output is about 140 volts which is more than adequate for a 120-volt load.) By employing full-wave rectification, the period between peaks is halved, thereby allowing a small, more economical filter capacitor to be used. The 3-ohm resistor in series with the controlled avalanche-type diode bridge limits the surge current to a safe value during turn-on.

The TI3031 series-regulator transistor is a low-cost germanium *p-n-p* audio power device. When it is properly heat sinked, this transistor is untroubled by high ambient temperature conditions and line-voltage variations.

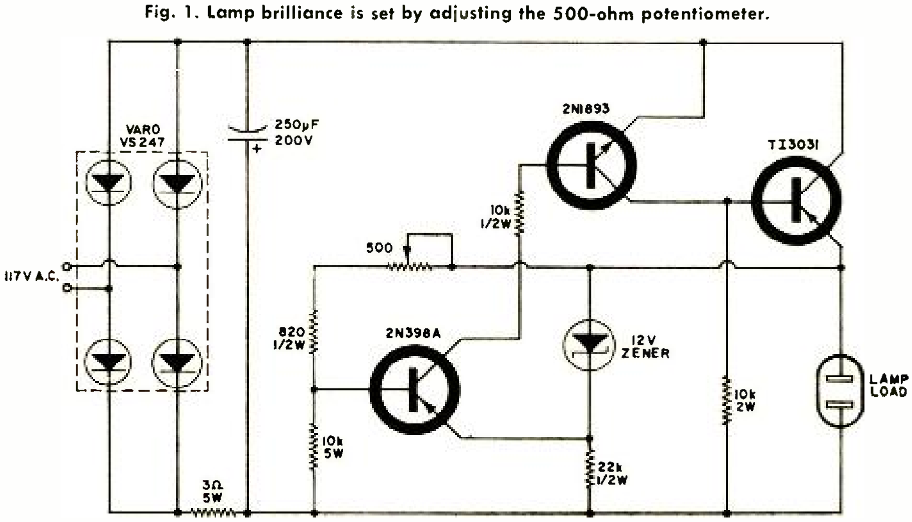
The regulator transistor is driven by a two-stage error amplifier referenced by a 12-volt zener diode. Zener and resistor tolerances are accommodated by the base-bias control potentiometer in the first error stage. Since the final output voltage is sensitive to changes in bias resistance, the 10,000-ohm, 5-watt resistor is purposely overrated to limit temperature rise and minimize shifts in resistance over extended periods of operation.

Setting Light Output

One of the easiest ways to set the voltage control is by the comparison method. Plug a 75-watt lamp into a standard household outlet, and carefully take a light-meter reading at a fixed distance away. Plug the same lamp into the power supply and carefully adjust the voltage control until the lamp brilliance gives the same light-meter reading as in the previous measurement. The constant-voltage supply will now maintain this brilliance, regardless of line-voltage variations.

Several prototype voltage regulator systems were built by the author. Each performed well under conditions of wide line-voltage fluctuations. ▲

Fig. 1. Lamp brilliance is set by adjusting the 500-ohm potentiometer.

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Public-Address Systems

(Continued from page 36)

series-output circuit as used in the *University Sound* Model UPL-60, a 60-watt amplifier, is shown in Fig. 8.

Two class-AB-operated *n-p-n* transistors, Q401 and Q402, are operated in series fashion as in the earlier circuit, except that separate positive and negative power supplies are used. This configuration eliminates the need for the output capacitor with its inherent low-frequency power limitation.

Instead of a driver transformer, a complementary pair of transistors, Q304 (*n-p-n*) and Q308 (*p-n-p*), are used to accomplish the phase inversion. A complementary series pair of transistors may be driven with the same signal phase because the characteristics of the *p-n-p* and *n-p-n* devices automatically select the proper phase and invert one for driving the output transistors.

Forward bias is derived from the drop across diodes *D*305, *D*306, and *D*307. By using junction diodes it is possible to attain excellent compensation for the variation in the base-emitter drop of Q304 and Q308 with temperature. By thermally coupling the diodes to the transistors, idling current of the output stage is kept fairly constant over a wide range of temperature and supply voltage. This prevents thermal runaway.

The d.c. voltage at the output is essentially zero. This condition is maintained over a wide range of temperature and drive conditions by the use of an extremely large amount of d.c. feedback, back to the base of Q302, one half of the differential amplifier.

Protection of the output transistors is accomplished through a sophisticated circuit which operates as follows. When a high emitter current results from a short circuit in the load, it develops a sufficiently high voltage at the bases of Q305 and Q306 so that they are switched into the "on" mode. As a result, diodes *D*304 and *D*308 provide a shunt path for the drive current from the driver. This limits the drive current, and consequent dissipation of the output transistors, to a level which prevents immediate destruction. If operated in this fashion for more than a second or so the output transistors may be damaged. To keep this from occurring, Q305 also switches Q307 on, which with its associated circuitry controls the base voltage of Q208. This, in turn, acts as a switch controlling the signal to the power stage. The time constants are chosen so that with a severe overload condition the signal is off for about 3 seconds, after which the amplifier is automatically turned on again. If the short circuit persists, the amplifier is turned off again in about 100 milliseconds for another 3-second period. This duty cycle is such that the amplifier may be left operating continuously into a short circuit without damage to the transistors.

A unique feature of this amplifier is that it is available with an output autotransformer or, at lower cost, without a transformer. Since a transformer represents one of the more costly components in the amplifier, eliminating it in those installations where the loudspeaker is capable of true wide-range reproduction and is located close to the amplifier, represents a tidy saving.

The use of the output-transformerless amplifier for large multi-speaker installations does not appear practical. Sound technicians have enough to do laying out the system using transformers marked in watts without making the cumbersome calculations needed to lay out a series-parallel combination of voice coils. Furthermore, the frequent need to re-allocate power to some speakers in the system after it is "fired up" precludes a method which requires a complete rewiring of a group of speakers to adjust the power from one speaker to a different level.

(Continued Next Month)

Multiplexing Entertainment

(*Continued from page 41*)

wire is a distributor (demultiplexer) rather than an input selector. This output distributor is synchronized with the speed and frequency at which the inputs are sampled. When input A is sampled, the output circuitry is connected to speaker A. When B is sampled, the output is connected to speaker B. The speaker that is selected reproduces the small portion originally sampled at the input.

