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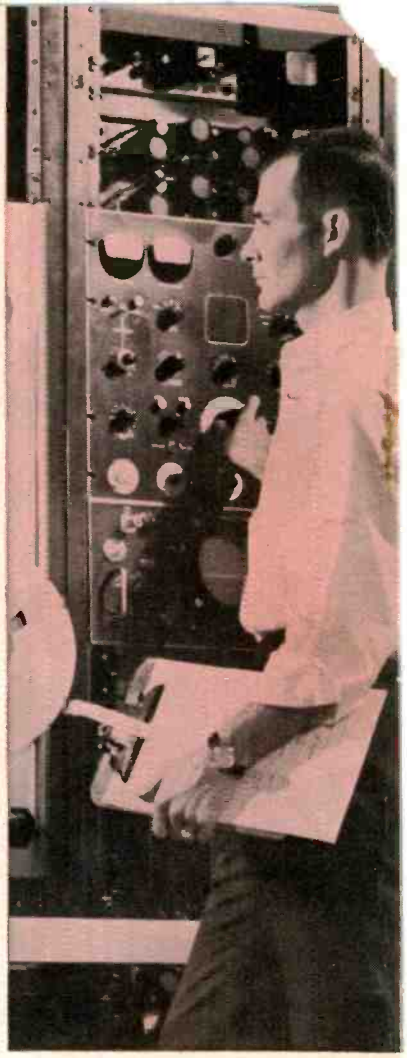

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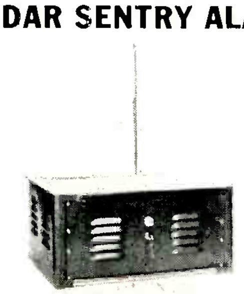

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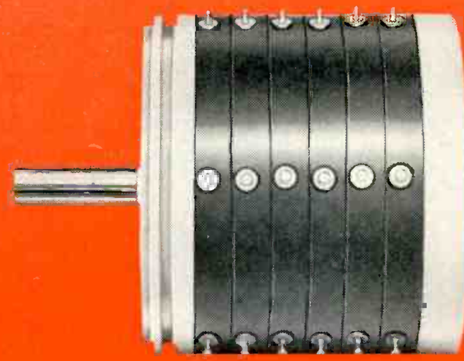

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SPECIFICATIONS			
MODEL NO.	177S	205S	305S
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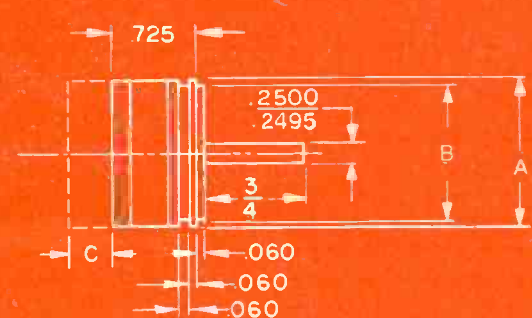
B	1.5620 / 1.5615	1.8750 / 1.8745	2.8750 / 2.8745
C (ADDITIONAL LENGTH PER CUP)	0.200		
BEST LINEARITY	0.035%		0.02%



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OUR COVER ties in with three special articles in this month's issue dealing with public-address systems. These are on p.a. amplifiers, microphones, and loudspeakers. The amplifier shown is a Bogen MTX-30A, an all-silicon transistor 30-watt p.a. unit, with an accessory monitor speaker and sound-level meter. The microphone is a new Electro-Voice 674, a dynamic cardioid designed for public address, recording, and communications uses. The two loudspeakers are outdoor University units, the Models CLC and the CSO-4 sound column. The former uses a wide-range cone speaker with horn loading of the rear; the latter employs 4 8-inch cone speakers in a vertical array..... ..Photo: Bruce Pendleton.

ZIFF-DAVIS PUBLISHING COMPANY

Electronics World

JUNE 1966 VOL. 75, No. 6

CONTENTS

MONTHLY FEATURES

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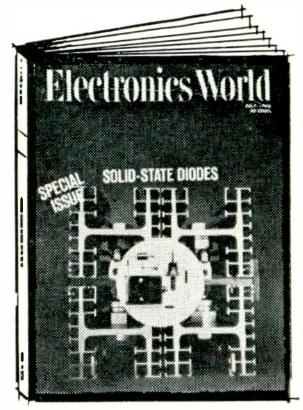

SPECIAL ISSUE

Semiconductor Diodes—In this special 24-page section, six major authors provide a wealth of authoritative information on all types of diodes:
Frank Gift of International Rectifier on Rectifier Diodes.
Robert M. Minton of RCA on Tunnel Diodes.
J. Clifton of Texas Instruments on Reference and Regulator Diodes.
John P. Brown of Fairchild Semiconductor on Switching Diodes.
Gerald Schaffner of Motorola Inc. on Varactor Diodes.
Eugene J. Feldman of Sylvania on Mixer and Detector Diodes.

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

INSULATED GATE TRANSISTOR
The most important advantage of this new semiconductor, which is also called MOST, MOSFET, or IGFET, is its extremely high input impedance. It can be used in any circuit application where this characteristic is required.

AUTOMATIC STEREO MULTIPLEX DEMODULATOR
Details on a new transistorized circuit for use in hi-fi FM tuners whereby the demodulator diodes perform wholly automatic switching from mono to stereo. The circuit is being used in Scott tuners.

*All these and many more interesting and informative articles will be yours in the **July** issue of ELECTRONICS WORLD . . . **on sale June 16th.***

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CIRCLE NO. 103 ON READER SERVICE CARD

For the record

WM. A. STOCKLIN, EDITOR

INTEGRATED CIRCUITS FOR CONSUMER PRODUCTS

ALMOST simultaneously, two separate divisions of *RCA* made important announcements concerning linear integrated circuits for TV and FM receivers. Although IC's have been used for several years in the *Zenith* hearing aids, the new *RCA* announcements—particularly in regard to price breakthroughs—should inaugurate a new era in consumer product design.

It has been common knowledge among design engineers that to use linear-type integrated circuits for consumer products economically, it would mean that the prices would have to fall below $5.00. *RCA's* new circuits will cost from $1.25 for a simple wideband amplifier to $1.95 for a deluxe version of a wideband amplifier/discriminator (in lots of over 1000 units). This is a significant breakthrough and now, for the first time, IC's can be used in consumer products on an economical basis.

RCA's Home Instrument Division, in unveiling its latest 12" black-and-white TV set, publicly demonstrated for the first time the application of an integrated circuit in a home entertainment system. This extremely small chip, housed in a TO-5 can, contains 24 active and 14 passive components. It replaces a total of 26 discrete components (two transistors, two diodes, seven capacitors, 14 resistors, and an interstage coil). By itself, it provides i.f. amplification, limiting, FM detection, and audio preamplification. (See page 28.)

In a separate announcement, *RCA's* Electronic Components Division offered to all original equipment manufacturers of consumer products, four separate integrated circuits of the linear type, designed specifically for FM sound for both TV and FM receivers. These are the units that are attracting considerable attention in view of their extremely low unit price, as mentioned above.

RCA isn't alone, though. Almost all of the semiconductor manufacturers have been working on linear IC's and quite a few such units are on the market. None, however, is as involved as the *RCA* design nor have they been directed so specifically to the circuits for FM detection.

This doesn't mean that most of the 1967 TV sets will use IC's. In fact, it is difficult to conceive of any major changes in the design of television sets as long as sales hold up as they are at present. The demand for color sets is still beyond belief and there is a 50/50 chance that there will be a shortage for the coming Christmas market. Sales for 1966 are estimated to be around 5.2 million, which is double that of last year. Even black-and-white sales have not dropped as much as was anticipated.

In spite of this, however, work is still progressing in the circuit-design laboratories. Every engineer involved in the design of consumer products should, without hesitation, start experimenting with IC applications. Most engineers in this area have had no experience with IC's. In fact there are even some who have not had any experience with transistors. Much has to be learned. IC's are peculiar components. The applications engineer must design circuits and equipment around existing IC's rather than creating new IC's for his circuits.

Engineers should also realize that linear IC's are not restricted simply to FM and TV receivers. Circuit design engineers should give serious thought to use of these devices as preamplifiers for oscilloscopes and v.t.v.m.'s, broadband line amplifiers for CCTV and master-antenna systems, antenna signal boosters for short-wave and FM receivers, and in many other analog circuits where extreme reliability in a small package is desired. Let's not overlook the use of digital IC's in the test equipment area. As a matter of fact, the *Boeing Co.* is currently experimenting with IC test equipment, such as tunnel-diode voltmeters, frequency standards, and reference voltage generators, that will be permanently incorporated into jet airliners or spacecraft for self-checking purposes. They are ideal for use in the countdown circuits of CCTV sync generators and color-bar generators. Why couldn't the digital IC be coupled with inexpensive visual readout devices to make low-priced counters and visual readout meters? Integrated circuits for all these applications are available today.

Much has been said about functional designing (see "Functional Designing" by J.J. Suran of *G-E* in the March 1966 issue) where IC's are referred to strictly as black boxes with a simple input and output. Those developed by *RCA* and others to date differ in that, in a sense, they are hybrids. Many other components such as large-value capacitors, coils, and transformers must be connected externally to complete the specific function. This design pattern will be followed for some time.

The advantages of eventually using IC's are twofold in that they should cut manufacturing costs and should provide the consumer with a product that is much more stable and reliable than before.

As to how this will affect servicing is rather difficult to predict. Servicing is bound to change and component or circuit replacements in the home, for the most part, will be eliminated. Since these integrated circuits will be soldered in, most sets will have to be returned to the shop for servicing. It should mean, though, that there will be less need for servicing. But when failure does occur, cost for service will most likely be higher. ▲

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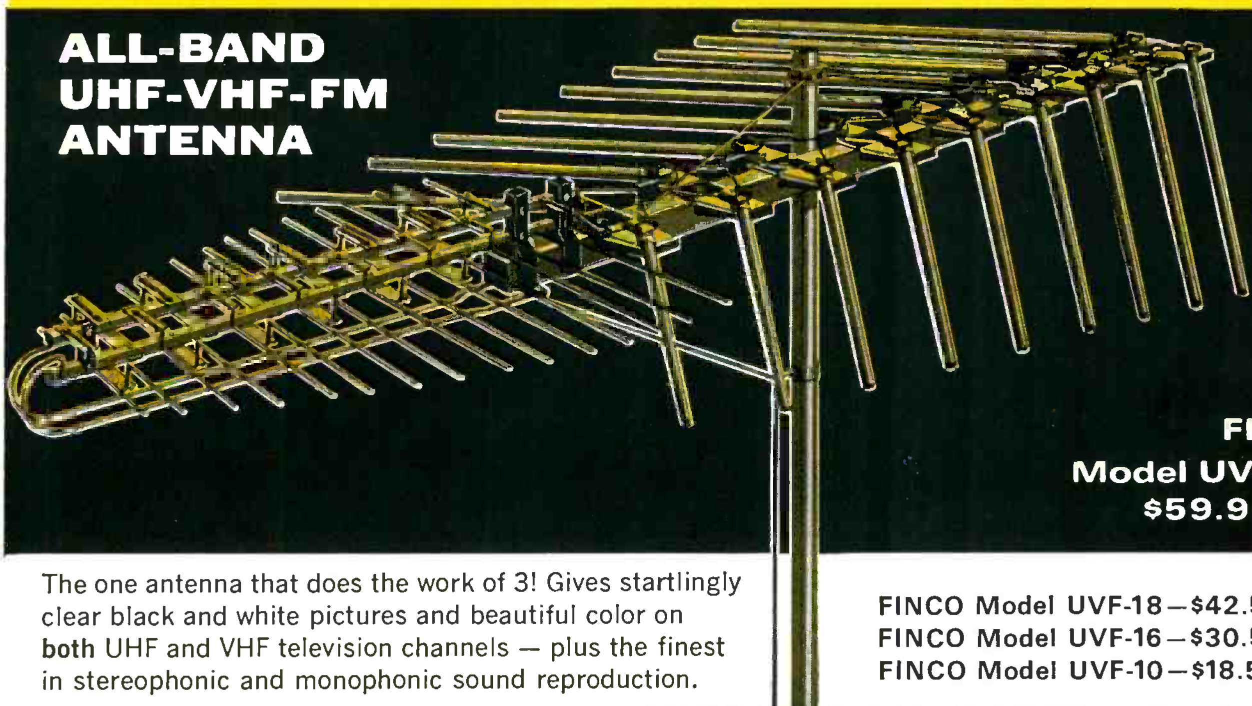

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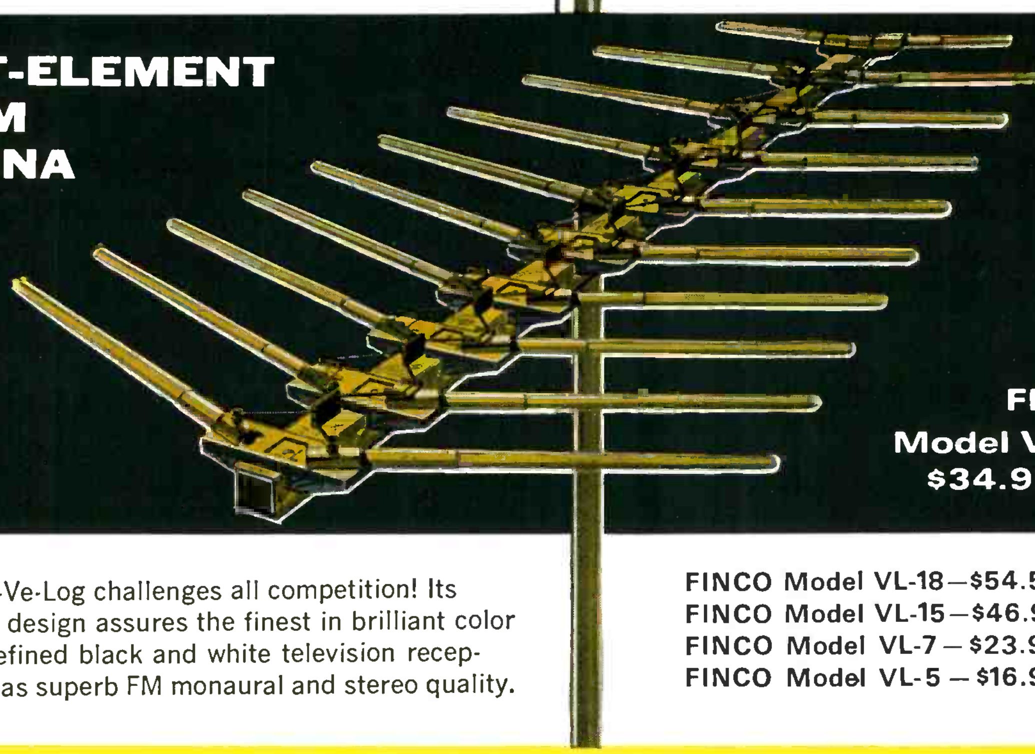

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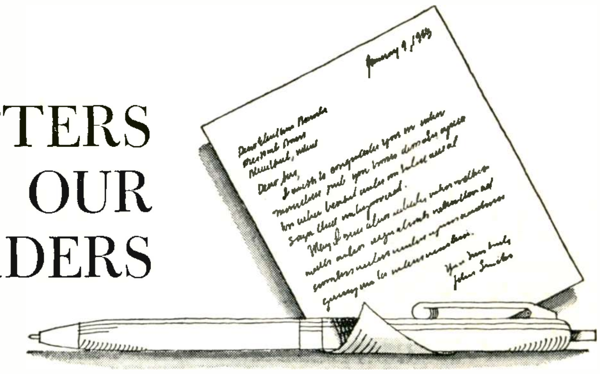


NANOSECOND PULSES

To the Editors:

There are several misstatements in the article "Nanosecond Pulses: Techniques & Applications" appearing in your February, 1966 issue.

Time-domain reflectometry is indeed a most useful method. It is more useful than indicated in the article as the resolution is considerably better. First, the reflection from the first discontinuity starts back to the scope while the remainder of the incident pulse continues to the next discontinuity. When the incident pulse reaches the next discontinuity, the reflected pulse from the first discontinuity is already away from the first discontinuity a distance equal to the distance between the two discontinuities (assuming the propagation constants are not different). So the two sets of reflections arrive at the scope twice the time apart that the article indicates. Hence resolution is half that given.

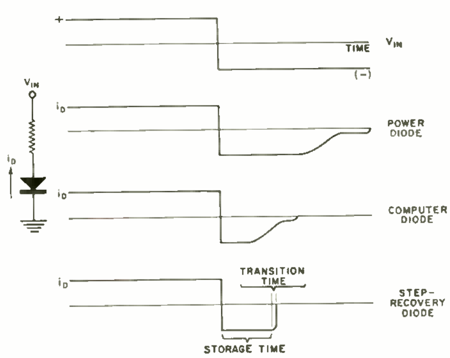
Secondly, the propagation for most polyethylene cables is very nearly ⅔ that of the speed of light. So resolution in a typical coax is yet a further ⅔ of the corrected figure.

Then, finally, the rise time of the scope and generator combination is less a limitation on the resolution than implied, as the discontinuities must be closer together to be seen as two peaks with the scope trace not falling to the baseline between then.

Nanosecond pulses don't necessarily have a high harmonic content unless reference is made to the frequencies of the harmonics, since Fourier analysis indicates that the harmonic spectrum (the number of a harmonic and its amplitude) depends only upon the shape of the pulse, not its speed. A nanosecond square wave has the exact same array of harmonics (all odd, with calculable harmonics) as does a millisecond square wave; the difference lies in the frequency of each harmonic, as the fundamental frequencies differ. What the article should really say is that step-recovery diodes produce a harmonic spectrum that is better than most other harmonic-generating devices.

I'll go along with what the author says about special techniques. It is amazing what ringing even a carelessly wired resistor can contribute to a nanosecond circuit. A ground plane of some sort is a virtual necessity for bypassing in a circuit.

When the voltage across any diode is reversed, the current through that diode also reverses, then ceases after the stored charge in the diode is cleaned out of the junction area. Hence, Fig. 2A is wrong. The diode current waveforms should appear as shown below.



A few words of clarification may be useful: the transitions of each diode to negative currents are fast *if the voltage transition is fast*. But if the voltage transition to a negative voltage is slow, then only the step-recovery diode will have any fast transition, and this at the end of the negative pulse. All transitions to a negative current will occur in time with the voltage transition.

JAMES WRIGHT BEVILLE, III
Gainesville, Fla.

A portion of Author Lancaster's reply follows:

To the Editors:

Reader Beville is to be complimented on certain points he has made. Fig. 2A is wrong as charged.

Also, I would be one of the last to argue with Fourier. My statement should have read, "Nanosecond pulses invariably have many *high-frequency* harmonics." The fact that these are pulses guarantees a wide frequency spectrum in itself.

Time-domain reflectometry is often used with microwave and v.h.f. devices whose propagation times are nearly equal to that of free space, and the technique is occasionally used in one direc-

tion only for such things as attenuation, impedance, and rise-time measurements. For a strictly worst-case use, it is simply the free-space distance that determines the resolution, not that distance multiplied by two or some velocity factor, although these factors are often a great help in many practical problems.

The rise time of the sampling oscilloscope may not be of great importance for time-delay measurements, but if realistic or accurate measurements of attenuation and reflection coefficients are to be made, it is very important to have an oscilloscope with a rise time at least marginally better than the pulses used.

Donald E. Lancaster
Phoenix, Ariz.

* * *

TRANSISTOR IGNITION SYSTEM

To the Editors:

Mr. Morris deserves credit for his efforts to present an interesting and useful article on a transistor ignition system (January, 1966 issue). However, though there is no doubt that some of these improved methods are superior to the conventional ignition system, Mr. Morris' conclusions from the tests are questionable. It is quite possible the sample spark plugs photographed were inadvertently mixed up. (*They were not.—Ed.*)

I feel the main advantages of these new electronic ignition systems are the conventional systems' major defects. These advantages are improved and more linear spark performance in the upper-half rpm range and long breaker-points life with very little wear, rather than increased spark-plug life. I have had 20,000 miles of very good, trouble-free, high-mileage spark-plug service with high-rpm English sports cars with conventional ignition. This proved the contact points are most important. I did spend much time cleaning, adjusting, and replacing this troublesome item, the neglect of which will drop performance and mileage. A light burn results in a definite engine efficiency loss.

Considering the work and stresses involved, spark plugs are a cheap item for 10,000 miles of transportation.

Mr. Morris' spark-plug troubles with conventional ignition indicate some serious difficulties are present and unsolved, and these problems would very likely reflect in his transistor system findings. However, because the difficulties decreased or disappeared with the transistor system, it is no proof that the conventional system is at fault, extended life excluded.

The entire character of the engine is changed with the improved ignition system. The requirements for efficient spark-plug operation remain the same. The extended plug life, by itself, is not a measure of engine operating efficiency.

Peter C. Holden
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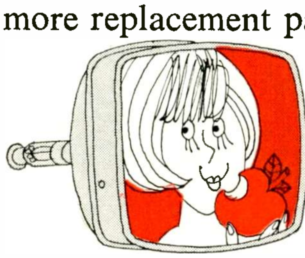

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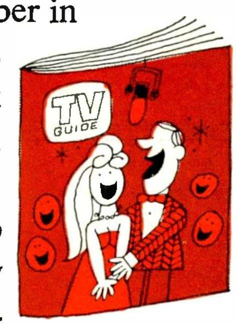

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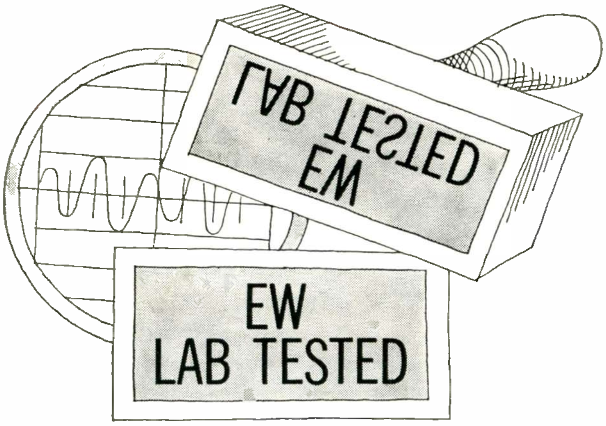


HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Dynaco PAS-3X Stereo Preamplifier
Telex Stereo Headphones

Dynaco PAS-3X Stereo Preamplifier

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

THE *Dynaco* PAS-2 and PAS-3 preamplifiers (identical except for styling details) have earned an enviable reputation for highest quality at minimum cost. Current models of the preamplifier, designated PAS-2X and PAS-3X, incorporate a new tone-control circuit, on which patents are pending. The tone controls use special potentiometers which provide extremely flat frequency response and low phase shift when mechanically centered. In effect, the tone controls are switched out of the circuit in their mid-positions, although no switches or detents are used.

The PAS-3X tone controls are in the feedback circuit, resulting in extremely low distortion throughout the audio range. The output impedance has been lowered to 1000 ohms, so that low-input-impedance transistor amplifiers may be driven (the earlier models had a relatively high output impedance).

The circuits of the PAS-3X have a disarming simplicity. Each channel has only two 12AX7 dual triodes. One is a low-level preamplifier with feedback equalization. The other supplies tone-control and scratch-filter functions, as well as serving as an output stage. The built-in power supply includes a full-wave rectified d.c. heater supply for all tubes.

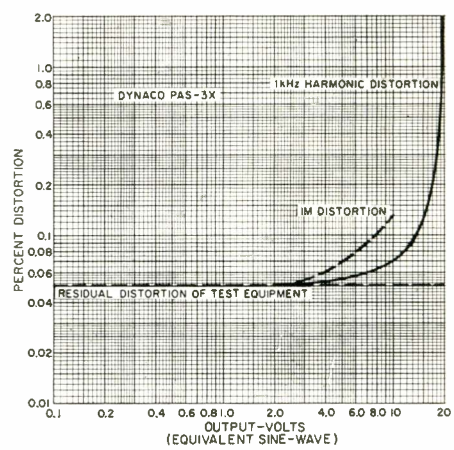
The input selector has positions for tape head, magnetic phono cartridge, FM-AM, FM-MPX, a spare low-level input for another phono circuit or a microphone, and a spare high-level input. The volume controls for the two channels are ganged, but there are four separate tone controls. The balance control can cut off either channel completely with negligible effect on the level of the other.

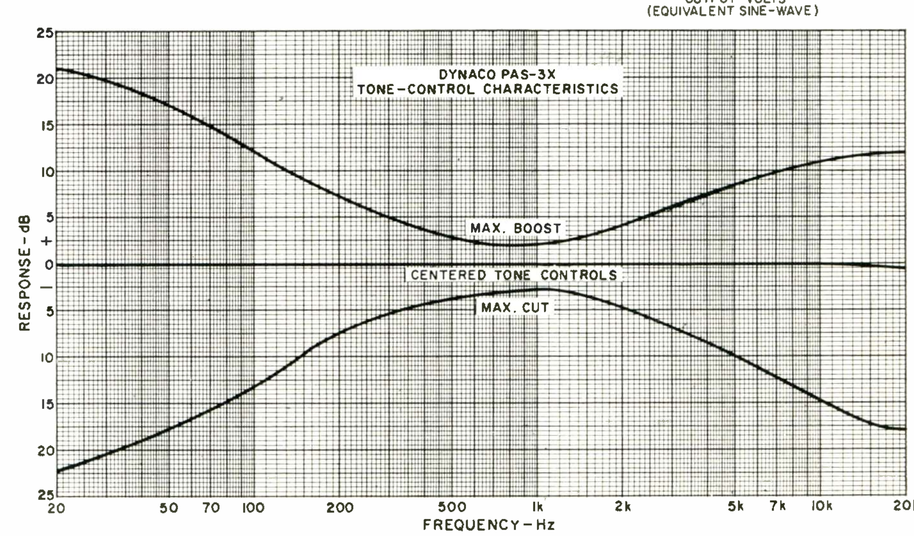
The mode selector is a unique feature. In addition to full stereo, mono (A+B), and reproduction of either channel through both outputs, it has two blend positions. These reduce channel separation to minimize the "hole in the center" effect sometimes encountered with excessive loudspeaker spacing.

Slide switches control the tape-monitor function, loudness compensation, scratch filter, and power. There are two switched and two unswitched a.c. outlets in the rear of the unit.

Our laboratory measurements of the new preamp were limited in most cases by the residual errors of our test equipment. Its frequency response was perfectly flat up to beyond 10,000 Hz and down only 0.4 dB at 20,000 Hz. There was a definite "flat" setting at the center of the range of each tone control.

The loudness compensation boosted low-frequency response below 400 Hz with no effect on middles or highs. The degree of boost did not seem to be affected by volume control setting, at least





in the lower half of its range. The compensation was effective and pleasing, without muddiness or boomy sound.

The scratch filter is quite unusual among such devices. It has practically no effect below 7000 Hz but cuts off sharply above that frequency. It removed scratch and hiss very effectively with no effect on the program content in most cases. The phono and tape equalization are perhaps the most precise we have ever measured. Even though the RIAA curve is only defined between 30 and 15,000 Hz, we extrapolated it to the full 20-20,000 Hz range and found the preamplifier to be within ±0.5 dB of the ideal curve. The NAB tape equalization was exact.

Hum was 70 dB below 1-volt output on the phono and tape inputs at normal gain settings, and −54 dB at maximum gain (which is unlikely to be used). On the high-level inputs the hum was unmeasurable (below −80 dB). The unit can be driven to 1-volt output with 1.7 millivolts on the phono input, 3.2 millivolts on the tape input, and 125 millivolts on the tuner input. It had no measurable crosstalk between inputs. Stereo crosstalk was −40 dB at 1000 Hz, decreasing to 12 dB and 6 dB in the "blend" positions.

Last, but not least, the distortion was entirely unmeasurable for any output under a couple of volts (sufficient to drive any power amplifier to full output). The intermodulation distortion reached 0.07% at 5 volts output and the harmonic distortion reached 0.07% at 10 volts.

The performance of the *Dynaco* PAS-3X would make it an outstanding preamplifier at any price. Selling, as it does, for $69.95 in kit form and $109.95 factory wired, it is surely one of the greatest values in high-fidelity components. ▲

Telex Stereo Headphones

For copy of manufacturer's brochure, circle No. 24 on Reader Service Card.

TELEX *Acoustic Products* has introduced four new models of stereo headphones, spanning a range of prices and with distinctly different sonic properties. They are all similar in basic construction, being essentially miniature cone-type loudspeakers. They are all rated to be driven from amplifier outputs of from 3 to 16 ohms. Power levels of less than a watt are sufficient to produce comfortably loud levels.

The lowest priced unit is the "Adjustatone," selling for $15.95. This is also the largest in its internal structure, using 3½-inch soft-cone speakers. Approximately 60% of the opening of each driver is blocked by a perforated plate, the balance of the area being open to the ear cavity (protected by a grille).

The name "Adjustatone" refers to the fact that the frequency response can be tailored to some degree by the user, according to the placement of the earpieces on the head. Normally the open area over each reproducer is toward the back of the head. Moving the earpieces farther back reduces the amount of high-frequency output reaching the ear drum directly, which can subdue excess high-frequency noise of some program material in the manner of a treble tone control. On the other hand, moving the phones forward on the head places the openings directly over the ear opening, giving maximum treble response.

The "Adjustatone" headphones are ruggedly made of high-impact plastic, with a foam-padded headband. They weigh 12 ounces, with the integral 8-foot cord and three-circuit phone plug. The sliding adjustment for fitting the headphones to one's head has a tendency to slip, but the large ear cups support the earpieces on the ear without too much dependence on the headband.

The Model ST-20 "Stereo-Twin" headphones (see photo) use smaller, 1½" x 2⅜", elliptical cone speakers. The soft foam plastic ear cushions are removable for cleaning (with water and detergent, or with alcohol). They have ear openings about 1¼" in diameter and seal around the ear somewhat more effectively than the simple foam rubber cushions of the "Adjustatone" phones.

The weight, impedance, and power ratings of the ST-20 phones are similar to those of the "Adjustatone." It is recommended by the manufacturer that care be taken not to overdrive the phones, since the drivers are considerably smaller than those of the "Adjustatone" phones. Unlike the "Adjustatone," which has separate cords coming from each earpiece, the ST-20 has a single four-conductor cord coming from the left phone. This eliminates some of the nuisance of two cords joining beneath one's chin and simplifies putting on and removing the phones.

Each headphone unit of the ST-20 has its own volume control. This is a great convenience since the listener can adjust volume and balance without getting up to go to the receiver or amplifier, if it is not directly at hand. The plastic-covered headband is easy to adjust and holds its setting once adjusted.

(Continued on page 20)

TINY ELECTRONIC "CHIPS," each no bigger than the head of a pin, are bringing about a fantastic new Industrial Revolution. The time is near at hand when "chips" may save your life, balance your checkbook, and land a man on the moon.

Chips may also put you out of a job ...or into a better one.

"One thing is certain," said *The New York Times* recently. Chips "will unalterably change our lives and the lives of our children probably far beyond recognition."

A single chip or miniature integrated circuit can perform the function of 20 transistors, 18 resistors, and 2 capacitors. Yet it is so small that a thimbleful can hold enough circuitry for a dozen computers or a thousand radios.

Miniature Miracles of Today and Tomorrow

Already, as a result, a two-way radio can now be fitted inside a signet ring. A complete hearing aid can be worn entirely inside the ear. There is a new desk-top computer, no bigger than a typewriter yet capable of 166,000 operations per second. And it is almost possible to put the entire circuitry of a color television set inside a man's wristwatch case.

And this is only the beginning!

Soon kitchen computers may keep the housewife's refrigerator stocked, her menus planned, and her calories counted. Her vacuum cleaner may creep out at night and vacuum the floor all by itself.

Money may become obsolete. Instead you will simply carry an electronic charge account card. Your employer will credit your account after each week's work and merchants will charge each of your purchases against it.

When your telephone rings and nobody's home, your call will automatically be switched to the phone where you can be reached.

Doctors will be able to examine you internally by watching a TV screen while a pill-size camera passes through your digestive tract.

New Opportunities for Trained Men

What does all this mean to someone working in electronics who never went beyond high school? It means the opportunity of a lifetime—if you take advantage of it.

It's true that the "chip" may make a lot of manual skills no longer necessary.

But at the same time the booming sales of articles and equipment using integrated circuitry has created a tremendous demand for trained electronics personnel to help design, manufacture, test, operate, and service all these marvels.

There simply aren't enough college-trained engineers to go around. So men with a high school education who have mastered the fundamentals of electronics theory are being begged to accept really interesting, high-pay jobs as engineering aides, junior engineers, and field engineers.

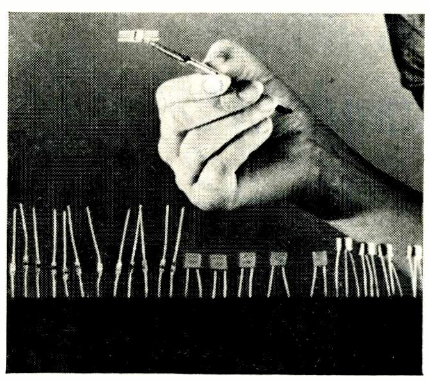
How To Get The Training You Need

You can get the up-to-date training in electronics fundamentals that you need through a carefully chosen home study course. In fact, some authorities feel that a home study course is the best way. "By its very nature," stated one electronics publication recently, "home study develops your ability to analyze and extract information as well as to strengthen your sense of responsibility and initiative." These are qualities every employer is always looking for.

If you do decide to advance your career through spare-time study at home, it makes sense to pick an electronics school that specializes in the home study method. Electronics is complicated enough without trying to learn it from texts and lessons that were designed for the classroom instead of correspondence training.

The Cleveland Institute of Electronics has everything you're looking for. We teach only Electronics—no other subjects. And our courses are designed especially for home study. We have spent over 30 years perfecting techniques that make learning Electronics at home easy, even for those who previously had trouble studying.

Your instructor gives your assignments his undivided personal attention —it's like being the only student in his "class." He not only grades your work, he analyzes it. And he mails back his corrections and comments the same day he gets your lessons, so you read his notations while everything is still fresh in your mind.



50 FUNCTIONS IN A SINGLE CHIP. *The functions of these 50 separate transistors, diodes, resistors and capacitors can now be formed by the tiny dot in the center of the integrated circuit held by the tweezers.*

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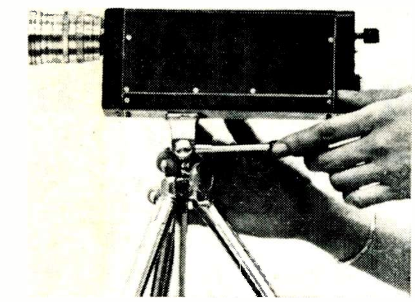
Because of rapid developments in electronics, CIE courses are constantly being revised. Students receive the most recent revised material as they progress through their course. This year, for example, CIE students are receiving exclusive up-to-the-minute lessons in Microminiaturization, Logical Troubleshooting, Laser Theory and Application, Single Sideband Techniques, Pulse Theory and Application, and Boolean Algebra. For this reason CIE courses are invaluable not only to newcomers in Electronics but also for "old timers" who need a refresher course in current developments.

Praised by Students Who've Compared

Students who have taken other courses often comment on how much more they learn from CIE. Mark E. Newland of Santa Maria, California, recently wrote: "Of 11 different correspondence courses I've taken, CIE's was the best prepared, most interesting, and easiest to understand. I passed my 1st Class FCC exam after completing my course, and have increased my earnings $120 a month."



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The ST-20 sells for $29.95. The same phones, without the individual volume controls, is called the ST-10 and is priced at $24.95.

The deluxe model of the *Telex* line is the "Serenata." These phones use tiny, 1⅛"-diameter round speaker units, with the cavity between diaphragm and ear almost completely filled with foam plastic to damp resonances. The "Serenata" has removable, liquid-filled plastic ear cushions which seal the ears almost perfectly. When wearing these phones, sounds in the listening room simply cannot be heard, so the user enjoys total isolation from distracting sounds.

The padded headband has a knurled knob which adjusts the clamping pressure of the earphones on the head. Slippage is eliminated and the phones fit the user as though they were custom molded to his head. The 8-foot detachable cord plugs into the bottom of the left phone. A tone control is located on the bottom of the right phone. Price of this unit is $59.95.

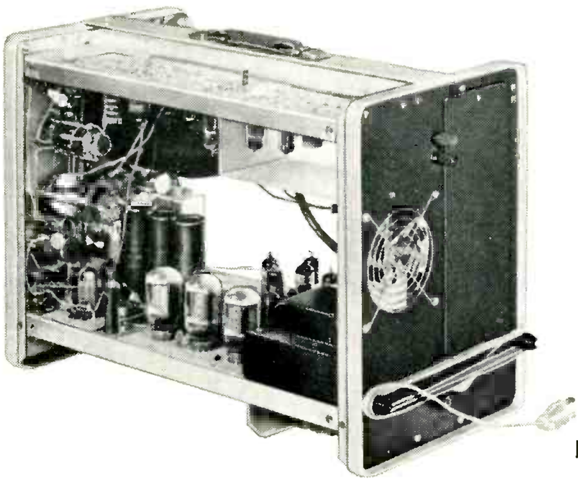
Since measurements of headphone response are quite difficult to make with meaningful accuracy, we evaluated the "Adjustatone," the ST-20, and the "Serenata" by listening to two popular solid-state stereo receivers with them. The sonic differences were distinct, although not easy to describe. The "Adjustatone" was the most efficient, producing the loudest sound. The ST-20 was slightly less efficient, while the "Serenata" was noticeably less efficient than the others All of them could produce very loud listening levels with relatively low audio power, however.

The "Adjustatone" has the largest, most full-blown sound. It is rich and "big" sounding, nearest to the character of some speakers. Its highs, although not particularly strong, are adequate for good balance. Its low frequencies, which are prominent, are slightly indistinct compared with the other models.

The ST-20 has an excellent balance of frequency response. It does not sound as heavy in the bass but is brighter and clearer than the "Adjustatone." The "Serenata" sounds somewhat distant, with the slightly inert character that denotes the absence of resonances and peaks. It is clean and seems to be quite flat and delivers *via* headphones something of the same type of quality that characterizes certain acoustic-suspension speakers.

If anything can be said with certainty, it is that these phones differ as much in sound quality as any three types of loudspeaker which one might choose to compare. Therefore, individual preferences must play a vital part in making a choice. As with speakers, one should hear them before buying, if at all possible. All are capable of providing satisfying stereo reproduction. ▲

New Professional DC 'Scope Heathkit® IO-14



Kit **$299**

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Eighteen Years Ago Heath Broke The Price Barrier On Oscilloscopes With A Low-Cost Scope For Hams, Hobbyists, And Service Technicians. Now Heath Breaks The Price Barrier Again! . . . With A Precision, Fast-Response, Triggered Sweep, Delay Line Oscilloscope For The Serious Experimenter, Industrial Or Academic Laboratory, And Medical Or Physiology Research Laboratory.