This multiplexing system has the capability of transmitting audio signals to the seat transducers with a flat response of from 50 to 10,000 Hz, and with an output power of 150 mW per ear. Signal-to-noise ratio and dynamic response are both 70 dB and the audio sample quantization is 12 bits per sample.

Advantages & Future Uses

The use of multiplexing in an aircraft yields many advantages. One is the weight savings that result from the use of a single coaxial wire rather than a conventional multiple hard-wire system. Many miles of wire, many multi-pin connectors, and interconnecting wire harnesses are eliminated. Approximately 500 pounds is saved per plane through the use of the multiplexing system in the 747.

Improved reliability results in improved maintenance and repair. The elimination of numerous multiple-pin connectors and large, bulky harnesses does away with a prime source of system problems.

Since the boxes are small and lightweight, they are easy to install, remove, and maintain. Modular construction techniques facilitate rapid checkout and repair of any system malfunction. Built-in self-test equipment automatically isolates any fault to the individual unit responsible in the event of a malfunction in the system.

What does the future hold for the multiplexing technique? Much of the information transmitted through and around an aircraft lends itself to the same advantages multiplexing has provided for the passenger service and entertainment system in the 747. For example, the sensors on engines, cockpit instrumentation, fuel management, and radio and intercom systems can all be adapted to the multiplexing technique with all its attendant advantages.

In other areas, communications and data-processing requirements for factories, schools, hospitals, and other large multiple-monitoring facilities could also take advantage of the cost savings, added reliability, and other features inherent in a data transmittal and/or communications system that uses the multiplexing technique. ▲

The "New Sound"
(*Continued from page 39*)

which place the narrower width at the lower edge of the tape path.

Tensions for one-inch tape are different than for two-inch tape and to facilitate rapid changes between the two, a switch is conveniently provided inside the back of the control relay box. Additionally, the brakes must have their tensions re-adjusted and this is accomplished by inserting machined "D-" shaped washers in the spring bolts which control the brake tensions. Additionally, there is approximately a 2-dB difference between the output levels of the heads of the 8- and 16-track assemblies, therefore requiring the electronics to be recalibrated.

The 16-track machine is heavy, but we carried it up to the third floor of the Avalon Ballroom in San Francisco to record the "Grateful Dead." Bob Matthews, the group's engineer, used fourteen mikes on the stage and two mikes for the hall. Each microphone was connected directly to an individual channel and all mixing was done later at the studio. The fact that the machine will accommodate reels larger than the standard 10½" will be appreciated by engineers who can get their hands on 14" ones. We have used 14" reels with 7200 feet of 1-mil tape which gives 90 minutes of playing time at a speed of 15 in/s.

Problem Areas

Some of the problem areas to look for in the operation of a 16-channel recorder are: (1) Improper tape guiding which can damage the lower edge of the tape. Factory engineers carefully shimmed the taped counter to relieve this problem. (2) In the shuttle mode using one-inch tape, the tape pack is sometimes loose in the center of the reel and extremely tight on the outside of the reel. This sometimes causes flanging or slight turning of the edge of the tape. (3) The monitoring of overdubs in our studio is accomplished by listening to the output of the recorder. When adding a channel, we flip the output and meter switch to the input position and back again to the output position for listening. If this were relay-operated, then the entire operation of the recorder could be handled remotely. (4) The meters are not grouped at a central panel for easy-eye monitoring.

Despite these few shortcomings, the multichannel recorder represents a major advance in sound recording and we have ordered a second machine for our studio. We are certain that the 16-channel recorder will rapidly become the standard workhorse of the master recording industry and will remain so for many years to come. ▲

Automatic Tint Control

(*Continued from page* 31)

the first three bars are moved closer together but they do not overlap as shown. Also notice that the blue, cyan, and green bars on the opposite side of the display are unaffected by the correction circuit.

Other Automatic Circuits

In addition to the a.t.c. circuit described, many of the new *Magnavox* color receivers are continuing to feature automatic frequency control. This pulls the fine tuning to its proper setting for best color and maintains it, provided the manual fine-tuning control is reasonably close. This circuit has been in use for several years.

Also, a new automatic chroma control (a.c.c.) circuit is incorporated in top-of-the-line sets that use the automatic tint control. The a.c.c. circuit minimizes large variations in chroma amplitude so that it should not be necessary to readjust the Color (saturation) control frequently. Control is accomplished by changing the gain of the bandpass amplifier by means of a d.c. voltage. This voltage is negative and is applied to the grid of the bandpass amplifier tube. The amplitude of this negative voltage varies directly with the amplitude of the burst and the chroma signals.

The burst signal is rectified by killer detector diodes whose negative output feeds the grid of the bandpass amplifier. The chroma signal is also detected by a diode and this resultant output is amplified by a single-transistor amplifier. As the chroma signal increases in amplitude, the transistor conducts more heavily and applies a negative-going voltage to the grid of the bandpass amplifier tube. This reduces the gain of the bandpass amplifier and acts to maintain the chroma signal output constant. If the incoming chroma signal and burst go down in level, the negative voltage applied to the grid of the amplifier tube is reduced and gain is allowed to increase. In this way, the gain of the bandpass amplifier is adjusted automatically to keep its output relatively constant.

Magnavox is using the phrase "Total Automatic Color" to refer to its new models that include all three automatic features described above; namely, automatic frequency control, automatic chroma control, and automatic tint control. With circuits such as these being added to color receivers, the task of the viewer is being made more simple as the automatic features help to produce a still better color picture on the TV set.

The inventor of the a.t.c. circuit is Paul Knauer, Chief Color TV Engineer for *Magnavox*. We understand that patents on the circuitry have been applied for. ▲

NEW PRODUCTS & LITERATURE

For additional information on items identified by a code number, simply fill in coupon on Reader Service Card. In those cases where code numbers are not given, may we suggest you write direct to the manufacturer.

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AUTO TUNE-UP METER

A solid-state auto tune-up meter that uses no batteries and measures dwell, r/min, and d.c. voltage on any 4-cycle, 3-, 4-, 6-, or 8-cylinder engine with standard ignition has just been introduced as the ID-29.

The meter connects directly to the primary of the coil for both dwell and tach measurements,

and receives both signal and power directly from the engine under test. For breaker point settings, the function switch is set to the Dwell position and the dwell angle is read directly from the 4½" meter. To check r/min, the function switch is set to either the High (0-4500) or Low (0-1500) r/min position, the Cylinder switch is set to the proper number of cylinders and r/min is read on the meter. The built-in d.c. voltmeter can be used for checking faults in the electrical system.