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

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

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

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

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

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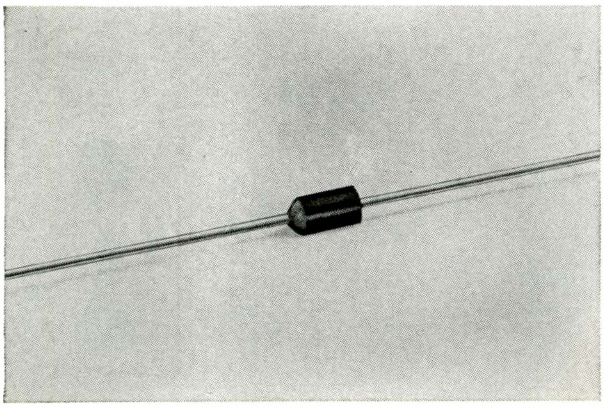
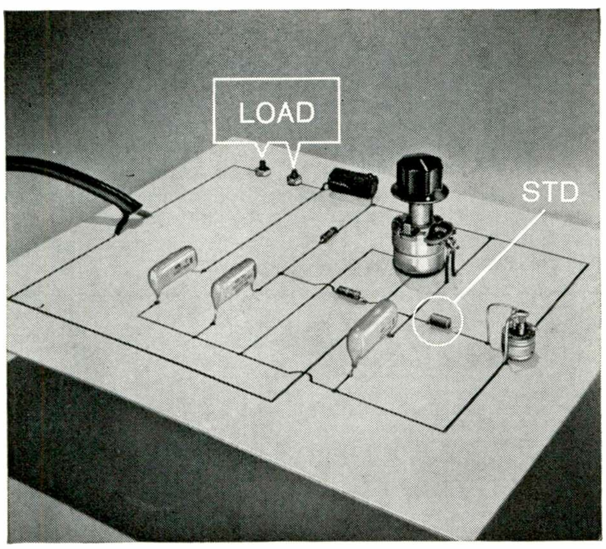
MALLORY Tips for Technicians

Using Dual Trigger Diodes in SCR Control Circuits





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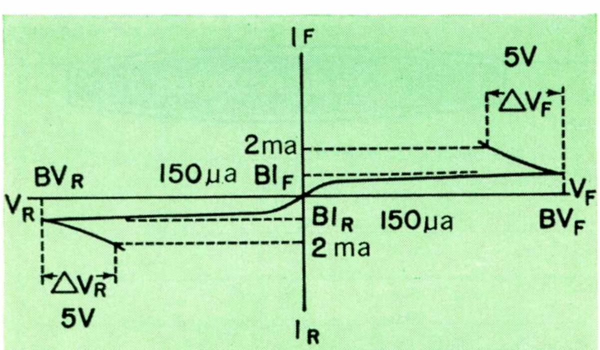


TYPICAL TRIGGER CHARACTERISTIC

The new Mallory dual trigger diode has many interesting applications in control circuits, as a means of supplying adjustable voltage peaks to the gate of an SCR or a bi-switch.

First, let's look at this device. It's somewhat like two zener diodes connected back to back. If you apply AC to it, the trigger will only allow current to pass during that part of each half cycle when applied voltage exceeds its rated firing voltage. So it's sort of a clipper. And as such it's an ideal way to feed pulses to switch on an SCR.

The light dimmer circuit diagrammed here is an example of how the dual trigger can be used. You might want to try this out. It's easily assembled in compact space to fit into a standard wall switch receptacle. Dress it up with a decorator-styled knob and panel, and you've got a high-fashion lighting system handling up to 750 watts. For details, write to Mallory or circle Reader Service number.

In this circuit, the dual trigger feeds the gate of a bi-switch (or dual SCR). The resistor-capacitor combination in series acts as a voltage divider. At the zero resistance end of the control, zero voltage is applied to the SCR gate through the trigger diode, and there's no load current. As you turn up the control, you apply more voltage to the trigger until you exceed its firing point; then you begin to allow current through the lamp load. The higher you turn up the control, the more voltage pulse goes to the SCR gate, and conduction through the SCR takes place during a greater portion of each half cycle . . . since the trigger fires in both directions. Net result: continuous control of lighting current *without* the heat dissipation of a power rheostat.

The Mallory STD dual trigger diode has several qualities which make it especially useful for this kind of control. Its breakover characteristic is symmetrical in both directions within 5%. And it has a "snap back" action, shown by the reverse traces at each end of the trigger characteristic curve; that is, past the breakover point, resistance suddenly decreases and current increases. This is the correct control characteristic for working with the SCR. The STD dual trigger, by the way, is only 3/8" long and 3/16" in diameter, so it fits practically anywhere, and has an insulated case.

See your Mallory Distributor for complete data and for STD dual triggers for your own experimentation. Breakdown voltage ratings go from 24 to 120 volts. Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

50th ANNIVERSARY

P.A. LOUDSPEAKER PRINCIPLES AND PRACTICE

By ABRAHAM B. COHEN
Manager of Engineering, University Sound, Div. of LTV

How to select the proper reproducer to achieve best sound coverage for public-address use. Speaker connections, the constant-voltage system, and power requirements are covered.

THE function of a public-address system is to deliver an audible message either to a particular individual or to a group of individuals. The choice of a loudspeaker, or speaker system, will be based not only on the number of people who must be reached but also upon the environment in which these particular people are expected to receive the information or message.

SECTION 1—THE REPRODUCER

The p.a. family of reproducers can be broken down into specific groups, such as relatively small paging and talk-back speakers, larger higher power projector trumpets with spatially uniform sound coverage, wide-angle horns for contouring the reproduced sound pattern into one preferred plane, and column speakers (or line radiators) for combined high-directivity control and extended frequency response.

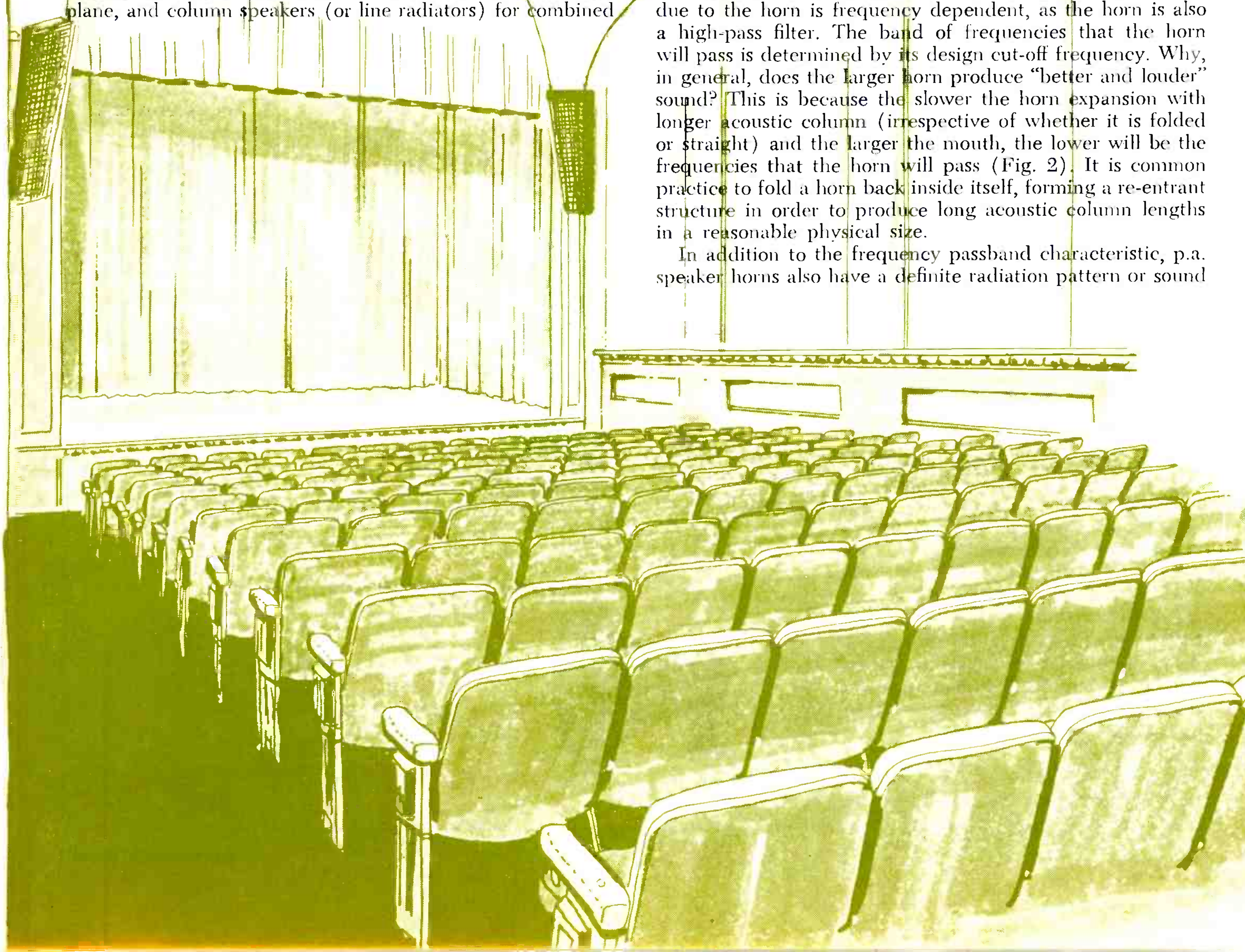
With the exception of the column speakers, p.a. reproducers use compression-driver, horn-loaded types. This design assures high efficiency of conversion of electrical power into acoustic power, on the order of up to approximately 35 to 50 percent in some cases.

The Horn—An Acoustic Transformer

A horn is a tapered acoustic transmission line, or an acoustic transformer, which provides an effective impedance match between the driver unit (the source of the sound) and the air around it. The mechanism by which this takes place is illustrated in Fig. 1.

The improvement in the radiation efficiency of the system due to the horn is frequency dependent, as the horn is also a high-pass filter. The band of frequencies that the horn will pass is determined by its design cut-off frequency. Why, in general, does the larger horn produce "better and louder" sound? This is because the slower the horn expansion with longer acoustic column (irrespective of whether it is folded or straight) and the larger the mouth, the lower will be the frequencies that the horn will pass (Fig. 2). It is common practice to fold a horn back inside itself, forming a re-entrant structure in order to produce long acoustic column lengths in a reasonable physical size.

In addition to the frequency passband characteristic, p.a. speaker horns also have a definite radiation pattern or sound



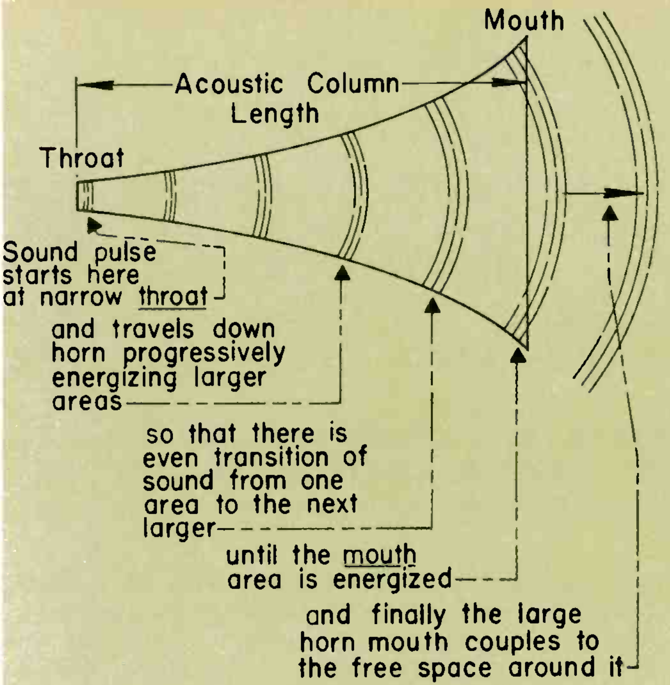
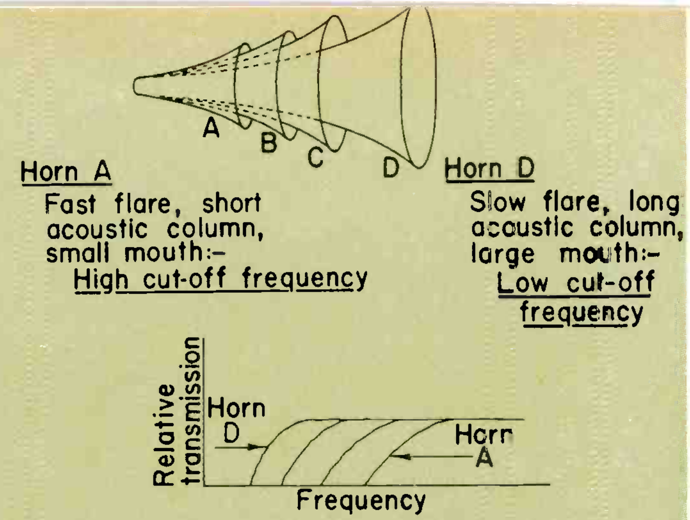


Fig. 1. Wave progression down a horn, which acts as an impedance-matching device between driver at throat and free space.



Air-Column Length	Mouth Dia.	Cut-off freq.	Dispersion
6 1/2'	32"	85Hz	65°
4 1/2'	26"	120Hz	75°
3 1/2'	21"	150Hz	85°
2 1/2'	16"	200Hz	95°

Fig. 2. The long, large-mouth horn has a lower cut-off frequency and less dispersion (more directivity) of sound.

dispersion. Not all horns have the same spatial distribution, even though they all may be of round or uniform cross section. As in a cone speaker, the larger the radiating piston (or mouth), the sharper the beam for a given frequency.

We can increase the dispersion, if required, by putting two (or more) horns side by side, arranged in an arc. There are applications where wide-angle coverage is desired from a *single* horn, rather than a cluster of horns; hence, acoustic structures have been designed to provide such wide-angle dispersion. It is also possible to contour the last section of the horn – usually called the "bell"–which does the actual radiating, in such a fashion that the sound pattern is no longer symmetrical about a given axis but is concentrated in and spread out over one plane and minimized in the other. Two such horn structures are shown in Fig. 3. Another means of producing the wide-angle sound is with the double-mouth structure shown.

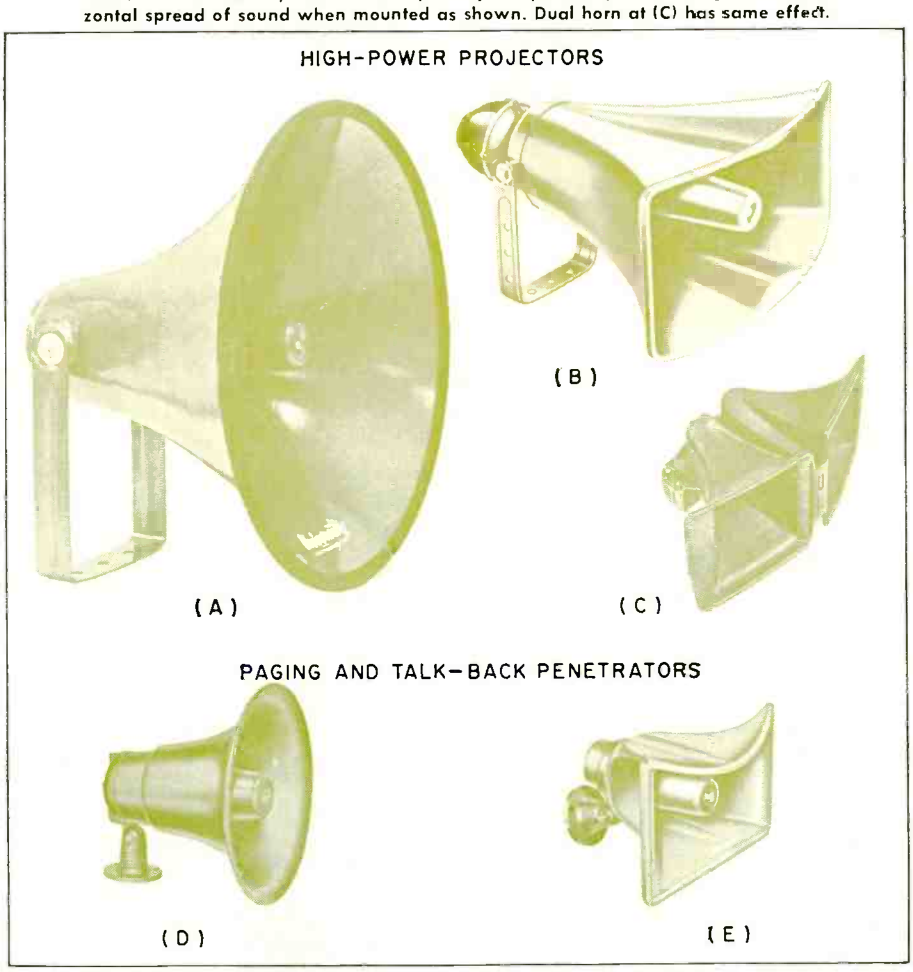
When dealing with wide-angle p.a. speaker systems, we must pay particular attention to a non-horn system – the column speaker or linear array. Such columns are made up of a multiplicity of cone speakers, usually stacked vertically, as illustrated in Fig. 4. The pattern of radiation for a column speaker is one where wide-angle distribution is obtained in the *horizontal plane* through the center of the vertical axis as shown. Its distribution in the vertical plane is, however, severely restricted and highly directive.

The Driver Unit

The driver unit, so-named because it drives or energizes the horn, is remarkably small considering the amount of power it can handle and for the amount of acoustic power it can develop in conjunction with a well-designed acoustic horn.

One often hears the horn system referred to as being

Fig. 3. Standard horns at (A) and (D) produce symmetrical sound patterns. Horns at (B) and (E) have been specially shaped to produce a greater horizontal spread of sound when mounted as shown. Dual horn at (C) has same effect.



energized by a *compression* driver unit. The compression is the sealed rear volume behind the diaphragm in the driver unit. Rather than acting as a deterrent to diaphragm motion, this stiff rear cushion actually improves the performance of the system. This rear acoustic stiffness acts as an acoustic capacitance and, in a properly integrated driver-horn combination, the capacitive reactance balances out the inductive reactance of the horn that loads the front of the diaphragm. As a result, the system becomes totally resistive and most efficient.

Driver units come in various power ratings from 5 watts up to 75 watts for standard, commercially available systems. The size of the voice coil, including wire size and coil diameter as well as the cements that hold the voice coil together, determine the electrical power that can be fed into the coil before it fails electrically. The design of the diaphragm and its edge suspension will determine to what degree the diaphragm can be vibrated mechanically before its suspension ruptures or its main body breaks up. Thus, power handling capability depends on electrical as well as mechanical considerations.

Driver units have much in common and yet they may be made to differ widely, *and intentionally so*, in performance. Some of these important variables are power-handling capacity, conversion sensitivity (related to magnetic circuit efficiency), frequency response (related to diaphragm and head design), size, whether parts of the unit as a whole can be replaced, and built-in transformer facility. Fig. 5 pinpoints all of the components going into the construction of a well-designed driver unit for public-address applications.

SECTION 2—SOUND COVERAGE

Despite the many types of p.a. speakers, there are two common factors that dictate what type of unit will best serve a given application. The first is the acoustic environment into which the sound is to be projected; this includes size, reverberation characteristics, and expected noise levels. The second factor is listener distribution.

Symmetrical Long Throw

As previously mentioned, the standard round horn has a symmetrical distribution pattern about its central axis with maximum energy directly on the axis. Such symmetrical horns are, therefore, to be preferred for either long-throw sound projection or short-throw penetration. The former means putting as much energy as possible as far ahead and in front of the horn, while the latter is concerned with getting a message directly into a nearby spot by penetrating into moderate or high-noise-level spot areas.

To illustrate: several hundred people may be gathered in an assembly area, such as an open field, to listen to a political speech. Such a group usually gathers as near on-center to the speaker's platform as possible. They would almost certainly form a lobed-out pattern so that they could see the speaker as well as hear him. Such a distribution lends itself ideally to the pattern of coverage obtained from a symmetrical horn for that horn lays down its most effective sound pattern directly along its axis. For such long-throw projection, one usually sees horns of the larger type used. The advantage of such a large horn is that the lower cut-off frequency extends the reproducible band of frequencies down into the area where most of the voice *power* lies. This means that greater sound pressures are obtained farther away from the horn mouth.

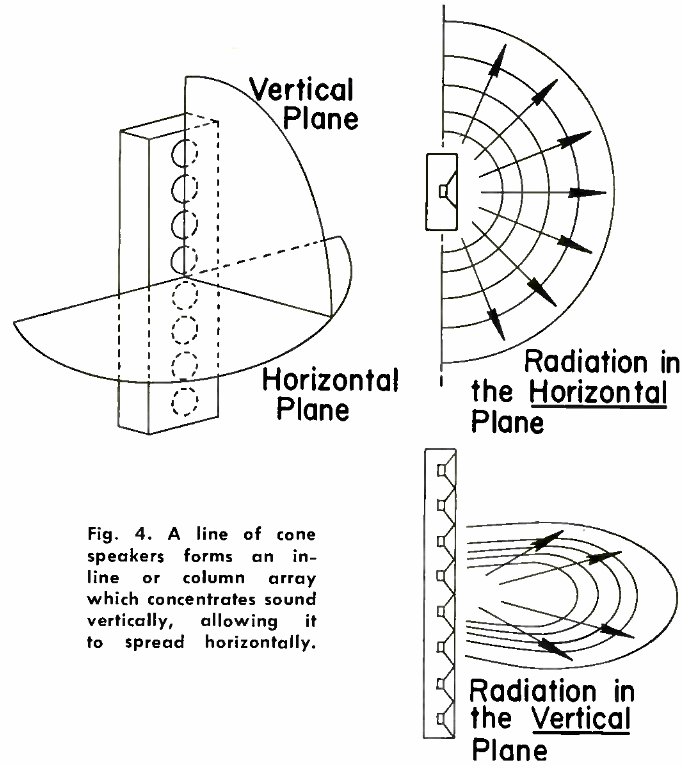
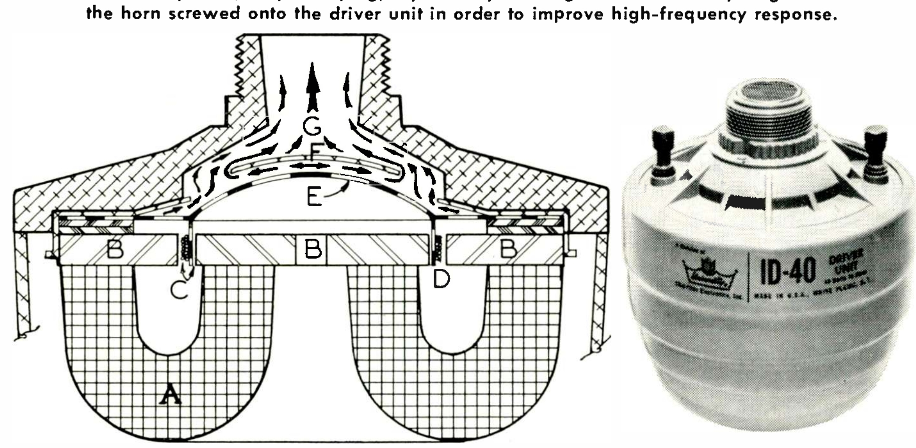


Fig. 4. A line of cone speakers forms an in-line or column array which concentrates sound vertically, allowing it to spread horizontally.

But, how about the middle and high frequencies governing articulation? Here we benefit from the fact that this horn has a large mouth which exhibits strong directional characteristics, especially at the frequencies in question. We thus achieve more projected voice power (lower band) with more articulation (high band) beaming riding on top of the power part of the spectrum. The end result is long-throw forward projection for the large symmetrical horn.

It may come as a surprise to learn that it is often easier to overcome a high noise level with a small, medium, or low-power penetrator than with a larger, more powerful projector. In this manner, we are enlisting the aid of the "6-dB increase

Fig. 5. Internal construction of compression driver unit along with photo of typical driver. A palate, or phase plug, equalizes path lengths from the diaphragm into the horn screwed onto the driver unit in order to improve high-frequency response.



A —Magnet, which energizes
B-B-B —magnetic circuit, in which
C —magnetic gap is bridged with magnetic flux.
D —Voice-coil field reacts with gap field, moving
E —the diaphragm, which produces sound waves against palate
F —through whose aperture equal path lengths of sound reach head chamber
G —from which path-corrected waves are transmitted to horn.

with halving the distance" law, as will be described below.

Consider a high-power loudspeaker projector that, for a given power input, produces a sound intensity of 80 dB, 80 feet away from it. Now place a lower power projector in the same location; for instance, one that will safely take half the power (−3 dB) of the larger one and, moreover, because of the smaller magnetic circuit may be less efficient. Assume that the smaller unit can produce only 70 dB sound intensity at the same distance. Now move the smaller unit toward the listener by 40 feet (halving the distance) and we gain 6 dB in sound intensity. Move it forward another 20 feet (again halving the previous distance) and we gain another 6 dB. Finally, move the reproducer forward 10 feet more (half of 20) and we are able to gain still another 6 dB. We have gained a total of 18 dB over the original sound intensity at that reference point; instead of 70 dB, we have 88 dB at the listening location. All we have done here is to move the reproducer closer to one group of listeners, but to cover a large group of listeners spread over a wide area we will need many such units distributed over the area.

A distributed sound system, consisting of many small speakers placed close-in at the noisy areas, will provide better penetration into those areas than one larger speaker placed far away with the hopes of covering one large area. Such a distribution system is useful, for example, at a railroad or subway platform where the noise of the incoming train may, at times, be almost deafening high. One powerful loudspeaker at one end of the platform will not do the passenger at the other end of the platform any good when the engine or cars are clattering noisily by. However, a number of smaller penetrators spaced rather close together will ensure better transmission of the station master's message.

Distributed systems utilizing small penetrator speakers may also be employed to provide smooth *uniform low-level* coverage in relatively quiet areas. Consider a large warehouse, or a stockroom of considerable size where communications are required to stock clerks or other people working in the aisles between stacked cartons, shelves, or bales. One large, powerful projector placed somewhere in such an area would only blast the nearby working areas and its message would be completely washed out and absorbed by the nearby stock material; little sound would get to the major parts of the warehouse. Many smaller units strategically placed over the aisles (not necessarily one per aisle) would carry the message equally well to all parts of the working area.

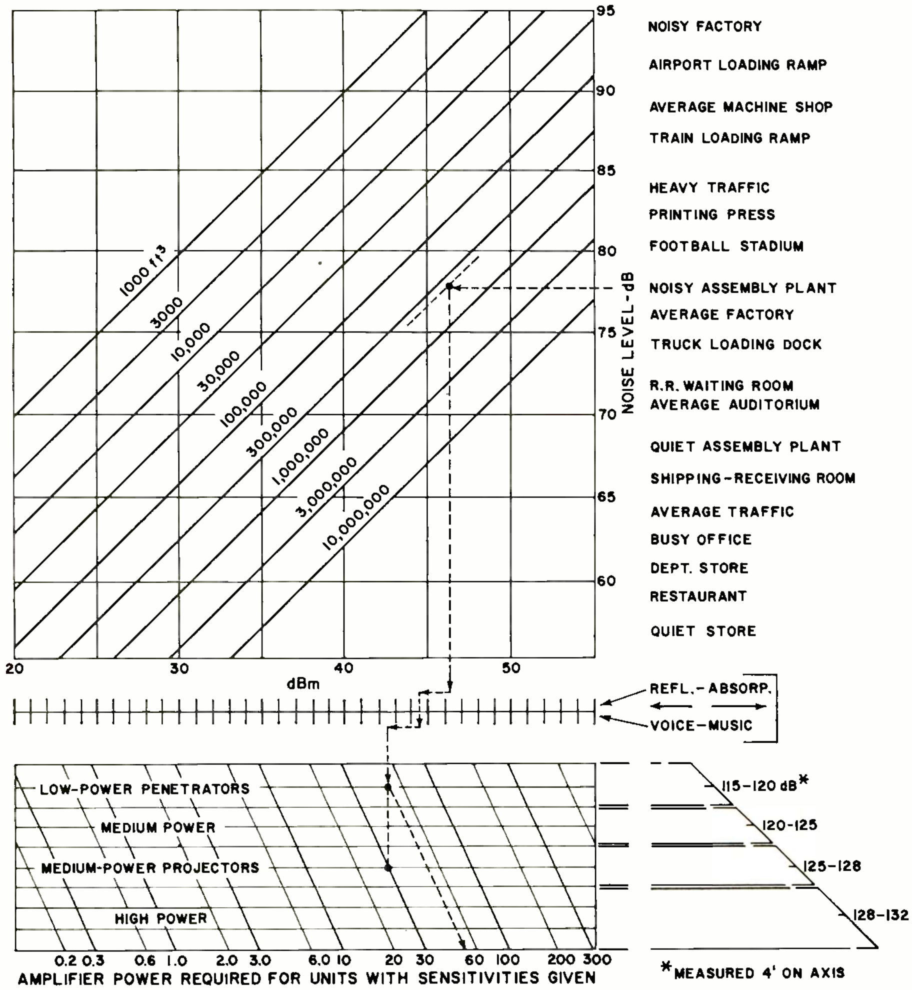


Fig. 6. Acoustic system design chart showing approximate power requirements.

Special Features

Of equal advantage with a multiple system of smaller units is that they may function as "talk-back" units if the amplifier electrical system is arranged for such operation. Many man-hours are saved and customer service is improved when "talk-to" and "talk-back" facilities are incorporated in a simple communications system. For such systems the smaller horn units make excellent on-the-spot message projectors, while because of the sound collecting properties of the horn aided by the heavy magnet structures, such units make very sensitive distant pick-up microphones for "talk-back" purposes.

Highly reverberant areas pose many problems. If reverberation is excessive, the p.a. system will be difficult to understand. If we can keep the sound out of the live areas, such as the hollow hard ceiling spaces or the hardwood floor of a basketball court, then we effectively minimize the detrimental reverberant sound. A large number of directional, wide-angle horns may be especially helpful under these particular conditions.

An Acoustic System Chart

A general chart, Fig. 6, may be prepared correlating factors of room size, room reverberation, ambient noise, and sound intensities necessary for either speech or music, with the required electrical power. This chart cannot be absolutely accurate but it can serve as a guide.

To illustrate its use, let us assume we have a fairly noisy assembly plant, 325,000 cubic feet in volume, that requires a p.a. system. We draw a line, as shown, horizontally to meet a diagonal at about 325,000 cubic feet. Assume the building to be a cinder block and glass structure, which is quite live. We drop down vertically to the horizontal reverberation-adjust line. Since the area will be quite live, we move to the left into the reverberant or reflective area by two units (representing about 2 dBm. If only voice transmission is required, we shift to the left by two units (about 2 dBm).

For the area considered, which may be made up of distributed spots of high noise levels, let us choose a distribution of small, low-power penetrators. We drop our vertical line down to meet the center of the low-power penetrator band. From here, we follow the tilt of the diagonal down to the scale calling out the electrical power required—in this case approximately 50 watts of amplifier power. These penetrators may be rated at, say, 10 watts apiece, but for conservative operation and more widespread (*Continued on page* 63)

Transistor Failure Predicted

A three-year study of high-reliability germanium-alloy transistors at NBS has shown that early increases in leakage current resulting from storage at elevated temperatures can indicate later failure.

FAILURES among certain transistor types can be predicted from measurements of leakage current before the transistors are placed in service, according to a study recently completed at the National Bureau of Standards Institute for Applied Technology. The application of screening procedures developed in this study to germanium-alloy transistors may increase the reliability of transistorized equipment, including weapons systems, communications systems, and space-vehicle instrumentation.

The NBS study was carried out over a period of three years by George T. Conrad, Jr. and Donald C. Shook using the technique of accelerated aging through exposure to modest elevated temperatures. They found that measurements of performance before and after six weeks of this aging enabled them to separate the transistors tested into two groups: those likely to fail during the first several years of service and those unlikely to fail.

The transistor-failure prediction study was composed of two experiments, the first a statistical evaluation of changes in parameters occurring during accelerated aging simulating years of actual operation. Early changes in leakage-current parameters were found to follow the same pattern for all transistors that would have failed within several years of normal use. A screening procedure was developed from these data and its effectiveness verified in a second experiment which also tested the usefulness of additional variations in aging conditions.

In the first experiment, groups of forty 2N396 inexpensive *p-n-p* germanium-alloy transistors, which had met stringent military requirements, were subjected to an initial series of measurements and then each group was placed in a temperature-controlled chamber. Ambient temperatures and bias powers were selected to provide junction temperatures of 25, 55, 100, 145, and 200°C. The transistors were removed for repeated measurement runs after 340 hours of aging and returned to the ovens. This was again done at 1000 hours, 4700 hours, and at intervals up to 20,000 hours of aging.

Transistor performance was evaluated on the basis of measurements of the following d.c. parameters: emitter-base current (I_{EBO}) at −2 and −10 V; collector-base current (I_{CBO}) at −2 and −10 V; collector-emitter current at −10 V with base grounded (I_{CES}), grounded through a 10,000-ohm resistor (I_{CER}), and open (I_{CEO}); and normal and inverse current-transfer ratios for the common-base configuration at 10 mA and −5V. Following are the findings.

Experimental Findings

Analysis of the measurements first showed that deterioration at 25 and 55°C was too slight and that deterioration at 145°C and above was too great to shed much light on the meaningfulness of small, early changes. For this reason, data from only the four groups of transistors aged at 100°C were analyzed further.

The aging was found to be accompanied by a gradual dispersion in values of the parameters and by ten failures during the 20,000-hour aging period. Two specimens failed because of avalanche conduction, six because of too great a leakage current, and the remaining two catastrophically, one possibly because of previous physical damage. The specimens failing came from all four aging conditions represented: zero bias, −24 V reverse collector bias, and 3-mW power dissipation (all for 100°C ambient); and the fourth, 100°C junction temperature from the combination of 70°C ambient and 120-mW power dissipation.

Early increases in leakage current, among the parameters tested, were found to be consistently associated with the first transistors failing. The first three failures among the 160 specimens would be expected to occur within about four years of normal use, based on the approximation that the rate of deterioration doubles for every 10°C increase in junction temperature. Normal operation is taken to be 55°C. The changes in leakage current during 1000 hours of accelerated aging—the ratio of the current at 1000 hours to the initial value—were found to be the best indicator of failure during the first four to ten years of projected actual use. Furthermore, the change identified which junction would deteriorate more rapidly.

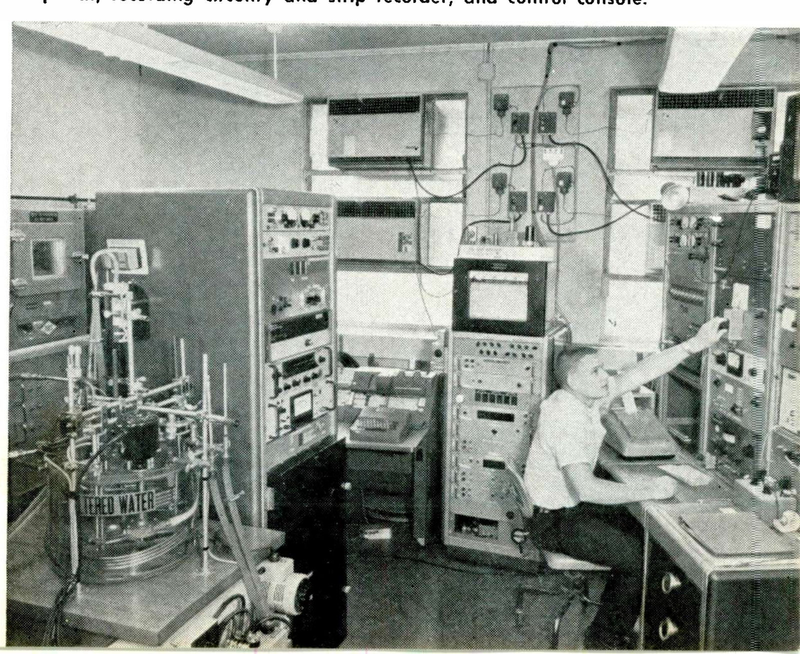
Results of a second experiment confirmed earlier findings on the usefulness of the leakage-current screening procedure.

Conclusions

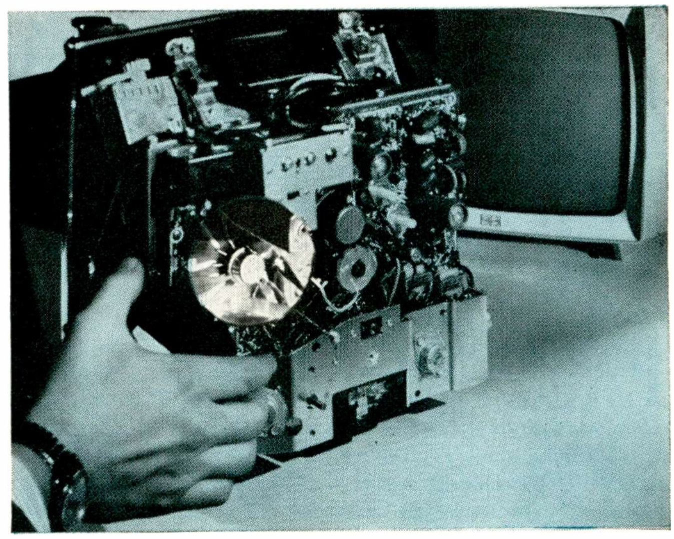
The best rejection criterion for the transistor types tested appears to be a minimum increase in leakage current by a factor within the range from 1.6 to 2.2 after storage for 1000 hours at 100°C.

This experiment also showed that questionable predictions may result from using dissipation of power to help maintain high junction temperatures. Under such conditions, differences in thermal resistance between specimens of different manufacture have been observed to lead to poor failure predictions. This was verified in the experiment by subsequent normal-stress aging and testing. ▲

Transistors are tested at intervals during accelerated aging conditions at NBS to identify patterns of early changes indicating failure-prone specimens. Here Engineer Donald Shook controls the automatic testing circuitry. Equipment shown is, left to right, an aging oven (rear), water temperature stabilizing and circulating apparatus (foreground), cabinet containing thermostatted test chamber (bottom) and control circuitry (top), automatic keypunch, recording circuitry and strip recorder, and control console.



The linear integrated circuit in consumer electronics makes its debut. The linear IC is shown here under magnification. Actually, unit is .335 inch in diameter and .180 inch thick.



TV SET USES INTEGRATED CIRCUIT

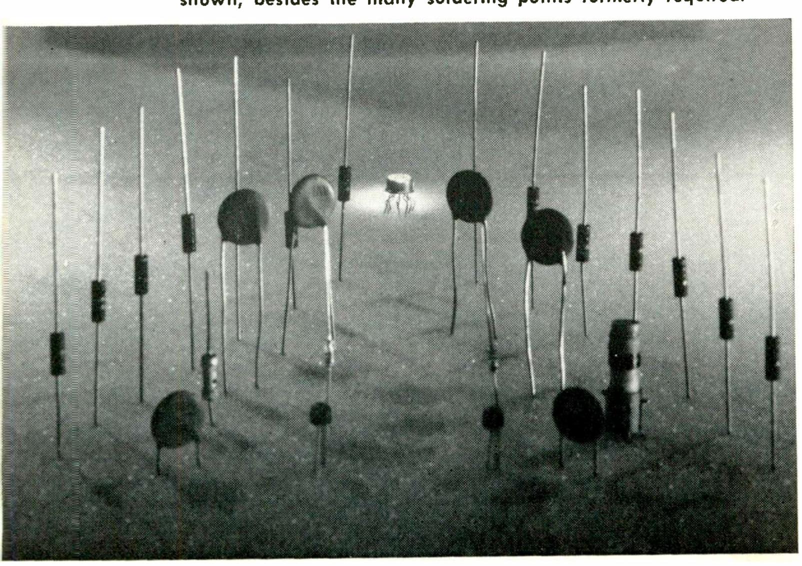
This first use of a relatively inexpensive linear integrated circuit to replace 26 discrete components plus their wiring, may foretell wide use of these devices in a broad range of consumer electronic products.