The company estimates that the meter can be assembled in 5 hours. The instrument can be calibrated directly from the a.c. power line. The completed unit, housed in a rugged polypropylene case with carrying handle, weighs just 2½ pounds. Heath

Circle No. 1 on Reader Service Card

ULTRAMINIATURE CONNECTORS

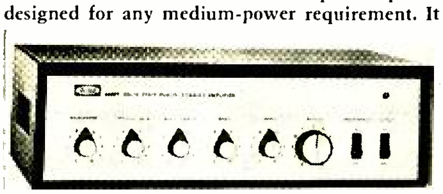
A new line of low-cost ultraminiature coaxial and multi-contact connectors to meet the demands of commercial and industrial markets has just been introduced.

To fabricate a coaxial cable assembly, the cable is simply threaded into the plug. To fabricate a multi-contact connector assembly, a special 4-conductor cable is soldered to the socket assembly and snapped into the plug body. Coaxial connectors are available in ultraminiature sizes with o.d.'s of ⅛" and ¼". Over-all length of the ultraminiature plug is less than ¼". The multi-contact connectors are available with either 4 or 7 pins having basic outer diameters of ¼" and 5/16", respectively. Over-all length of the plugs is less than ½".

For complete details on these connectors and special cables, write on your company letterhead to Microtech, Inc., 777 Henderson Blvd., Folcroft, Pa. 94032.

P.A. AMPLIFIER

The Model 3246T is a 45-watt p.a. amplifier designed for any medium-power requirement. It



will power sound columns, outdoor weatherproof trumpets, indoor baffled speakers, or may be packed into a speaker case for portable use.

An optional 4-speed manual phono-top can be attached with just a screwdriver to provide record reproduction.

Frequency response is 40-10,000 Hz. Outputs are 4, 8, 16 ohms plus 25 volts and 70.7 volts. An a.c. convenience outlet is provided. The circuit is solid-state and power consumption is 65 watts at 120 volts a.c. There are two microphone and two auxiliary inputs for crystal or ceramic phono cartridge, tuner, or tape recorder.

Complete specifications on this p.a. amplifier will be forwarded on request. Allied Radio

Circle No. 2 on Reader Service Card

DIGITAL A.C. VOLTMETER

A new a.c. voltmeter plug-in, the DP 130, has been designed to be used with any main frame of the firm's DMS 3200 digital measuring system to provide digital display of a.c. voltage measurements over an extremely wide range of level and frequency.

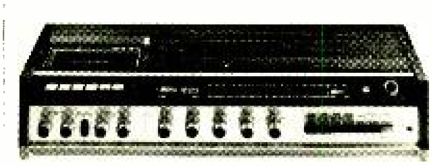
Measurements down to 10 microvolts and as great as 1000 volts are possible with an accuracy of ±0.1% of reading ±1 digit. Measurements may be made over the frequency range of 22 Hz to 1.0 MHz. Accuracy of 0.1% is maintained over the range 22-100,000 Hz and with slight reduction up to 1 MHz. The unit is designed to provide r.m.s. readings when measuring sine-wave a.c. signals; however, it will accept and display accurate indications of the r.m.s. value of square and triangular waveform inputs as well, if specified correction factors are applied to such measurements.

Additional information on the DP 130 will be supplied on request. Hickok

Circle No. 3 on Reader Service Card

RECEIVER/CASSETTE UNIT

The Model 3610 "Casseiver" is an AM/FM stereo receiver and cassette recorder combination



which features a silver-plated FET front-end and an integrated-circuit i.f. strip and preamplifier. H. H. Scott

Circle No. 4 on Reader Service Card

3-WAY SPEAKER SYSTEM

A new 3-way speaker system which features a 10" woofer, 6½" midrange, and 1" dome-shaped tweeter has just been introduced as the Model SP-1001. The system is housed in a walnut enclosure with hand-carved speaker grille.

Unique features of the system include push-button connection terminals for connecting input wires, electronic crossover system terminals for simple hookup of bi- or tri-amplification systems, in addition to the regular network system terminals. Another feature is a special step-down attenuator using a 12 dB/octave network which makes it possible to change output levels of the midrange and tweeter independently. The change is made in 3-dB steps.

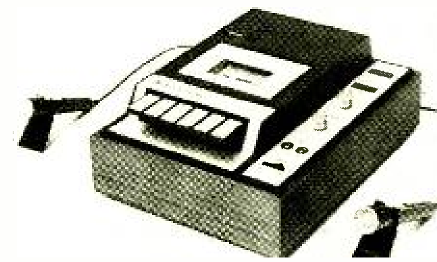
Maximum input is 40 W (IHF), impedance is 8 ohms, and the frequency response is 35-20,000 Hz. The unit measures 14" w. x 24½" h. x 12" d. Sansui

Circle No. 5 on Reader Service Card

CASSETTE RECORDER/PLAYER

The new TRA-14 cassette stereo recorder/player is housed in a genuine walnut case which measures 8½" w. x 4" h. x 11" d.

The unit is designed to play back through the company's "Space Age" stereo consoles but may



be used with other audio systems. The TRA-14 features two microphones and four connection cables, a.c. power cord, input-output jacks, and microphone jacks. It uses standard cassettes, has a speed of 1⅞ in/s, and has two level meters for accurate monitoring of signal input level. Packard Bell

Circle No. 6 on Reader Service Card

"DO-IT-YOURSELF" FILTERS

A recently introduced method by which a circuit designer can build his own 455-kHz filters easily and cheaply is based on a new standard Identical Resonator (IR). By using two or more of these standard IR's in conjunction with standard capacitors, the designer can build filters of any complexity with a continuous range of band-widths and selectivities.