THE home entertainment industry met its latest electronic component recently when *RCA* introduced its new 12-inch, solid-state "Cherub" TV that incorporates a linear integrated circuit (IC). Although *Zenith* has been using an integrated circuit in its line of hearing aids, and several organizations have built and demonstrated laboratory prototypes of various types of communication equipment to prove IC use feasibility, this is the first time that an integrated circuit has made an appearance in a commercially available TV set.

Although the digital member of the IC family is in common use in data processing equipment, the relatively little-used linear IC is just starting to make its presence felt in TV sets as well as putting pressure on circuit designers of a long list of electronic devices including AM, FM, and short-wave receivers, audio systems, and most electronic test equipment.

According to Bryce S. Durant, President of *RCA Sales Corp.*, "The advent of integrated circuits in home entertainment products paves the way for greater reliability, improved circuit performance characteristics, and a longer operating life." Dr. James Hillier, Vice-President of *RCA Laboratories*, states "... we expect that the benefits of integrated circuits can soon spread throughout the entire communications industry. This can lead to radical advances in the design, capability, and economy of many types of systems."

Fig. 1. The linear IC (in spotlight) replaces 26 components shown, besides the many soldering points formerly required.



There were two major stumbling blocks in the path of introducing IC's into consumer devices—their cost compared to the cost of the items they replace, and where they could best be used considering the present state of the IC art.

The cost of the new *RCA* i.f.-limiter-detector-audio preamplifier IC ranges from $3.15 each in quantities less than 24 to $1.95 for quantities in excess of 1000. Another, similar type linear IC operating from a lower voltage source sells for $2.65 each, in quantities less than 24, to $1.65 for quantities in excess of 1000. These prices compare very favorably with the estimated per unit cost of $5 that many industry circuit designers felt would swing them in favor of using IC's over discrete components.

Because it is not possible, at this time, to integrate inductive components of useful value, some functions such as certain types of i.f.'s and tuners are not economically practical. Since integrated capacitors cannot exceed 50 pF while integrated resistors cannot exceed 30,000 ohms, certain other areas are excluded at present. Also, because operating voltages and currents of IC's are still limited, sweep and other power circuits are out of the question.

RCA found that the easiest and most economical area in which to use IC's initially is the intercarrier sound system of TV sets (with the exception of the audio power amplifier). The signal power requirements for this type of circuit are low, while the requirements for capacitor and resistor values fall within IC limits. The one or two inductive components, or large-value bypass capacitors that may be required, can be mounted external to the IC on the printed board.

The particular IC used by *RCA*, the CA3013, is contained in a ten-lead package only 0.335-inch in diameter by 0.180-inch thick. As shown in Fig. 1, this tiny package replaces 26 discrete components including one coil, two transistors, two diodes, seven capacitors, and 14 resistors, plus their chassis space, weight, and solder connections.

Characteristics of this IC include a voltage gain of 67 dB, noise figure of 8.7 dB, knee of limiting 300 μV, and AM rejection of 50 dB. The output (audio) voltage is 220 mV at a total harmonic distortion of 1.8 percent.

The performance of this IC is equal or better than its discrete component counterpart. Because of the excellent limiting provided by this circuit, with input signals ranging from 500 to 200,-000 μV, the output signal remains constant within 0.5 dB.

Also, because direct coupling is used between the stages, there are no time constants to charge up on impulse noise, thus greatly reducing spike interference.

The circuit of the intercarrier audio system, including the linear IC and the necessary outboard components, is shown in Fig. 2. This system feeds a conventional transistor audio power amplifier.

The 4.5-MHz input, derived from the TV set's second detector, is selected by a high-"Q" 4.5-MHz transformer before being passed on to the amplifying circuit. Use of a high-"Q" transformer removes spurious beat components and limits the effective noise bandwidth of the system, thus improving threshold sensitivity.

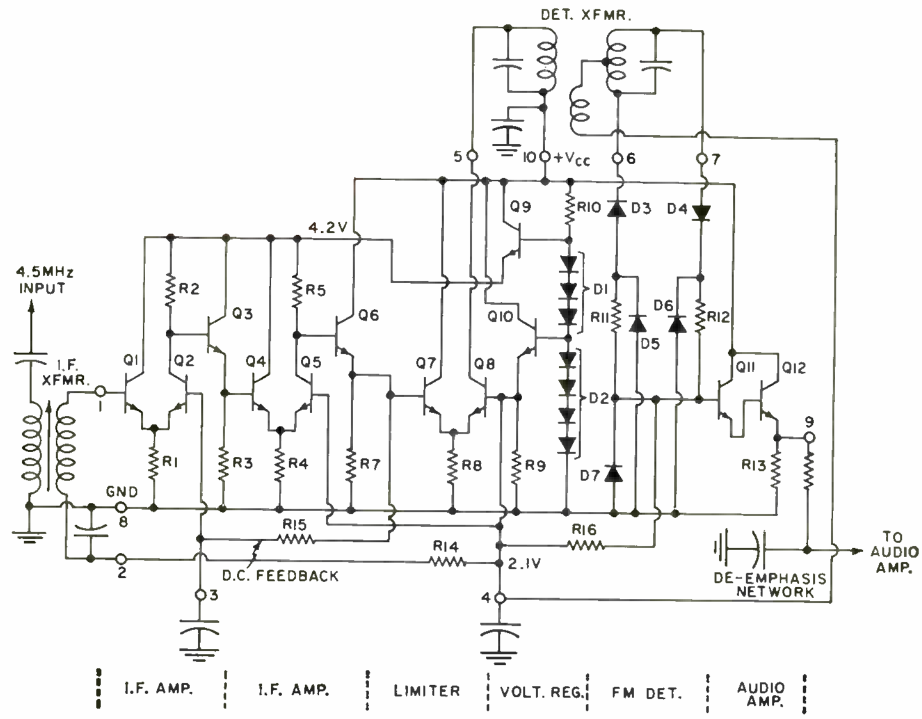


Fig. 2. The linear IC provides i.f. amplification, limiting, detection, and audio preamplification. The outboard components are connected to numbered terminals of 10-lead package.

The signal selected by the transformer is then amplified by a direct-coupled, two-transistor, emitter-coupled i.f. amplifier (*Q*1,*Q*2) having an emitter-follower output (*Q*3). This amplifier is directly coupled to a similar triad (three-transistor configuration) where the signal is further amplified.

The limiter circuit consists of a pair of emitter-coupled transistors (*Q*7, *Q*8) with *Q*8 driving the primary of the outboard detector transformer. Limiting is accomplished by biasing the transistors so that the output of *Q*8 will swing symmetrically about the zero signal axis so that limiting will not create spurious phase modulation. The d.c. operating point is correctly maintained by using d.c. feedback around the first two stages *via R*15. The third stage (*Q*7, *Q*8) is then automatically held at the correct operating point.

The ratio detector circuit consists of diodes *D*3 and *D*4 with diodes *D*5, *D*6, and *D*7, and resistors *R*11 and *R*12 acting as the detector load. This detector uses a substantially resistive load where filtering of the signal frequency and its harmonics is improved by the distributed capacitance of the diffused load resistors (*R*11 and *R*12), and the small-value capacitances created by reverse biasing diodes *D*5, *D*6, and *D*7.

Operating the detector into a substantially resistive load lowers the loading effect of the detector on its transformer, thus improving linearity. This is because in such a detector, variation in the detector load components by about 20% (which is quite common), greatly alters the peak-to-peak separation of the detector curve besides distorting the linearity of the straight-line portion.

Because the diffused resistors and diodes are almost exactly matched in value in an integrated circuit, an excellent FM detector curve is maintained and amplitude-modulation components are reduced to a minimum.

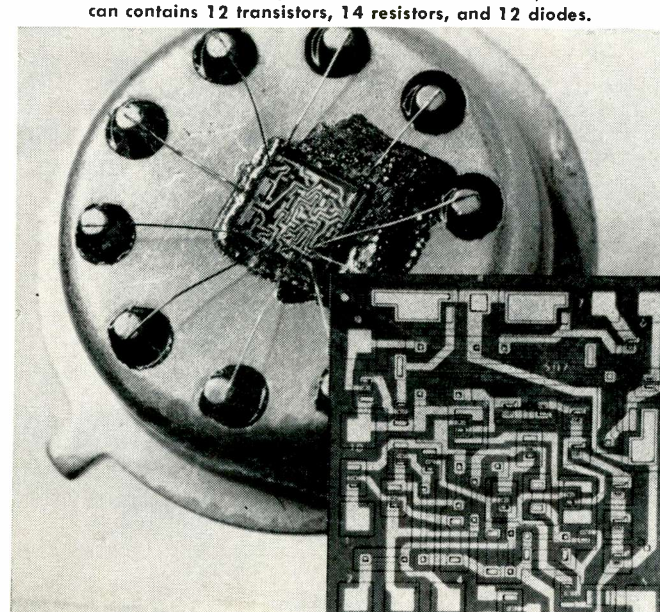
An additional benefit occurs with the use of this detector. If r.f. interference should reach the FM detector, causing pulses of energy to be created, instead of radiating these interference spikes (which introduces the possibility that they could be picked up by neighboring i.f. or antenna circuits), the unwanted spikes are greatly reduced because of the resistive loading while the small area of the diffused resistors confines the interference to a very small area within a shielded metal can.

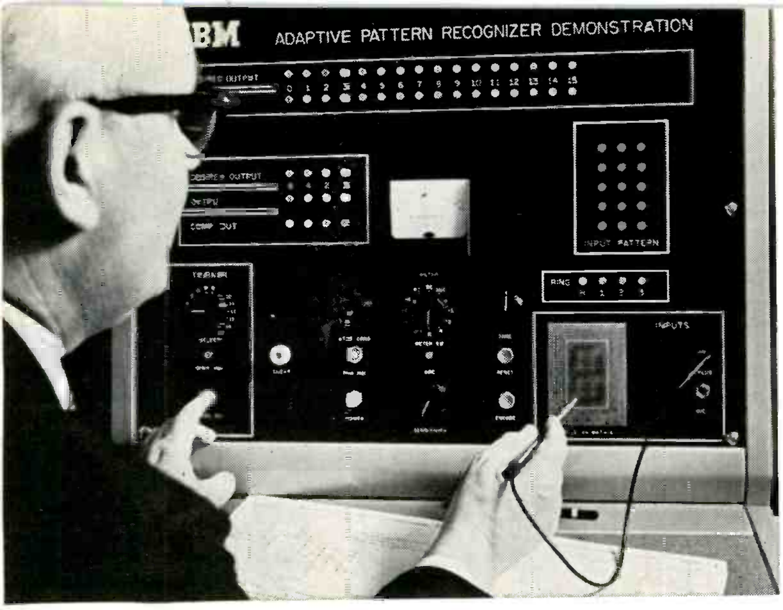
The output of the ratio detector is then directly coupled to a two-transistor (*Q*11, *Q*12) audio preamplifier. The output is followed by an external de-emphasis network and coupled to the remainder of the audio system.

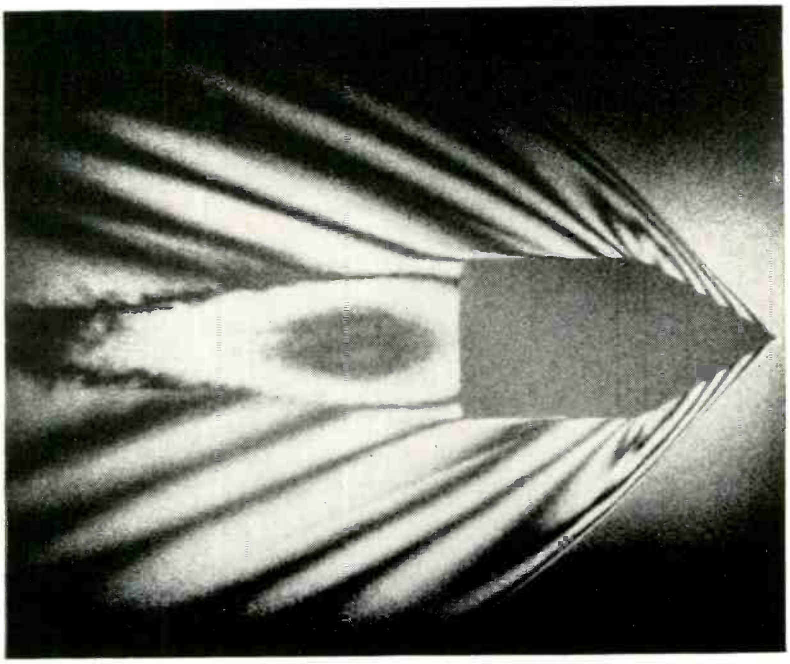
Unlike most integrated circuits, this particular unit is supplied with an internal voltage regulator consisting of diodes *D*1 and *D*2, and transistors*Q*9 and *Q*10. The over-all IC is operated from a +7-volt supply in the TV set. This voltage is applied to the internal regulator which, in turn, supplies regulated 4.2 and 2.1 volts to critical portions of the circuit. In this way, the over-all gain remains constant with changes in the supply voltage between 6 and 10 volts.

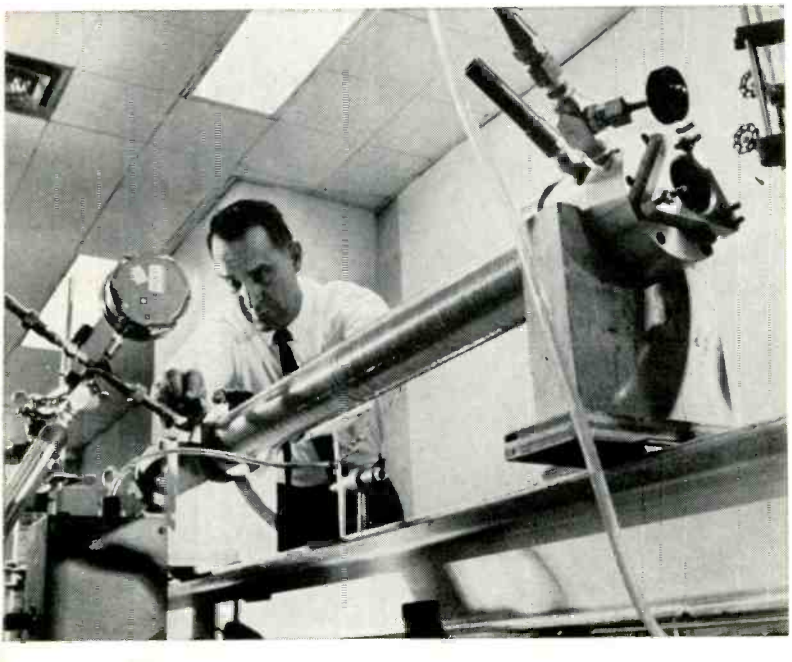
Although *RCA* is the first to incorporate an IC into its line of TV sets, other manufacturers are hard at work. One persistent rumor is that *Admiral* is developing an IC for use in its 1967 color-TV line. *Zenith Corp.*, already using an IC in its hearing aids, has started an in-house development program for other IC uses in the near future. Other manufacturers have not disclosed their IC plans. ▲

Miniscule linear integrated circuit in the 10-lead, TO-5 can contains 12 transistors, 14 resistors, and 12 diodes.









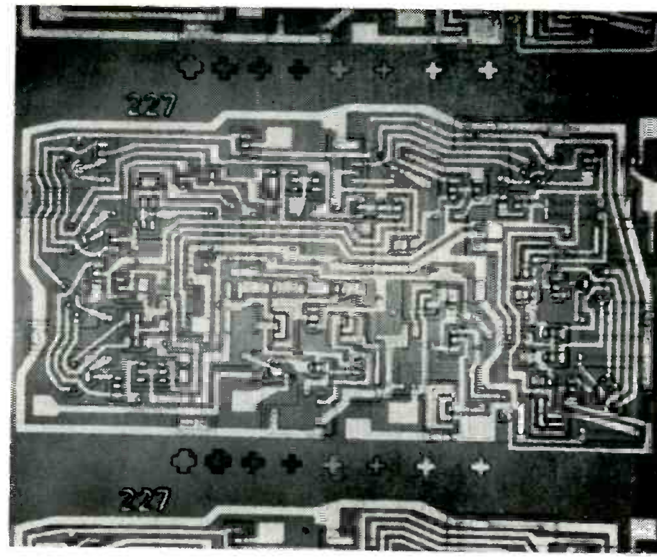
RECENT DEVELOPMENTS IN ELECTRONICS

Self-Teaching Computer. (Top left) An experimental machine that can be taught to recognize written and spoken information is shown here. In a typical "learning" operation, the numeral "3," for example, is written on the metal plate at the bottom right or spoken through a microphone. An electronic "portrait" of the numeral is set up within the machine and displayed in lights as an input pattern (right of panel). By indicating the number on the "trainer" dial and pressing the conditioning switch (lower left), the operator tells the machine's internal electronic logic it has just perceived a "3." After a few such training cycles, the machine will consistently recognize the pattern. Adaptive logic machines using these principles hold promise for future applications such as diagnosis of illness from "patterns" of symptoms, analysis of weather and economic patterns, handwriting and speech recognition, and in self-repairing electronic systems for space exploration. The machine was demonstrated recently by IBM Corp.

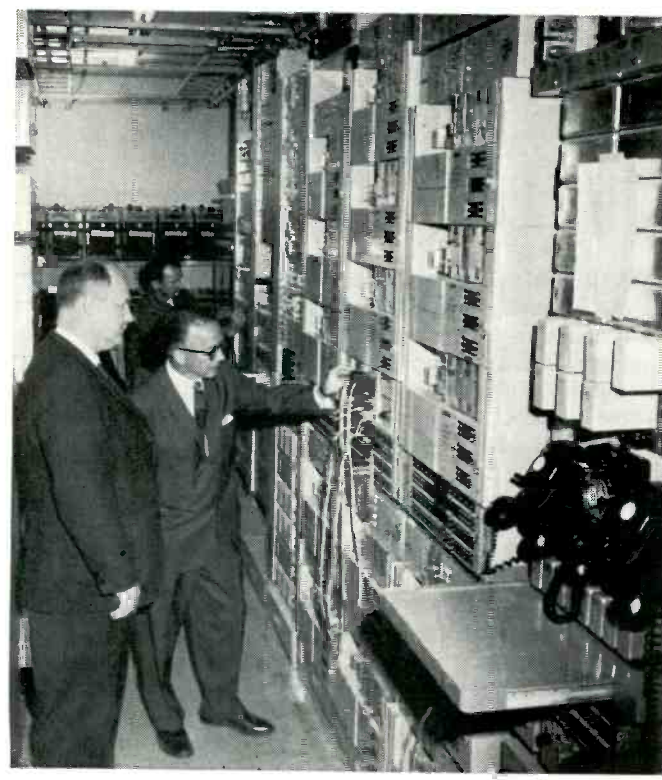
Doubly Exposed Laser Hologram. (Center) A conically tipped 22-caliber bullet is photographed from the image produced by a doubly exposed laser hologram. The original hologram was exposed twice within half a thousandth of a second by a Q-switched ruby laser. The bullet is travelling in krypton gas at 2½ times the speed of sound. The laser photograph is used to show an object in full three-dimensional detail, while the rapid double exposure produces an interference pattern that shows the effect of the object on the surrounding gas. Holographic interferometry does not require accurate alignment procedures and precision optical elements used for conventional interferometry. The three-dimensional record of the interference phenomena can be examined from various directions, so that the technique should be useful in aerodynamic and fluid dynamic research, as well as in studies of material strain and vibration, erosion, and optical testing. This work has been reported on by TRW Systems physicists.

Coax Pump-Light Laser. (Bottom left) This large laser is energized, or "pumped," by a new type of coaxial flash tube. This tube is the long, spirally wrapped cylinder. It completely surrounds a water-cooled laser rod and floods it with short bursts of brilliant white light. This pumping light stimulates the rod to re-emit it as a much brighter, narrow beam of coherent light. The pump is of special ceramic and glass construction to withstand, during the brief instants that it is on, the shock of handling the equivalent of the total electrical power needs of a city of 100,000 people, or a peak power of 100 megawatts. The pump does away with the bulky and expensive reflecting cavities needed by conventional flash tubes to focus light onto the laser rod. The new coaxial tube acts as its own reflector. A Westinghouse research engineer is shown preparing the laser for firing —which is done by remote control from adjoining laboratory.

Computer on a Slice. (Top right) The industry's first single-chip monolithic silicon integrated circuit decade frequency divider is shown. This is a complete multi-function computer sub-system on a standard size integrated-circuit chip. It contains 40 gates made up of 116 transistors, resistors, and diodes. The unit can be used in computers or in communications systems. It will be particularly significant in airborne, satellite, or space applications where size and weight are of prime importance. The divider, manufactured by Sylvania, will process both analog and digital input signals and produce a square-wave output precisely 1/10th the input frequency. This particular circuit will operate properly between frequencies of 5 Hz and 30 MHz.

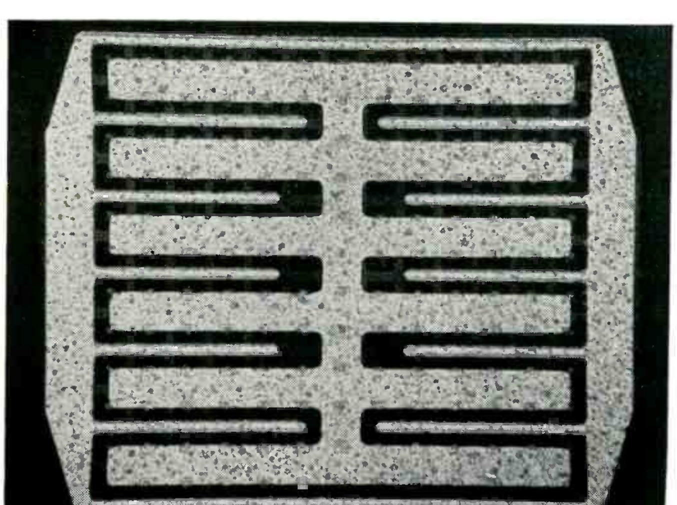


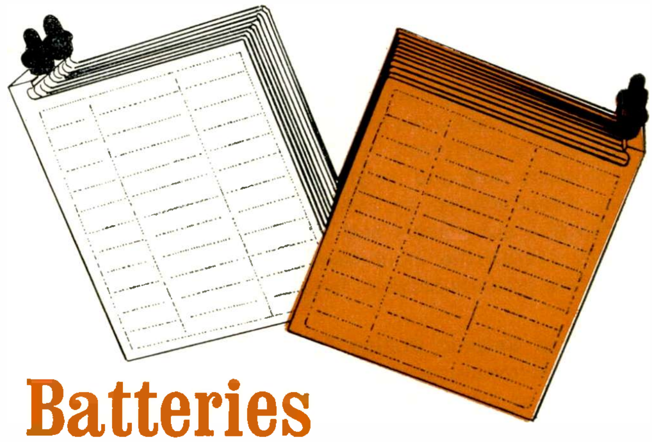
Underground Seismic Station Communications Link. (Center) Advanced microwave and carrier equipment is playing an important role in the transmission of data from an underground seismic station in Montana. The station will detect nuclear explosions occurring anywhere in the world, particularly in the northern hemisphere. The installation, known as LASA (Large Aperture Seismic Array), consists of a network of 525 seismic detectors laid out over a 6000 square mile area. With so many detection units spaced so far apart, it will be possible to trace the direction and distance of an incoming shock wave because it will be received by all detectors at slightly different times. M.I.T.'s Lincoln Laboratories is in charge of the project which employs equipment supplied by Lenkurt and Western Electric.



"Overlay" R.F. Power Transistor. (Below left) In order to obtain higher powers at higher r.f. frequencies from transistors, special fabrication techniques are required. One of these, illustrated here, is used in RCA's "overlay" transistors, which can deliver watts of power in the gigacycle frequency range. In this design, there are a large number of separate emitters, all connected in parallel by the metal-film pattern shown. This multiplies emitter periphery for more power but reduces emitter area for higher frequencies, as well as significant increases in gain and efficiency. Transistors of this type are finding use in various types of communications transmitters.

Atomic Dirt Detector. (Below right) A special detector that spots impurities in particles of matter thousands of times smaller than a pinpoint is used at a British subsidiary of ITT for building better transistors. A speck of material only one-fiftieth of a thousandth of an inch in size is heated behind the picture-tube screen at the lower left. When a high voltage is placed between the sample and the screen, atomic particles are torn off the sample and hit the screen. They produce a 500,000-times-enlarged picture of the sample and indicate the nature, extent, and position of the impurities. The glass apparatus shown is a vacuum system used for the picture tube.





Sealed Lead-Acid Batteries

By E.T. DeBLOCK and JOHN R. THOMAS
Globe-Union Inc., Battery Division

From the workhorse of all rechargeable electro-chemical systems, this newest advance in sealed compact power sources offers highest cell voltage, heavy drain capability, and maximum watt-hour capacity at extreme temperatures.

INCREASING design effort on the part of manufacturers in the entertainment, military, and industrial electronics industries in achieving portability combined with miniaturization has awakened the marketplace to a host of cordless power applications. A rechargeable power supply is a very important adjunct to such products.

The lead-acid battery offers product-design engineers a very desirable compromise among the varieties of characteristics provided by members of the secondary power-supply family. At a reasonable cost, this battery is capable of meeting the heavy drains found in the duty cycles of such electronic-component-equipped products as TV, phonographs, tape machines, transceivers, CB radios, power tools, instruments, and even certain appliances. Its future is promising, due to a wide range of operating characteristics, low manufacturing costs, and the use of inexpensive, readily available materials.

A grouping of the new rechargeable batteries designed for portable and cordless electrical and electronic equipment. Ten sizes are currently available, ranging from 2 to 8 V with capacities from approximately 1 to 8 ampere-hours.

Although small, leakproof lead-acid batteries have been on the market only a few years, the basic system is one of the oldest and most reliable. The first lead-acid storage battery was presented to the French Academy of Sciences in 1860 by its inventor, Gaston Planté. Since then it has become the most widely used type of secondary battery. Probably the best known application of the lead-acid battery is in the automotive industry, which used 41 million units in 1965.

Without even thinking much about it, we have all come to expect long life and dependability from the batteries in our automobiles, even though they must endure physical abuse, wide temperature swings, and frequent high-current drains. Other applications have been in supplying large amounts of electrical power for telephone systems, to ships, for diesel starting, and for standby emergencies.

One may well wonder why small lead-acid batteries have not been on the market before now. The answer is fairly simple. First, there just was not much demand for small rechargeable batteries until a few years ago. Primary batteries were capable of meeting the light load and one-time-use requirements of transistor radios, toys, and flashlights. Similarly, nickel-cadmium batteries met the rechargeable requirements of low drain and extended life in premium-priced articles such as electric toothbrushes, carving knives, and shavers. Second, new methods of sealing and venting lead batteries were only recently developed. These improvements have now added to the lead-acid battery all of the safety and all of the handling ease of conventional dry-cell batteries.

Battery Construction

The lead-acid cell is composed of negative plates (lead-alloy grids covered with a deposit of lead having a special spongy structure); positive plates (also lead-alloy grids, but covered with a porous lead dioxide); and a sulfuric-acid electrolyte (see Fig. 1). Upon discharge, the lead on the negative plates reacts with the sulfuric acid present in the electrolyte to form lead sulfate, and in the process electrons are freed. Meanwhile, the lead dioxide on the positive plates also reacts with sulfuric acid to form lead sulfate and, in the process, electrons are accepted. The electrons flow from the negative terminal of the cell, through an external circuit, to the positive terminal. In the process, power is delivered to the external circuit.

Other important parts of the cell which do not take part in the actual current-producing reactions are: the case and terminals, straps used to connect positive or negative plates in any one cell, and separators which are non-conductive and are placed between the positive and negative plates in order to keep them from coming in direct contact with one another.

These small lead-acid batteries have several unique and interesting design features not found in other rechargeable batteries. The cases are made of strong, lightweight plastics. These are insulators and the battery cannot be shorted accidentally through contact to the container, as can happen with metal-cased batteries. This also makes it easy to equip the batteries with many types of connectors required by the user. Batteries are now available with solderable terminals or with a variety of pressure-contact, snap, or plug-in terminals.

The *sealing methods* of the lead-acid battery differ from the fail-safe venting method used in other rechargeable cells. Due to the fact that small amounts of gas may be generated in any type battery during charge and discharge, the lead-acid batteries are equipped with vents, which will allow gas to escape from the battery, but will not allow electrolyte to leave the battery or air to enter it. Thus, in a sense, these batteries are sealed, but not gas tight. The day may come when these batteries will be completely sealed without any venting. When that happens, any gases generated within the battery will be immediately recombined to form the original compound from which they were generated. But in the present batteries only small amounts of dry gas are released in normal operation so that, as far as the user is concerned, the batteries can be handled as if they were sealed.

Another feature found in these small sealed batteries which is not found in the larger lead-acid versions is an *immobilized electrolyte*. The advantages of such an immobilized electrolyte are great. First, by immobilizing the electrolyte between the plates of a battery, it is possible to operate the battery in any position. If, for example, a battery containing a free-flowing electrolyte were operated on its side rather than in an upright position, some of the electrolyte would move into the head section of the battery leaving, in turn, part of the plates uncovered and useless. Second, immobilizing the electrolyte minimizes a chance of electrolyte leakage from the battery.

There are two methods of immobilizing electrolytes. The first method involves the use of a gelling agent to solidify the electrolyte and keep it from flowing. In these batteries the gel is thixotropic and is rejuvenated on every cycle. (A thixotropic gel is one that becomes fluid when disturbed and sets again when allowed to stand, like mayonnaise.) This rejuvenation eliminates cracking, shrinkage, and separation of the gel from the plates—problems which occur in gels which are not thixotropic.

The second method of immobilizing electrolytes is the storage of the electrolyte in highly porous separators. In order

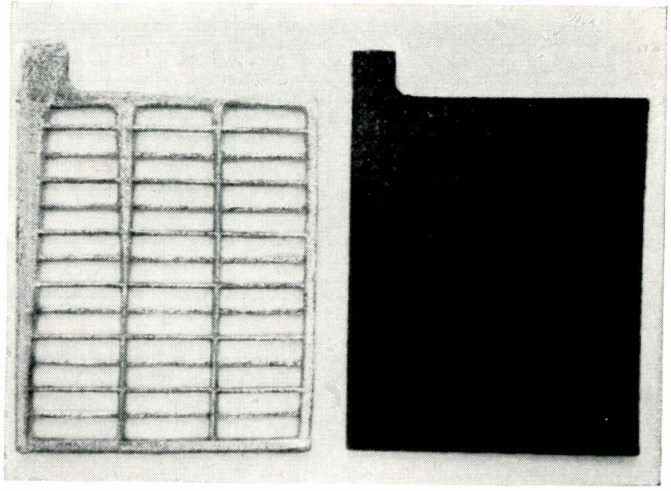


Fig. 1. At left is a calcium-lead alloy grid from a typical small lead-acid battery. At right is finished positive plate.

to be acceptable for use in this dual function of separating positive and negative plates and storing the cell's electrolyte, a material must be non-conductive, capable of holding several times its weight in acid, and resistant to attack by sulfuric acid and lead dioxide.

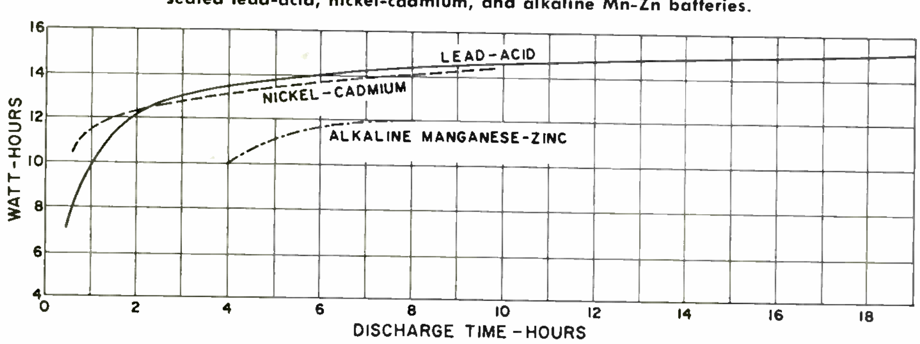
A third special feature of these batteries is the use of calcium-lead grids. They are used rather than the common lead-antimony alloys because they minimize self-discharge. They thereby minimize the loss of water from the battery, because the self-discharge reactions use up water. Although the amount of water lost is usually very small, replacement water cannot be supplied to a sealed battery. For that reason the battery must be designed to minimize loss of water.

Performance Characteristics

One of the major advantages of the lead-acid system is its high capacity and the fact that it will deliver most of its capacity even if discharged at high rates. Despite the high density of lead, the small lead-acid battery compares quite favorably with other rechargeable systems in power available per unit weight. A typical battery is capable of delivering 14.9 watt-hours per pound. This battery is even more impressive when compared in terms of power available per unit volume, where it delivers 1.1 watt-hours per cubic inch. The availability of the lead-acid battery's capacity over a wide range of discharge rates is shown in Fig. 2, where the relative performance of two competitive systems is also shown.

The open-circuit cell voltage in the lead-acid system is a little over two volts. This voltage is the highest found in any commonly used cell system and is an important factor in the high capacity exhibited by lead-acid batteries. The closed-circuit voltage of this system will vary slightly with the load placed on the battery. Nevertheless, these cells will maintain high voltage over a large range of discharge rates (see Fig. 3). The end-of-discharge voltage is also somewhat dependent on the rate of discharge, but it is 1.75 volts per cell for most common discharge rates.

Fig. 2. Variations in time taken to totally discharge comparable sealed lead-acid, nickel-cadmium, and alkaline Mn-Zn batteries.



There are two distinct advantages in having high cell voltage. First, fewer cells are needed in the manufacture of higher-voltage batteries. For example, a 6-volt nickel-cadmium battery has five cells as opposed to three cells in a 6-volt lead-acid battery. Fewer cells lead to definite savings in manufacturing costs.

The second advantage lies in the fact that battery capacity is dependent upon the capacity of its individual cells. Therefore, as fewer cells are needed in a lead-

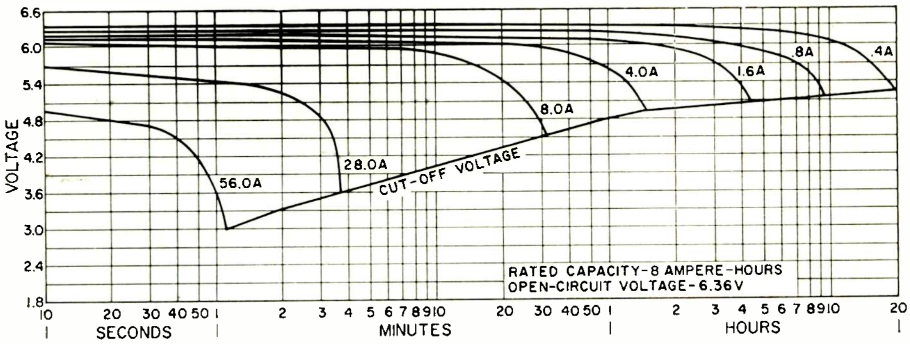


Fig. 3. Voltage vs time for various discharge currents of an 8 ampere-hour sealed lead-acid battery ($V_{open\ ckt}$=6.36 V).

acid battery to obtain the desired voltage, these cells may be made larger and of greater capacity without increasing the external dimensions beyond those found in other electrochemical batteries of equal output voltage.

Charge Characteristics

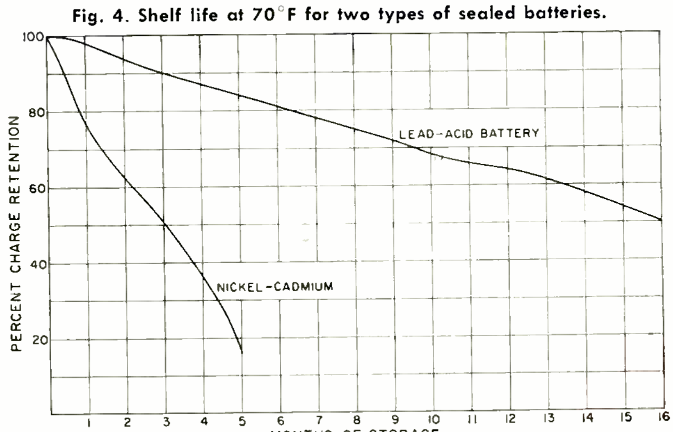
Recharging the sealed lead-acid battery is relatively simple. In many instances the portable equipment in which the battery is used is designed to operate on alternating current as well as on battery. Such equipment will already contain a d.c. power supply which can be used to charge the battery. Charging procedures vary somewhat with the design of the battery, so it is best to use the procedure recommended by the manufacturer. In general, the initial charging rate is at a current value close to 1/10th the battery capacity ($C/10$) for about 5 to 6 hours. This current is maintained until the battery is almost fully charged. From that point the current is decreased gradually, while the voltage continues to rise. When the battery has reached the desired maximum on-charge voltage and the current has dropped to approximately $C/200$, charging is discontinued. Final on-charge voltage is usually between 2.4 and 2.5 volts per cell.

This charging can be done with fairly simple equipment with some attention from the user. Or, if this is undesirable, more sophisticated chargers can be used which switch themselves off or which switch to a float voltage just above open-circuit voltage when charging is complete. Such chargers insure that the battery is always fresh and ready for use.

If using a charger which does not switch off automatically or switch over to a float mode, one must use care not to seriously overcharge the battery. A great deal of overcharging can remove enough water from the battery's electrolyte to cause premature failure.

The charging efficiency of the lead-acid system is quite high. In general, when dealing with the small sealed batteries, less than ten percent in excess of what was removed from the battery on the previous discharge must be replaced when recharging. This feature can mean substantially reduced charging time—an advantage to the consumer.

Fig. 4. Shelf life at 70°F for two types of sealed batteries.



The state of charge of any sealed battery is not easy to determine. The on-charge or on-discharge voltage of a lead-acid cell can give a rough idea of its state of charge. Open-circuit voltages, although affected by state of charge, do not vary enough to be useful as an indication of state of charge unless extremely sensitive voltage measuring instruments are available. Actually, the simplest way to handle one of these batteries if the state-of-charge is not known is to recharge it.