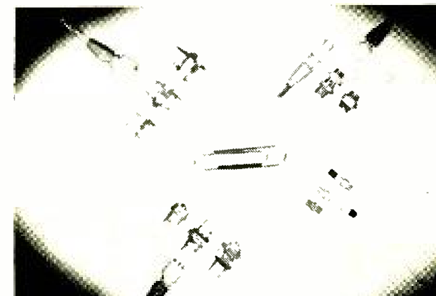
Tables listing the required capacitance values for a given filter response are available. By interconnecting known capacitors and IR's in a prescribed network configuration, the designer can build filters to his own specifications. Clevite

Circle No. 7 on Reader Service Card

LOW ON-RESISTANCE FET

Crystalonics, 147 Sherman Street, Cambridge, Mass. 02139 has announced the stock availability of the new CMX740 FET. The extremely low on-resistance of this device (2.5 ohms max.) provides unprecedented analog switching accuracy in D/A and A/D converters, according to the company. In addition, the CMX740 is said to be the fastest core-driving transistor, handling short-duration, very high current pulses (up to ½-amp minimum).

For full technical specifications and information on availability, address your letterhead request to



Joel Cohen, Director of Engineering, at the above address.

PRECISION RLC BRIDGE

The Model 2785 is a precision multi-purpose bridge for measuring capacitance, inductance, resistance, and "Q." Powered by two long-life 9-volt batteries, the built-in generator provides all the voltages needed for a wide range of measure-

ments. The generator operates on the standard test frequency of 1 kHz. For testing components at other frequencies, an external voltage input jack is provided.

Resistance measurements are made with voltage direct from the batteries or rectified from the generator for those ranges requiring higher voltages. A long slide-rule dial and sensitive galvanometer make it simple and fast to use the instrument. Accuracy is within ±1% on most resistance and capacitance ranges and to within ±1.5% on most inductance ranges. "Q" measurements have a maximum error of ±5%.

A catalogue sheet (L-1009) giving detailed specifications will be forwarded on request. Simpson

Circle No. 8 on Reader Service Card

COMPACT SYSTEMS

A new series of four stereo hi-fi component compacts has recently been introduced, each having both radio and phono facilities and including speaker systems.

The Model 1045, for example, includes the Miracord Model 50 changer with an Elac 244 stereo magnetic cartridge with diamond stylus, two EMI Model 62 two-way speaker systems, and an AM-FM stereo multiplex receiver.

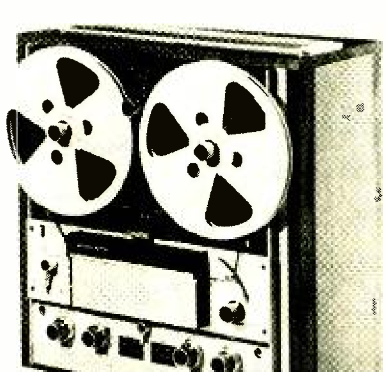
Output power is 60 watts (IHF) and power bandwidth is 25-30,000 Hz, with frequency response 10-100,000 Hz ±1 dB. S/N ratio on phono is −55 dB. The FM receiver sensitivity is 1.6 μV for 20 dB quieting and maximum separation is 28 dB at 1 kHz.

Optional accessories for use with this model include a dust cover, a 45 r/min spindle, and a cassette tape recorder. Benjamin

Circle No. 9 on Reader Service Card

TAPE RECORDER

The Ferrograph "Series Seven" tape recorder is now available in the U.S. in a 60-Hz, 117-V version. The fully transistorized unit incorporates three heads and unique editing features.



Complete details on the recorder are available on request, plus servicing and parts stocking in the U.S. Elpa Marketing

Circle No. 10 on Reader Service Card

FOGHORN/HAILER

A new marine accessory which combines five different functions into a single compact unit is now available as the Model MD-19. It consists of a foghorn, boathorn, hailer, listener, and, with the addition of the MDA-19-1 remote speaker accessory, an intercom.

The unit comes with a rugged push-to-talk microphone and a weather-resistant Jensen horn-type speaker with universal mounting base. The system operates from 12 V d.c. ship's power and comes complete with 20 feet of interconnecting cable and a handy gimbal mounting bracket. It measures 4½" h. x 8½" w. x 6" and is styled in marine blue and white. Heath

Circle No. 11 on Reader Service Card

REVERB AMPLIFIER

The Model SR-202 reverberation amplifier is a solid-state double scatter unit which produces sound with natural reverberation. When used in combination with stereo sound, it provides added depth, resulting in three-dimensional sound of concert hall "presence," according to the manufacturer.

The amount of reverb time can be adjusted as desired and the amount of depth used may be set to fit the recording and environmental acoustics. An easy-to-see light panel, with various patterns,

is coupled to the manually adjustable reverb control, supplying both aural and visual control of reverb.

Full details on the Model SR-202 will be supplied on request. Pioneer

Circle No. 12 on Reader Service Card

AUTOMATIC TURNTABLE

The new Model 300T automatic turntable is supplied premounted on an ebony base with walnut accents and is fitted with a Shure "Hi-Track" M75 stereo magnetic cartridge. It also features a factory set dynamic anti-skate control, low-mass tubular aluminum tonearm, light tracking design, and other features not usually associated with automatic turntables in its price range. BSR McDonald

Circle No. 13 on Reader Service Card

STEREO TUNER

The Model AT-200U stereo tuner incorporates a five-gang tuning capacitor in its front-end in addition to three FET's. The unit uses hybrid IC's and mechanical filters in the i.f. stage. It also has an active filter for subcarrier elimination, a high-blend noise-canceller circuit, and an adjustable FM separation circuit.

Frequency response of the FM section on stereo is 20-15,000 Hz ±1 dB. HD is 0.5% or better at 400 Hz, and stereo separation is 40 dB or better.

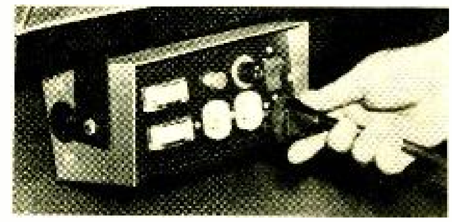
The tuner measures 16½" x 5⅜" x 11⅞". Teac

Circle No. 14 on Reader Service Card

INVERTERS FOR CARS

A compact inverter (8" x 4" x 4") designed to be mounted under the dash of any motor vehicle provides one 120-volt, 1800-watt (15-amp) receptacle plus outlets for 12-volt appliances and battery charging. Larger capacity models are also available that are able to deliver 2400 and 3600 watts.

These units feature a bypass system which eliminates any drain on the vehicle battery. An



automatic throttle control is also provided. Available as an accessory is an auto-start device which gives complete remote control to the operator.