Frequent deep discharge or over-discharge will damage any battery, but these small lead-acid batteries can take such abuse fairly well. This is an important factor since appliances are often left on accidentally, running the battery to exhaustion. These batteries have been short circuited for as long as one month, after which they still functioned normally. The charging time required after such a deep discharge is, of course, much longer than after a normal discharge.

The small sealed lead-acid batteries have good cycle life. It is impossible to give one meaningful figure because cycle life always depends on what a "cycle" is; but over the range of normal uses, cycle life will be from 50 cycles (for the most severe conditions) to over 200 cycles (for the most favorable conditions).

Shelf life is exceptionally good in the batteries using calcium-lead grids. These batteries lose only 3% of their total capacity per month when stored at room temperature (see Fig. 4). This means that no recharging is necessary during normal storage periods.

The lead-acid battery system is less affected by extremes of temperature than are most others. At 0°F the battery will still retain nearly 70% of its room-temperature capacity. At high temperatures the lead-acid battery performance is even more startling. Capacity at 120°F runs at least 10% higher than at room temperature. The battery can be used from about −60°F to 140°F. When in a charged state, it will not freeze unless exposed to temperatures in the vicinity of −85°F.

One of the most important features of the lead-acid system has no connection with its performance. This feature is low cost. As has been pointed out, the design of the small lead-acid battery is simple. This, of course, helps to keep production costs low, but even more important is the fact that the materials used in the manufacture of the battery are both inexpensive and readily available. There is no doubt, for example, that lead will always be available and at low prices. This is not true of the basic materials used in manufacturing any other comparable battery.

At the present time, these batteries are being offered in sizes and voltages which the manufacturers have selected as most likely to find wide acceptance. As the market grows in volume and new battery-powered appliances are developed, new battery sizes will be developed to meet these needs and probably there will be many more batteries available rather than fewer. It is likely, however, that after the initial flurry of many new models the batteries will become standardized in dimensions as well as in voltages and capacities. The standard models will be those which have won the greatest acceptance during the initial introductory period.

Two large American battery manufacturers are now marketing small, sealed lead-acid batteries with capacities ranging from one to 8 ampere-hours. These companies are *Globe-Union Inc.* and the *Electric Storage Battery Co.* The batteries offered by these companies fill a gap in the small-battery field which opens new markets to designers of cordless equipment. In fact, these batteries will make possible new cordless devices which would not have been practical with other types of batteries. ▲

Chroma Synchronization in Color Sets: RCA

By WALTER H. BUCHSBAUM

To reproduce the correct colors, the chromatic demodulators must be supplied with an accurate source of two-axes reference signals. Here are the details on the CTC-16, -17, and -19 color chassis.

THE most critical of the three major circuit sections that makes color reception possible is the color sync section. If the color sync of the receiver is not exactly in phase with the color signal of the transmitter, it is impossible to reproduce the correct colors. This is because all chroma information is phase and amplitude modulated on the 3.58-MHz color subcarrier and, to properly demodulate, a replica of the original unmodulated subcarrier reference signal must be available. The demodulating circuits of the new *RCA* color sets were described in detail in the May issue. At that time, the presence of a correct *X* and *Z* color sync signal was taken for granted. This article covers the circuits and processes by which the correct *X* and *Z* color sync signals are generated from the 8-cycle chroma subcarrier reference burst which is transmitted on the trailing blanking back porch of every active horizontal sync pulse.

All color sets must provide at least three basic functions to go from the color sync burst to the final two chroma axes reference signals. These steps are illustrated in the block diagram of Fig. 1.

First, the reference burst must be removed from the horizontal sync back porch and this is accomplished in the burst gating amplifier. Next, the burst must be used to accurately control the receiver's 3.58-MHz sine-wave generator. This is a critical circuit because this 3.58-MHz sine-wave signal is the basis of the two chroma axes reference signals which are used to demodulate the *X* and *Z* information. If the phase error in the 3.58-MHz generator exceeds 10°, incorrect colors will appear. The 10° error figure is the absolute maximum that can be tolerated and most receivers should be adjusted to less than 5° error. The final step is phase shifting the receiver 3.58-MHz sine-wave signal to obtain the correct axes phase for the two color demodulators.

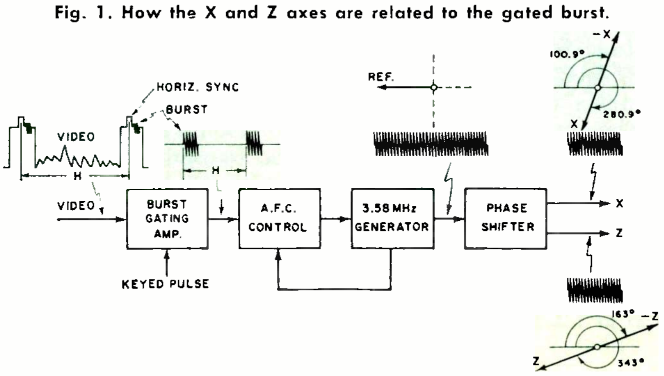
In addition to color sync generation, this section also includes the color killer circuit that turns the chroma section off when the transmitted signal does not contain a color sync burst. During monochrome transmission, all chroma signals must be suppressed to keep spurious colors from appearing superimposed on the monochrome picture. To accomplish this, the color killer circuit "looks for" the color burst which has been removed from the horizontal pulse in the burst gating amplifier and generates a bias that controls operation of the chroma bandpass amplifier.

CTC-16, 17 Operation

The circuit of the color sync and color-killer section of the CTC-16 and 17 models is shown in Fig. 2. The video signal is applied at the grid of burst gating amplifier, *V*1, which is normally cut off due to its biasing arrangement. During the horizontal flyback pulse interval, the control grid of *V*1 is driven sufficiently positive to permit the color sync burst to be gated from the video and amplified. Only the 3.58-MHz reference bursts then appear at the plate of the tube. Transformer *T*1 is tuned to 3.58 MHz and its secondary is a bifilar winding that provides an effective center tap to ground for a.c. only. This bifilar winding is more accurately balanced than if a physical center tap were provided. Opposite-polarity 3.58-MHz signals appear at the plate and cathode of the double-diode, *V*2, while the 3.58-MHz oscillator signal is applied to the opposing plate and cathode. If the burst signal and the oscillator signal are exactly in-phase, the diode currents will cancel each other and no error voltage will appear at the junction of *R*1 and *R*2. If the oscillator signal differs in phase from the reference burst, an error voltage, either positive or negative depending on the phase relationship between the two signals, will be applied to reactance tube *V*3.

Because the color sync burst is present for only 8 cycles during each horizontal flyback period, the phase error voltage must be filtered to remain constant during the periods between bursts. Network *C*1, *R*3, and *C*2 form this filter. The reactance control tube (*V*3) represents a capacitance which tunes the resonant circuit *L*1-*C*3. This resonant circuit, together with the 3.58-MHz crystal, form the 3.58-MHz oscillator. Note that the crystal is connected between screen grid and control grid of *V*4, making these two elements the actual oscillating portion of the pentode. The plate,

Fig. 1. How the X and Z axes are related to the gated burst.



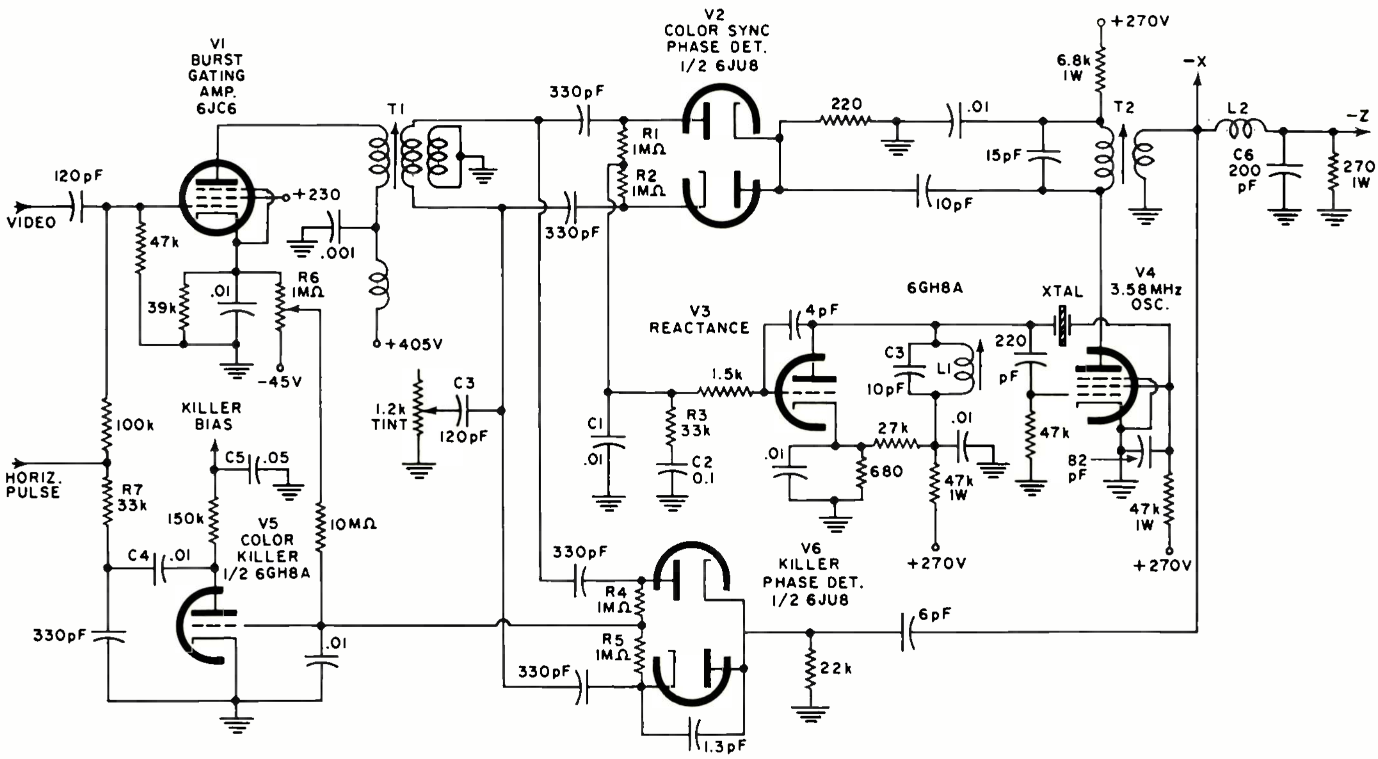


Fig. 2. The color sync and color killer circuits as used in the CTC-16 and -17 models. Output is $-X$ and $-Z$ axes signals.

which drives the 3.58-MHz output transformer, *T2*, acts as an amplifier that helps to isolate the oscillator from the following load.

In this circuit, the tint control consists of a capacitor, *C3*, and a potentiometer which unbalances and detunes the secondary of the phase detector transformer, *T1*. The actual oscillator phase is therefore controlled indirectly *via* the phase detector, the error voltage, and the reactance tube.

In the CTC-16 and 17, the color-killer circuit uses a separate phase detector (*V6*) that receives the same color sync burst signals as the color sync phase detector (*V2*). Instead of comparing the color sync with the feedback signal from the plate of the oscillator, the color-killer circuit compares it with the $-X$ chroma axis signal.

In effect, phase detector *V6* will have zero output at the junction of *R4* and *R5* when a burst signal appears with each horizontal pulse, and when the 3.58-MHz generator is in phase with the gated reference burst. The bias on color-killer amplifier *V5* can be controlled through potentiometer *R6* which connects between the cathode of the burst amplifier (*V1*) and -45 volts.

During horizontal flyback period, a strong positive pulse is applied through the plate of *V5* through *R7* and *C4*, that charges up *C5*. The voltage across this capacitor is the color-killer bias and is determined by the amount of current passed through the color-killer stage. This voltage, in turn, is determined by the *V5* grid bias which is a function of potentiometer *R6* setting and output of the phase detector *V6*. When color sync bursts are detected, the color-killer bias will be very low, allowing the bandpass amplifier to amplify. On black-and-white transmissions, however, the bandpass amplifier will be cut off.

The output of the 3.58-MHz oscillator *V4* and *T2* primary should be exactly in-phase with the transmitted color sync burst, as indicated in Fig. 3A. *RCA*'s demodulator and matrixing circuits use the $-X$ and $-Z$ vectors, as was explained in the May issue. For the $-X$ and $-Z$ demodulator, the color sync signals must be 100.9° and 163° from the reference signal. A 100.9° shift can be obtained in the transformer windings of *T2*. For the $-Z$ signal, the additional 62.1° are due to the phase shifting of *L2* and *C6*. This means that the relations between X and Z axes are fixed, but their phase relations to the reference sync can be varied somewhat by the tuning of *T2*, *via* core adjustment, about the nominal frequency.

To control the hue, or tint, of the picture the tint control, in effect, varies the phase between the reference sync and the incoming gated burst. One of the important features of this circuit is the fact that adjustment of *T1* affects the operating point of the phase detector and therefore the phase relation between the actual transmitted burst and the reference signal generated by the local oscillator. Adjustment of the tint control can compensate somewhat for any misadjustment of *T1*, but only over a limited range. For that reason, *T1* must be aligned for correct phase relations with the tint control set half way. In the CTC-19 color sync circuit these features are quite different.

CTC-19 Operation

The CTC-19 circuit uses only three stages to perform all color sync functions. A detailed circuit diagram is shown in Fig. 4 and, at first glance, indicates that the burst gating amplifier (*V1*) is essentially the same as that used in the CTC-16 and 17. Actually, only the value of the cathode resistor and horizontal pulse control grid feed resistor are different and the killer potentiometer is grounded.

The fundamental difference between the circuit of the CTC-17 and the CTC-19 is the "injection-locked" oscillator. According to the manufacturer, the oscillator is locked-in with the reference burst by the crystal ringing characteristics of the 3.58-MHz crystal. A similar circuit is used in the *G-E* "Porta-Color" set (see the March, 1966 issue) where the crystal is excited by the burst and then continues to "ring" until the next burst comes along. To provide a sine-wave signal of constant amplitude, the *G-E* circuit uses amplification and limiting. In the *RCA* CTC-19, an oscillator is used that derives its frequency from the crystal and sustains the oscillations by means of a resonant circuit (*L1* and *C1*) in the screen grid.

The circuit of Fig. 4 has a trimmer capacitor (*C2*) which is effectively in series with the ringing crystal and therefore has some effect on its phase angle, with reference to the gated burst. Transformer *T1* is tuned for maximum color sync burst amplitude and its secondary is loaded with 390-ohm resistor *R1* to broaden its frequency response. Capacitor *C3* feeds back some of the ringing signal to the primary of *T1* and this helps to sustain the ringing well beyond the end of the 8-cycle gated burst. With the ringing signal present at the control grid, the triode portion, consisting of the cathode, control grid, and screen grid with its tuned circuit, acts as an oscillator. The portion between screen grid and plate acts essentially as an amplifier, reducing any loading effect of the color sync signal.

Transformer *T2* couples the color sync signal to the phase shifting network, just as in the circuit found in the CTC-17. Again, tuning of *T2* has an effect on the phase of both the *X* and *Z* axes signals, but now the tint control also affects this phase. Depending on the setting of the tint potentiometer, tuning capacitor *C4* will cause more or less phase shift in the primary of *T2*.

The phase-shifting network of *C5* and *L2* is arranged opposite that used in the CTC-17, and for a very good reason. In the CTC-17 circuit, the plate of the 3.58-MHz oscillator had to produce a signal which was in-phase with the incoming burst, as shown in Fig. 3A. Therefore, the phase across the secondary of transformer *T2* was approximately 100° displaced, just about right of the −*X* axis signal. In the CTC-19, as shown in Fig. 3B, the "ringing" signal at the control grid of the 3.58-MHz oscillator is in-phase with the incoming burst and the signal at the plate is, therefore, 180° out-of-phase. It takes a combination of transformer *T2* winding arrangement and the phase shifting effect of the tint control to produce the 163° phase angle which corresponds to the −Z axis signal. In the CTC-17, the −*X* is obtained first and then a 62° phase delay is introduced by means of a series coil and shunt capacitor, as shown in Fig. 3A. To obtain a 62° phase shift in the other direction, the circuit of the CTC-19 uses a series capacitor *C5* and a shunt coil *L2* in Fig. 4. That is how the −*X* axis signal is derived from the −Z axis signal.

The color-killer circuit in the CTC-19 is also much simpler than that used in the CTC-17. As shown in Fig. 4, the plate of *V3* receives the horizontal pulse just as in the CTC-17 circuit of Fig. 2. The control grid, however, is connected to the output of the "ringing" crystal. If monochrome transmission is received, there will be no burst to excite the crystal and, therefore, there will be no crystal output. The grid bias on the 3.58-MHz oscillator is approximately −4 volts on monochrome and −8 volts on color reception. This grid bias is also applied to the color-killer amplifier and is sufficient to produce the killer bias which cuts the bandpass amplifier off during monochrome transmission. Adjustment

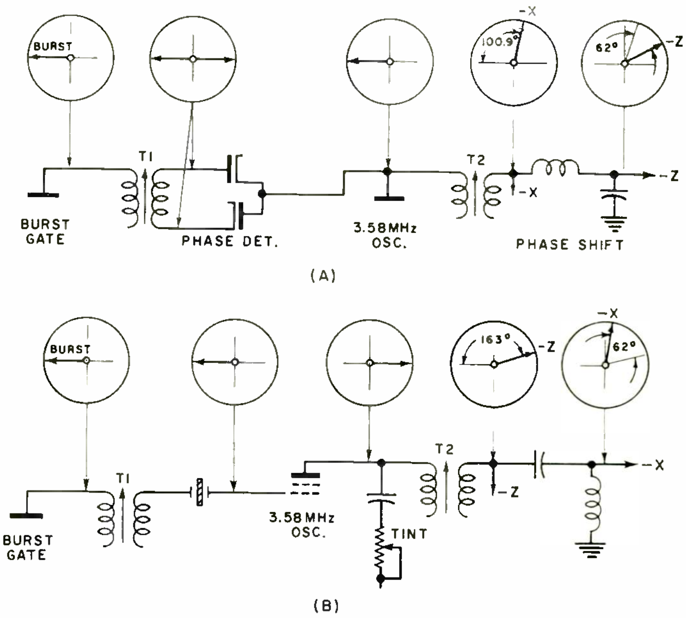


Fig. 3. (A) Phase relationship in the CTC-17 chroma circuit. (B) The phase relationship within the CTC-19 chroma circuit.

of the color-killer circuit operation is similar to that found in the CTC-17, a potentiometer located in the cathode circuit of the burst gating amplifier (*V1*).

Comparison

The color sync circuit of the CTC-17 and its predecessors has been used by *RCA* and many other manufacturers for at least 5 years. Its advantages include relative immunity to amplitude changes in the video signal and all of the benefits due to a continuous oscillator. These latter include some noise immunity, since loss of a single color sync burst will not substantially affect the oscillator output. In troubleshooting this section, it is not always necessary to have a color transmission or a color test signal because even if the oscillator is not synchronized, its signal can be measured and traced through.