The units can be used to operate most power tools, lighting, and appliances. A free brochure giving full details on the units is available on request. Dynamote

Circle No. 15 on Reader Service Card

AUTOMATIC TURNTABLE

The new Dual 1219 automatic turntable features 15° stylus tracking in single-play, a four-point gyroscopic gimbal, an 8¼" tonearm, separate anti-skating for conical and elliptical styli, synchronous/continuous-pole motor, full 12"-diameter dynamically balanced 7-lb platter, and a rotating single-play spindle.

The turntable will handle 33, 45, and 78 r/min records. The multiple-play spindle holds up to six records.

The chassis measures 14¾" x 12" plus 1" at rear and right for tonearm overhang. 5" clearance above and 3" below mounting board is required. United Audio

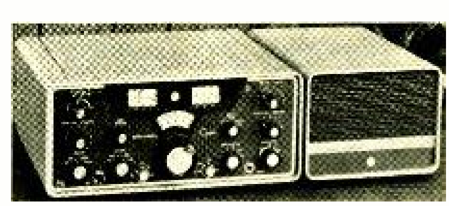
Circle No. 16 on Reader Service Card

COMMUNICATIONS SYSTEM

A 5-band, 10-meter SSB/c.w. transceiver has just been put on the market as the SR-400. The new unit features tuning which permits ±3 kHz adjustment of receiver frequency independent of transmitter for roundtable, net, or c.w. operation and a "dual-receive" v.f.o.

Dubbed the "Cyclone," the new unit provides full coverage for 80, 40, 20, 15, and 10 meters and is designed for dependable operation in the field, radio shack, or mobile. It has a built-in adjustable noise blanker unit which effectively blanks 10,000-μV pulses, making even less than 1-μV signals readable. It has a built-in c.w. filter (200 Hz), grid block keying, and a gear-driven tuning drive with less than 1-kHz readout.

The SR-400 measures 7¾" x 16½" x 15"



and is housed in a rugged two-tone grey enclosure with black control knobs.

Full specifications on this system for the advanced amateur will be forwarded on request. Hallicrafters

Circle No. 17 on Reader Service Card

AIRCRAFT MONITOR RECEIVER

A portable, solid-state aircraft monitor receiver which tunes from 108-136 MHz is now available in kit form as the GR-98.

A 6-to-1 vernier tuning control makes it easy to tune closely spaced stations while the built-in whip antenna, 40-kHz selectivity, and 1.5-μV sensitivity for a 10 dB (S + N)/N ratio insures good reception even under adverse conditions. An adjustable squelch control limits background noise, but still lets the transmitting station be heard.

For those wishing to monitor one station almost continuously, the GR-98 features crystal control of one channel.

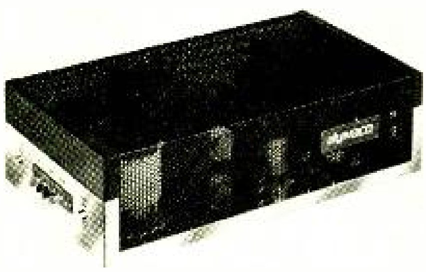
The unit weighs less than four pounds with its six "C" cells installed and measures 7¼" h. x 8½" w. x 3½" d. For fixed station use, the carrying handle converts into a tilt stand and an external antenna jack is provided. Heath

Circle No. 18 on Reader Service Card

TRANSISTORIZED STEREO AMP

The new transistorized Stereo 80 power amplifier is rated at 40 watts continuous r.m.s. power per channel across the entire audio spectrum with both channels driven simultaneously into 8 ohms. Harmonic distortion is under 0.5% and IM is under 0.1% at rated output. The two channels of the amplifier can be paralleled for 80 watt, 4-ohm monophonic operation when the inputs are also paralleled. The amplifier will operate reliably into such reactive loads as electrostatic speaker systems.

The Stereo 80 incorporates a patented current-



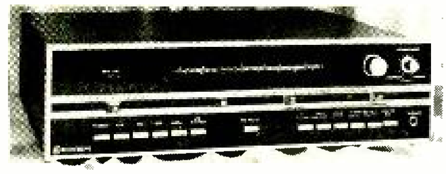
limiting protective circuit which acts automatically and eliminates the need for channel fuses or circuit breakers.

The amplifier is being offered in both kit and factory assembled versions. Dynaco

Circle No. 19 on Reader Service Card

STEREO RECEIVER

The Model BR360 AM-FM stereo receiver is rated 100 watts (IHF), 125 watts ±1 dB, and 40 watts per channel r.m.s. The unit features a new "Crescendo" control which is an all-electric dynamic range expander and compressor, high and low filters, ceramic i.f. filters, FM muting



circuit, tape monitor, IC's, an FET front-end, and all-silicon transistors.

The receiver panel is finished in silver and black and an optional walnut wood cabinet is available. Bogen

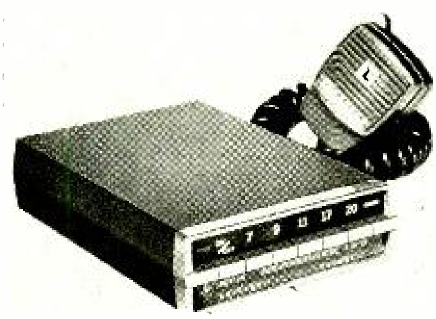
Circle No. 20 on Reader Service Card

COMPACT CB TRANSCEIVER

The new Messenger 125 CB transceiver measures just 1½" high x 4½" wide x 7" deep, making it suitable for installation in late model cars.

The five crystal-controlled channels plus the "on/off" function are controlled by push-buttons. The volume and squelch controls are of a new slide-lever type, located under the escutcheon, completely eliminating protruding knobs and other hardware.

Solid-state circuitry is used throughout, including 13 transistors, 7 diodes, and 2 thermistors. Sensitivity is 0.5 μV with 10 dB (S + N)/N ratio.



Selectivity is 6 kHz at −6 dB. This is achieved by using a newly developed ceramic filter. The r.f. output is rated at 4 watts at 13.8 volts d.c.

Complete details on this new 5-watt unit will be supplied on request. E. F. Johnson

Circle No. 21 on Reader Service Card

METAL LOCATOR

An all solid-state metal locator that will detect metal objects down to a six-foot depth has been introduced as the GD-48.

The new unit uses the induction-balance method of detecting buried metal, rather than the usual beat-frequency system in which the user must be able to detect a change in the frequency of the constant tone he hears. With the induction-balance system there is no tone until a metal object enters the field of the two coils and upsets their balance. A loud tone is then heard from the built-in speaker and increases in volume as the user nears the metal. For more accurate indications, a front-panel meter monitors the relative imbalance between the two coils. The unit is also equipped with a front-panel headphone jack to permit its use in noisy locations.

Both the search head and telescoping shaft are adjustable and the unit weighs just 3 pounds. It is powered by a single 9-volt battery and typical battery life is around 80 hours.

The circuit takes about 8 hours to assemble. The search head is supplied with both coils accurately aligned and cemented into place. Heath

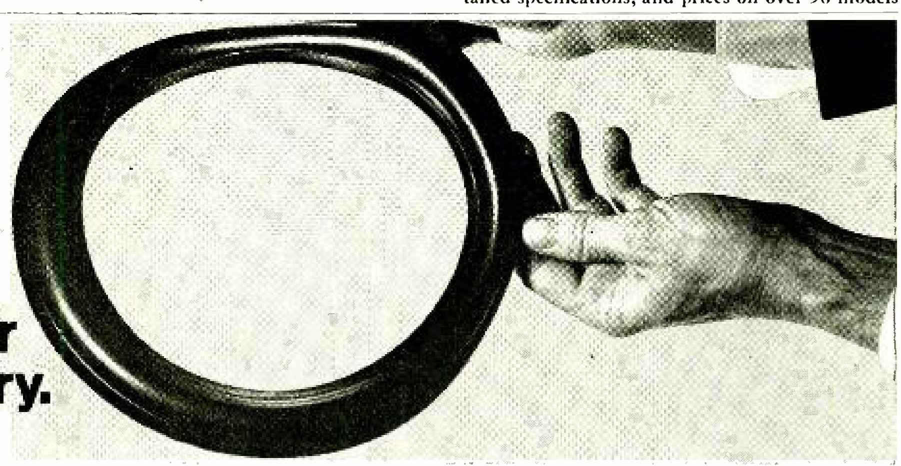
Circle No. 22 on Reader Service Card

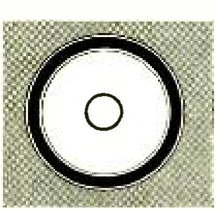
MANUFACTURERS' LITERATURE

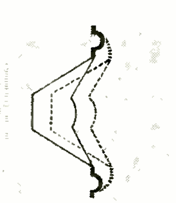
POWER INSTRUMENT LINE

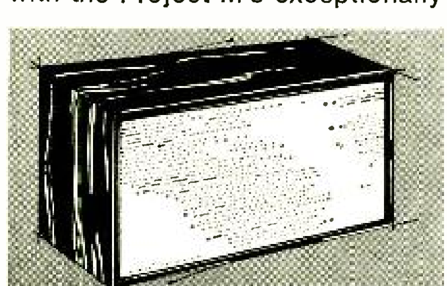
Lambda Electronics Corp., 515 Broad Hollow Road, Melville, N.Y. 11746 has just issued a new 16-page catalogue describing its line of all-silicon, convection-cooled power instruments for laboratory and test instrument use.

The catalogue gives performance features, detailed specifications, and prices on over 50 models









CIRCLE NO. 103 ON READER SERVICE CARD

of power instruments for rack or bench use. Also described is a new series of high-efficiency, high-current power instruments now available in a convection-cooled 7" package size. Accessories, including overvoltage protectors, chassis slides, metered and non-metered panels, are also described.

For a copy of catalogue L-4, write on your business letterhead to the address above.

LAMP CATALOGUE

A new catalogue describing a complete line of subminiature and microminiature lamps is now available for distribution.

Among the new units described are models of a T-⅜ unsupported-filament unbased lamp, a T-½ unsupported-filament unbased lamp, and nine line filament designs, ranging in length from 0.88 to 12.9 inches.

The line includes neon, helium-resistant, line filament, and axial lead lamps. The catalogue provides a technical review of the current state-of-the-art. The International Commission on Illumination's chromaticity diagram is also reproduced in full color.

Copies of this new catalogue are available on letterhead request to John F. Delaney, National Sales Manager, LAMPS, Incorporated, 17000 S. Western Ave., Gardena, California 90247.

ELECTRICAL TAPE DATA

A new Scotch brand electrical tape data and sample chart is now being offered by 3M Company, 3M Center, St. Paul, Minn. 55101.

In addition to sample strips and data on 37 types of standard Scotch brand electrical tapes, the chart contains a table of solvent and oil resistance of adhesive systems, a brief description of adhesive systems, curing data for thermosetting adhesives, and information on standard slitting tolerances and precision slitting services for special tapes.

A letterhead request to Dept. D19-2 at the above address will bring a copy.

PICTURE TUBE DATA

A 28-page "Picture Tube Product Guide" is now available for 40 cents a copy from RCA Electronic Components, Harrison, N.J. 07029.

The booklet lists data on all picture tubes where RCA has a replacement. The chart is based on industry registered picture tubes, industry standardized and registered bulb data, and manufacturers' published data. The information includes type number, envelope code, safety features, greatest deflection angle, heater, design maximum anode voltage, range of focus voltage in % of anode voltage, range of G2 voltage at G1 spot cut-off of −150 volts, screen diagonal, screen area, maximum over-all length, basing, and approximately tube weight.

An RCA picture tube interchangeability guide is also included.

Orders for this guide, PIX-300, should be sent direct to the company, accompanied by your payment.

KIT LINE

A four-page, two-color brochure covering an extensive line of solid-state kits is now available for distribution.

Details on a wide range of electronic project kits which include everything from AM wireless mikes to a battery-operated audio amplifier and electronic musical instrument accessories to ham gear are covered. Eico

Circle No. 23 on Reader Service Card

INDOOR TV ANTENNAS

A six-page data sheet describing a line of indoor antennas for color and black-and-white TV and FM stereo reception is available for distribution. Each unit is pictured and described in some detail and special features of the various units are covered. Spico

Circle No. 24 on Reader Service Card

REPLACEMENT COILS

A new 196-page coil replacement guide and catalogue has just been issued as Catalogue 170. The cross-reference section is a comprehensive and complete coil replacement guide for all known color and black-and-white TV sets, home and car radios. Over 35,000 replacement listings are included.

The catalogue gives specifications and prices on more than 3400 coils and components in the general catalogue section. J. W. Miller

Circle No. 25 on Reader Service Card

WORK-BENCH CATALOGUE

A 32-page catalogue entitled "Work Benches & Shop Equipment of Steel" is now available as No. 369.

The new publication describes in detail over 15 pages of work benches of all types and a wide variety of steel shop equipment, including storage racks, tool hardware, and storage cabinets; drafting room equipment, stools and chairs. Parent Metal

Circle No. 26 on Reader Service Card

SECOND-GENERATION IC's

A 24-page booklet describing a second generation of linear integrated circuits is now available. Included are seven currently available second-generation circuits and their applications and details on recent innovations that will appear as products in the near future in such applications as high-input-impedance operational amps, high-speed op amps, instrumentation amplifiers, a.c. power-control systems, micropower op amps, radiation-resistant op amps, wideband film memory amplifiers, and communications circuits.

Complete technical details are provided on the following IC's: μA719, μA722, μA723, μA727, μA733, μA739, and μA741. Ordering information and a listing of stocking distributors are also given.

For a copy of this booklet, write on your business letterhead to Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, California 94040.

ULTRASONIC CLEANING

An 8-page booklet, entitled "Principles of Ultrasonic Cleaning," is now available for distribution.

The booklet describes how ultrasonic cleaning is accomplished by energy produced by mechanical vibrations at a frequency above 20,000 Hz, inducing cavitation and a powerful scrubbing action which pulls dirt, soil, and contaminants free from parts immersed in the liquid. The booklet explains the methods and the equipment required for handling various types of ultrasonic cleaning jobs.

Write National Ultrasonic Division, Phillips Manufacturing Company, 7334 North Clark Street, Chicago, Illinois 60626 on your business letterhead for a copy. ▲

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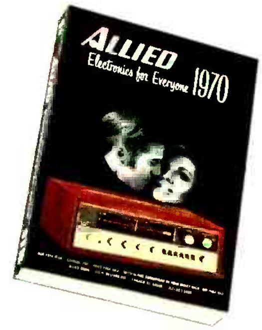

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EW Lab Tested

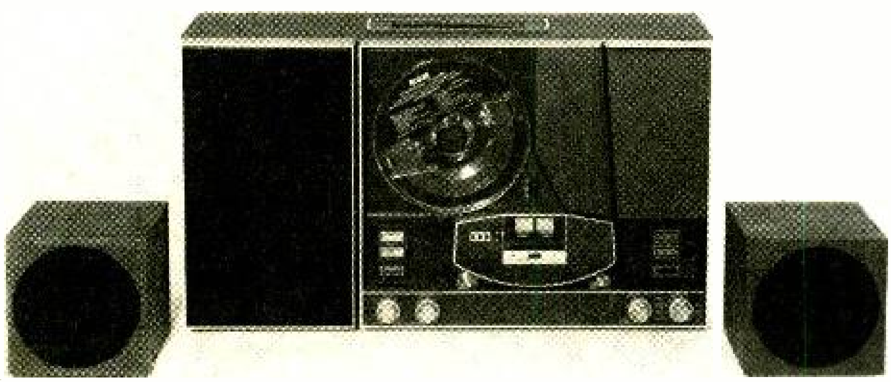
(*Continued from page* 16)

to be pleasing to the ear. The RIAA equalization error was less than 0.5 dB from 100 to 15,000 Hz, rising to +3 dB at 30 Hz. The filters had slopes of 6 dB/octave, which proved to be rather ineffective.

The *Eico* 3150 uses all silicon semiconductors, and suffered no ill effects from our extended full-power operation. In use, we did not uncover any vices or shortcomings. It is truly a first-class amplifier, and is appreciably more compact than other amplifiers of comparable power output. In kit form, it sells for only $149.95, complete with an attractive walnut-finished metal cabinet, which makes it an excellent value. It is also offered factory-wired for $225. At that price, it faces competition, but its small size enables it to be installed where many other powerful amplifiers could not fit. ▲

Ampex 1461 Tape Recorder

For copy of manufacturer's brochure, circle No. 28 on Reader Service Card.



THE *Ampex* 1461 tape recorder is basically similar to the Model 2161 which we reported on in the October, 1967 issue. However, it offers most of the features of the older model and some new ones as well, at a substantially lower price.

Like other recent *Ampex* home tape recorders, the 1461 can play tapes in either direction without interchanging reels. Separate capstans, each with its own heavy flywheel, are driven by a single motor which is coupled to the selected drive capstan by operation of a solenoid-actuated slide switch within the transport. Playback heads are automatically switched according to the direction of tape travel. Automatic reversing tones, at an inaudible 20 Hz, may be recorded at any point on the tape (usually at the beginning and end). Since the reversal takes only a second or two, continuity is maintained while playing an entire four-track stereo tape. The recorder may also be programmed to repeat a tape indefinitely if desired.

The unit can record only in the normal (left to right) direction of tape travel. Since it has separate recording and playback heads and amplifiers, signals can be monitored from the tape while recording. Individual recording switches for the two channels enable sound-with-sound recordings to be made. A mono program, such as music or language instruction, can be recorded on one channel. Then, while listening to the playback through headphones, responses or an accompaniment can be recorded on the second channel, without disturbing the first channel. When the tape is played back in the stereo mode, one can listen to both channels simultaneously.

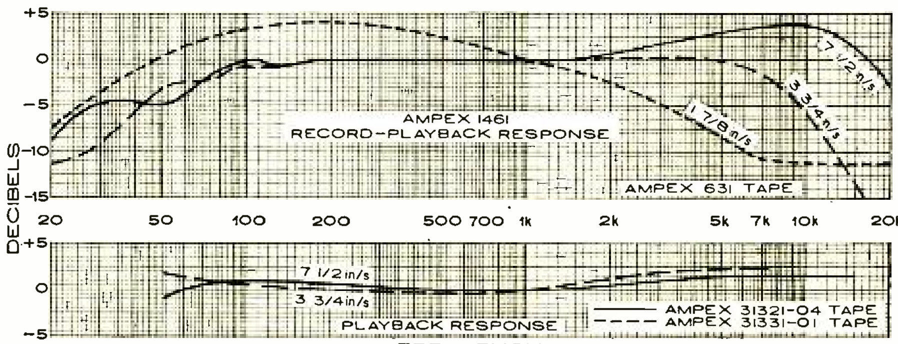
The automatic take-up reel, which is usable in playback and recording from left to right, simplifies tape loading considerably. The tape is passed across the heads and through a slot in the cover over the take-up reel. When the recorder is started, the tape engages the take-up mechanism automatically. To play the second channel, the tape reversal switch is operated, causing it to rewind on the supply reel as it plays. This may be done at any time, either manually or by means of the previously recorded reversing signal.

Since the automatic take-up reel cannot be removed when loaded with tape, and the recorder will only record in one direction, it is necessary to remove the automatic reel and replace it with a standard hub and conventional take-up reel before making a recording that is to be done in both directions. This involves removing a thumbscrew and installing a turntable shaft extender on the drive shaft. (This change is necessary only when planning to record in both directions.)

The 1461 contains a pair of 8-watt playback amplifiers, with bass and treble tone controls, and individual channel playback volume controls. Separate controls are provided to set recording levels, which are monitored by a pair of built-in meters.

Any of three speeds ($7\frac{1}{2}$, $3\frac{3}{4}$, and $1\frac{7}{8}$ in/s) can be selected by a switch. The amplifier equalization must be separately switched to match the tape speed. Transport motion is controlled by two slide levers, one for normal speed and one for fast speed (in either direction as established by the direction switch). A three-digit index counter with push-button reset completes the transport control lineup.

The 1461 is a portable machine, including two small but potent speaker systems. These are 6″ cubes, weighing about 3 pounds, and fitted with 10-foot cords and phono plugs. The speakers store in a compartment to the left of the deck, and may be played in that position, at the expense of stereo separation. They may be removed through a rear access door and separated up to 20 feet for a full stereo effect. Alternatively, larger external speakers may be driven from the internal amplifiers, or its line outputs may be connected to an external amplifier and speakers. The line outputs are not affected by the recorder's volume and tone controls.



The measured playback response of the recorder, using the *Ampex* test tapes, was ±1 dB from 50 to 15,000 Hz at 7½ in/s, and ±1.5 dB from 50 to 7500 Hz at 3¾ in/s. The combined record/playback response at 7½ in/s was ±4.5 dB from 30 to 20,000 Hz and at 3¾ in/s it was ±3 dB from 40 to 10,000 Hz. The 1⅞ in/s speed is intended only for voice recording and had a response down about 10 dB at 25 and 3000 Hz, relative to the maximum output which occurred between 100 and 300 Hz. *Ampex* 631 tape was used for the response measurements.

The signal-to-noise ratio was about 48 dB at all speeds, referred to indicated maximum recording level. Distortion was a relatively low 1.3% at that level. Wow and flutter were, respectively, 0.02% and 0.09% at 7½ in/s, and were both 0.08% at 3¾ in/s, as measured with *Ampex* flutter test tapes. A line input of 96 millivolts produced maximum recording level, and the corresponding line output on playback was 64 millivolts.

The tape speeds were very slightly slow. In fast speeds, 1200 feet of tape was handled in 115 seconds. When rewinding at fast speed, the end of the tape became caught in the automatic take-up reel and the last couple of feet were stretched. We recommend using a strong leader tape to prevent damage to material recorded at the beginning of the reel.

The sound of the Model 1461, with an external amplifying system, was excellent, as would be expected from its smooth, extended frequency response, low noise, and negligible flutter. The tiny cubical speakers included with the recorder sounded amazingly good, well balanced and clean at reasonable listening levels, although they obviously cannot do justice to the full frequency range of the recorder.

A pair of dynamic microphones with plastic desk stands are included with the recorder. Although no measurements were made on the microphones or speakers, they sounded fine and should be perfectly satisfactory for casual recording applications. The unit weighs some 46 pounds, which attests to its robust construction, but might discourage one from carrying it very far.

The *Ampex* 1461, complete with microphones and speakers, sells for $429. This is $170 less than the price of the earlier Model 2161, with essentially the same performance, and reflects the improved values to be found in modern audio equipment. The cubical Model 415 speakers are available separately for $39.90 a pair, and with their attractive walnut cabinets and compact dimensions should be well suited for use in a den or bedroom. ▲

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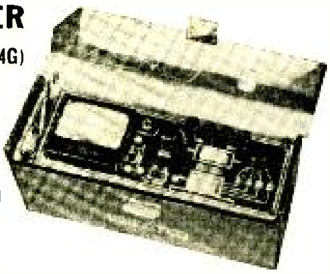

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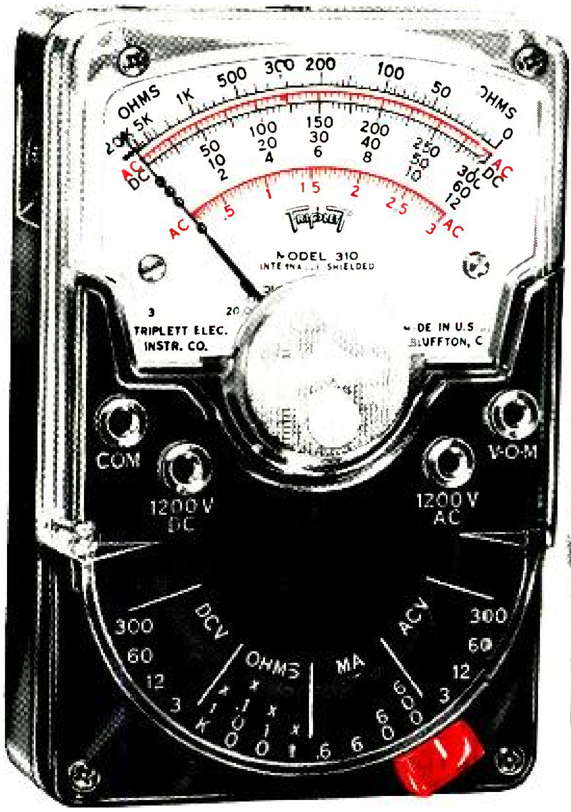

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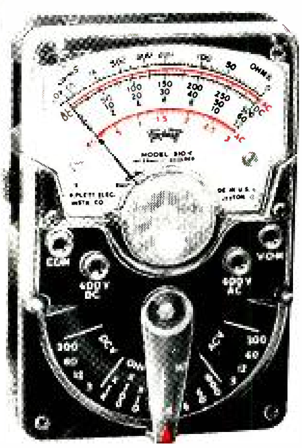

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