In the CTC-19, the amplitude of the oscillator output will depend to some extent on the amplitude of the video signal, because the crystal is excited by each incoming gated 3.58-MHz burst. If a single burst is missed, no color sync signals are generated during the subsequent horizontal line. For troubleshooting, it is essential (*Continued on page 75*)

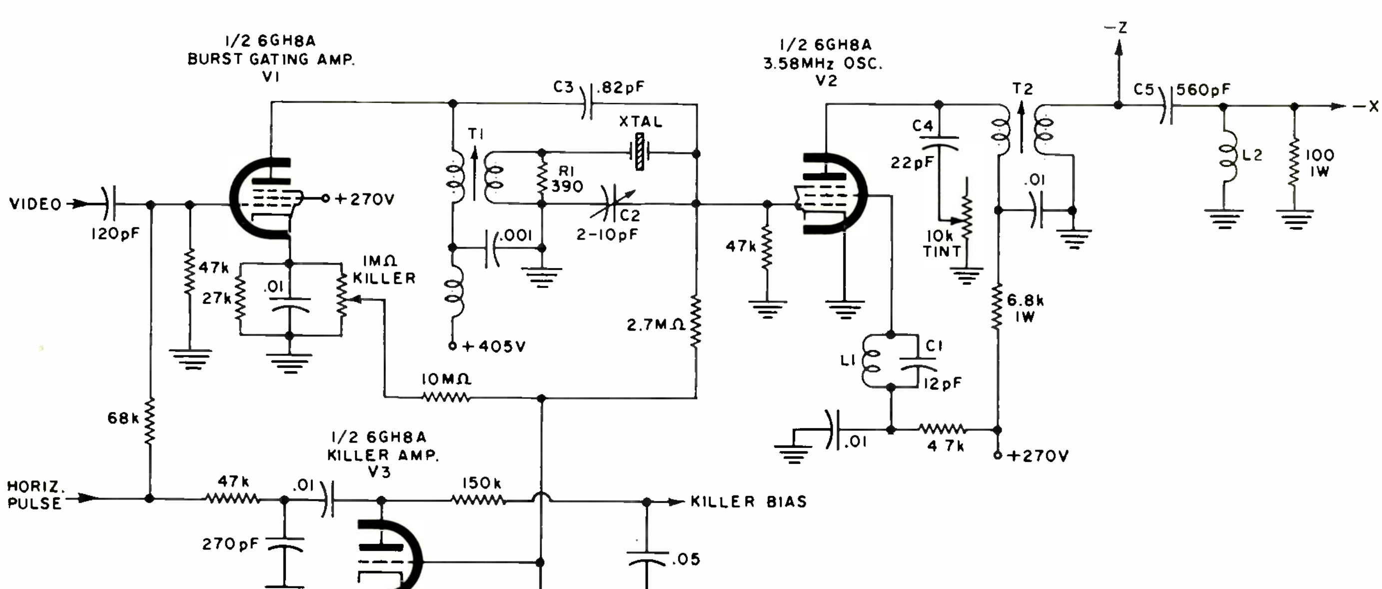


Fig. 4. The CTC-19 color sync circuit uses three stages and an injection-locked crystal oscillator to produce —X and —Z.

WIRELESS MICROPHONES

When the microphone cable becomes a hindrance, you can always take to the air with a microphone that is the ultimate in portability.

THE restrictive nature of a microphone cable upon the mobility of the user is quite apparent. There are many occasions, such as when a person speaking must move about an area, that the microphone cable limits full use of the p.a. system. It is for this reason that wireless microphones were developed.

There are two major types of wireless microphones: those that are FCC-licensed to operate on special Business Radio frequencies, and those frequencies made available for broadcast radio/TV use only; and those unlicensed but FCC type-approved units that operate on the standard FM broadcast band from 88 to 108 MHz.

The major specifications for wireless microphones are battery operation, small physical size and weight for true portability, and acceptable audio response (for the purpose). Because they are normally used within the same area as the p.a. systems they feed, the distance range of the unit is not critical as long as it delivers a usable signal to the associated receiver.

Typical of the high-quality commercial units licensed to operate in the Business Radio band, or in the special frequencies assigned exclusively to broadcast/TV use is the "*Vega-Mike*" shown in Fig. 1 with its associated FM receiver. This hand-held unit uses a dynamic microphone, has an audio response to 14 kHz, transmitter power to 40 mW, an FM-frequency swing of ±20 kHz, and the operating range is several hundred feet. The unit is one inch in diameter, five inches long, weighs 7½ ounces, and has a battery life in excess of 20 hours. The antenna is either the neck cord of the lavalier model, or a telescopic rod in the hand-held version.

The *Sony* CRT-10, shown in Fig. 2, is typical of the low-priced units used primarily for limited range communication. Using four transistors and a dynamic microphone as an FM transmitter, the unit is 5⅛" by 1¾6" by 1⁹⁄16" in size, weighs 6 ounces, is tunable across the 88-108-MHz FM band, and has an operating range of about 50 feet. The antenna is a 1½-inch rod radiator protruding from the top of the unit. Battery life is about 35 to 50 hours. The FCC Rules for the use of these particular devices are spelled out in detail in the box above.

> With regard to the proliferation of portable wireless microphones operating in the standard FM band, with a considerable number of these units being sold across the counter, and with construction projects appearing in many magazines, there are certain FCC Rules that users should be aware of. Part 15.212 of the FCC Rules specifies the following:
>
> 1. Operation in the 88- to 108-MHz FM band is limited to low-power communication devices, and the use of this band for two-way communication is forbidden.
> 2. Users of wireless mikes must make sure that they do not interfere with commercial TV or FM broadcasts. If such interference takes place, the use of these devices will be promptly suspended and will not be allowed to resume until the interference has been eliminated. Users of these devices must accept interference from any licensed station operating in this band.
> 3. Emission must be confined to within 200 kHz centered on the operating frequency and must lie entirely within the 88-108-MHz band.
> 4. The field strength of emissions radiated within the specified 200-kHz band must not exceed 50 μV/meter at 50 or more feet from the device.
> 5. The field strength of emissions on any frequency outside the 200-kHz-band must not exceed 40 μV/meter at 10 or more feet from the device.
> 6. No changes whatsoever may be made in any type-approved equipment, *including the antenna* (italics ours), except on specific prior approval by the FCC.
> 7. Except for certain classes of equipment used by educational institutions, all wireless microphones must be type-approved in accordance with Part 15.235 of the FCC Rules and should be so identified. The owner or operator need not certify his own device if it has already been certified by the manufacturer or distributor.
>
> Units not having FCC type approval, should not be operated.

The relatively simple wireless microphones, such as the *Sony* just described, use conventional 88-108-MHz FM receivers, while the receivers for the commercial wireless microphones are specially designed and have excellent low-noise characteristics and audio response. They also include a.f.c. and squelch to remove background noise when the wireless microphone is not being used for any reason.

Connection to the P.A. System

In the case of the simple 88-108-MHz wireless microphone, the output from a conventional FM receiver can be fed through an impedance-matching network to the input of the p.a. system being used. Provisions should be made to quiet the receiver internal speaker, while earphones connected to the audio stage can be used for monitoring.

Commercial units usually provide both high- and low-impedance outputs for matching to a p.a. system. These units normally provide internal monitoring devices such as controllable-volume loudspeakers or earphones.

Some commercial systems make provisions for connecting an outboard control unit to the receiver so that external devices can be activated by a switch on the wireless microphone. This enables the microphone user to turn on any remote electrical device such as a p.a. system, a tape recorder or playback system, or a slide projector, without the aid of a second person. ▲

Fig. 1. This "Vega-Mike" system is typical of the high-quality wireless microphones licensed to operate on commercial bands.

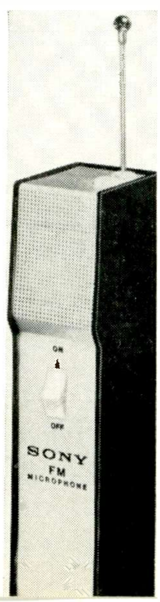


Fig. 2. The Sony CRT-10 is typical of the units operating in the 88-108-MHz FM band.

Selecting a P.A. Amplifier

By M. S. SUMBERG/ Bogen Communications Div., Lear Siegler, Inc.

A practical guide to the most important factors that must be considered: output power required, response and distortion, inputs, output impedance and voltage, filters and tone controls, power source, special features, important accessories, and cost.

ALL too often the inexperienced sound installer attempts a p.a. installation with an amplifier which is a poor choice for the job. It may perform satisfactorily but be much more costly than required. It may be underpowered or lack sufficient signal inputs. It may not incorporate any of the relatively low-cost accessories which will extend its flexibility and increase its usefulness.

The range of available amplifiers can be confusing, especially when trying to evaluate features and functions. However, for the majority of sound installations, an intelligent selection of a p.a. amplifier can be made if *all* of the important factors listed below are given careful consideration. It is not enough merely to estimate power requirements and number of microphone inputs.

Consider the predicament of the installer who purchased a 117-volt a.c. amplifier with the proper number of microphone inputs and adequate output power—but which cannot be operated from a 12-volt battery of the truck in which it was installed. This, and similar errors, can be easily avoided by delaying the purchase of the amplifier until each of the following factors has been considered carefully: 1. output power required, 2. frequency response and distortion, 3. microphone inputs (number and types), 4. auxiliary inputs, 5. output impedance and voltage, 6. filters and tone controls, 7. power source (117-volt a.c. or battery), 8. special features, 9. mounting and portability, 10. accessories, and 11. cost. These will all be discussed below.

1. Output Power

The experienced technician develops a "sixth sense" regarding the total audio power (in watts) which is required for moderately large and smaller sound installations. He recognizes that all of the following must be taken into account: (*a*) size of the area to be covered, (*b*) noise level, (*c*) efficiency of the loudspeakers, (*d*) acoustic conditions of the area, and (*e*) size of the audience.

Table 1 will serve as a starting point in relating amplifier output power to the size of the area to be covered. The exact amount of audio power required can be more accurately determined by trial and error, or by using a noise meter to measure sound pressure levels. Bear in mind that the average cone loudspeaker has an efficiency of about 2% (it is about 5% for high-quality two-way theater-type cone speakers), and that re-entrant horns are 15% or more efficient. A little arithmetic will show that in any given area horns will require only 2/15 as much audio power as the 2% efficiency cone speakers—to lay down the same level of loudness.

The acoustic conditions of the room and the size of the audience present will have a very definite bearing on the amount of audio power which the amplifier must deliver to the loudspeakers. In a large auditorium with average acoustics, a 50-W amplifier will be entirely adequate. On the other hand, a similar auditorium with sound absorptive walls—and a large audience which provides additional sound absorption and a higher noise level—may require 75 watts. If the auditorium has reflective walls and a quiet or small audience, a 35-watt amplifier might be indicated.

It makes sense to be conservative in computing the audio power. This is not only good insurance against errors in judgment; it also provides the reserve necessary for future expansion of the system. In addition, the amplifier will not distort when subjected to high peaks in the input signal levels.

Table 2 reveals an interesting and reassuring fact to the price-conscious installer who might tend to underpower his sound installations: *the cost per watt is less in a higher power*

LOCATION	DIMENSIONS (FT)	MINIMUM POWER (W)	RECOMMENDED AMPLIFIER RATING (WATTS)
Classroom	30 x 30 x 10	0.5	Depends on number of rooms[C]
Hotel Room	15 x 12 x 8	0.1	Depends on number of rooms[C]
Quiet Office	100 x 50 x 10	3.0	10[C]
Noisy Office	100 x 50 x 10	6.0	10-15[C]
Church	Small	—	10-15[SC]
Church	Large	—	30-60[SC]
Quiet Factory	100 x 200 x 20	—	30[H]
Noisy Factory	100 x 200 x 20	—	60-100[H]
Auditorium	Typical high school	—	30[SC]
Athletic Field Stands	50 x 200	—	50[H]

Assuming average noise levels and sound absorbing materials. C=cone loudspeakers; SC=sound columns; H=horns (re-entrant trumpets).

Table 1. Typical audio power requirements for various locations.

Table 2. Cost per watt is less in higher powered p.a. amplifiers.

	AMPLIFIER OUTPUT RATING	CONSUMER PRICE	COST PER WATT
Model A	30 watts	$113.00	$3.80
Model B	60 watts	$138.00	$2.30
Model C	120 watts	$195.00	$1.63

Above models are identical except for output power.

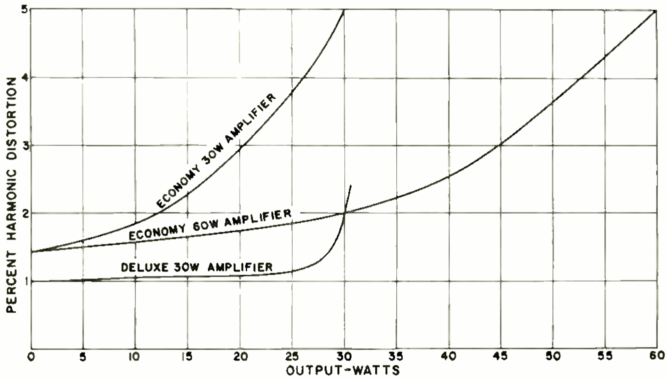


Fig. 1. Distortion of various public address amplifiers.

amplifier. Note that the 60-watt Model B is only 22% higher in price than the 30-watt Model A, while the 120-watt Model C is only 41% higher than the 60-watt Model B. In a system which includes many loudspeakers, microphones, cables, etc., the increased cost of the larger amplifier will be a small percentage of the total cost. All of this should encourage the sound specialist who cannot determine accurately the required output rating of the amplifier to provide fully adequate power for all jobs. He should bear in mind at this point that because our ears respond logarithmically to changes in sound levels, the "margin of safety" should be sizeable. An increase in sound level produced by doubling the audio power, *i.e.*, using a 60-watt amplifier instead of a 30-watt model, is only slightly noticeable to the ear. A 40-watt amplifier would sound but little louder than the 30-watt unit. The novice can afford to play safe when he is dealing with 15, 30, or 60-watt packaged amplifiers. He should, however, seek out expert help when confronted with very large sound installations, *e.g.*, 300 watts, since doubling the power to provide a safety margin in this case would be prohibitively expensive.

Until experience has been acquired, the sound installer should not hesitate to apply "cut-and-try" methods. In all but very large sound installations, he can empirically determine the optimum location of the loudspeakers—and the proper sound level for each—by simple tests. And, if he has not under-rated his amplifier output capability, he will have all the latitude he needs to accomplish his job satisfactorily.

2. Response and Distortion

In recent years much has been made of the exceptionally wide frequency response curves of high-priced, high-fidelity amplifiers designed for concert music reproduction. Many sound installers have incorrectly assumed that very wide frequency response is a "must" for every p.a. system. Although commercial p.a. amplifiers are available with frequency response characteristics which match hi-fi models, their cost is high and their performance capabilities cannot be realized unless the loudspeakers are of matching high quality.

To bring this misunderstood subject into proper focus, we should recognize that telephone systems perform very well with a restricted band of 200-3000 Hz. For speech amplification, a p.a. system will provide high intelligibility with a frequency range no broader than 100-6000 Hz. And reinforcement of live musical performances will be satisfactory with amplifiers having response curves of 50-12,000 Hz. What is more, it frequently becomes necessary to restrict the frequency response of a p.a. amplifier by means of tone controls and speech filters to reduce the adverse effects of reverberation and other unfavorable acoustic conditions. Unless the sound system calls for high-priced loudspeakers with very wide frequency response characteristics, it is uneconomical to purchase a p.a. amplifier with similar response curves.

It should also be understood that associated components—such as microphones and loudspeaker line-matching transformers—may limit the over-all response of the sound system. Of much greater concern is the fact that low-cost and/or improperly designed line-matching transformers (with light lamination stacks) have inadequate inductance at low frequencies which, in effect, presents a partial short to the amplifier output. This sometimes results in excessive amplifier output transformer or tube failure in economy p.a. amplifiers. Unnecessary amplifier servicing can be avoided by using line-matching transformers of reasonable quality.

In general, economy-priced p.a. amplifier models available today more than satisfy the frequency response requirements of most commercial sound installations.

Distortion is expressed as a percentage and may be considered as undesired difference between the input and output signals. As a rule, the amplifier price increases as the distortion figure decreases. Typical good p.a. amplifiers designed for commercial installations are rated at approximately 5% distortion (for full amplifier output). Some deluxe p.a. amplifiers are rated as low as 2%. It is interesting to note that the best of the home high-fidelity amplifiers designed for use with extremely expensive loudspeakers carry ratings as low as 0.1%.

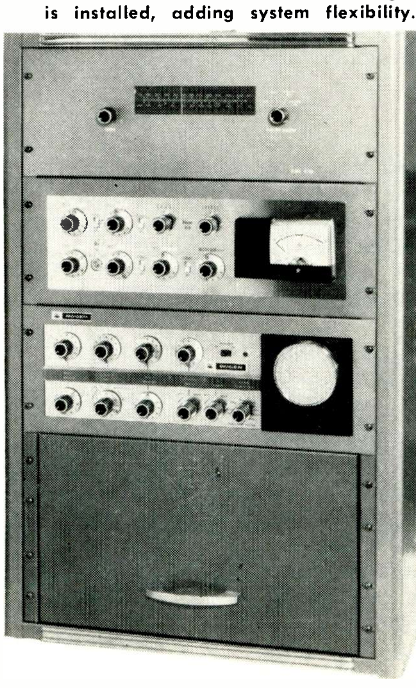
In a typical manufacturer's catalogue, it will be found that distortion percentage is usually indicated for *full* amplifier power output. Distortion decreases as the output is reduced from full power (see Fig. 1). Although deluxe amplifiers usually show a very low distortion percentage at all output levels, economy-priced models do improve at reduced outputs. An economy 60-watt amplifier which is rated at 5% distortion at full output may deliver 30 watts at only 2% distortion. The comparable economy 30-watt model measures 5% distortion at its full 30-watt output. The moderate price difference between these two amplifiers might dictate the choice of the 60-watt unit.

In a sound system used for speech, even large amounts of amplitude distortion in the amplifier will not seriously affect intelligibility. For reproduction of music, on the other hand, a low distortion figure, *i.e.*, 5% or better, is necessary to avoid deterioration of musical quality—a thing easy for even the untutored ear to detect.

3. Microphone Inputs

The number of microphones required for a given installation can usually be determined without difficulty by carefully checking with the purchaser as to the exact features he desires. A barker in a circus may need only one microphone; a Protestant church will usually use from two to four microphones (the latter if pick-up from choir or organ is desired);

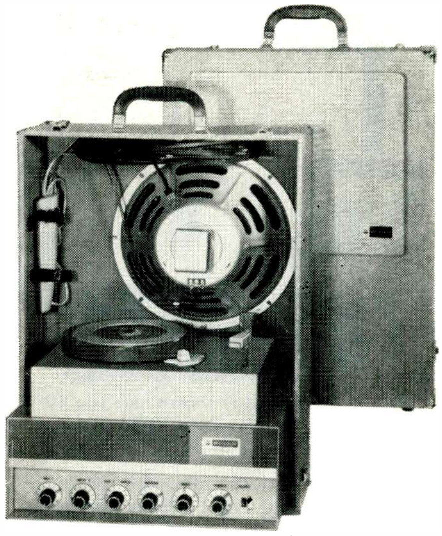
A typical p.a. amplifer installation made up of separate commercially available units mount in a 36-in rack. At the top is an AM/FM tuner. Below it is a preamp with 5 mike inputs and a level meter. The output of this preamp is connected to the auxiliary input of the 30-W p.a. amplifier just below, which has a monitor speaker. Hence, a total of 10 mike inputs is available. At the bottom of the rack, a slide-out record changer is installed, adding system flexibility.



a Catholic church will require, because of the recent liturgical changes, from four to eight microphones as follows: 1—altar; 1 or 2—pulpit; 1 for the lector and 1 for the commentator; 1 or 2—choir; and 1—organ.

For stage use in a theater as many as five microphones may be desirable. A night club featuring a dance band and vocalist will probably want to install four microphones.

Packaged amplifiers are available for systems requiring from one to five microphones, with individual volume controls to permit optimum mixing, *i.e.*, adjustment of individual input signal levels. As a rule, low-power amplifiers (10 to 15 watts) include only one or two microphone inputs; amplifiers of 30 watts or more may be purchased with 1, 2, 3, 4, or 5 microphone inputs (with separate volume controls to facilitate proper mixing). One manufacturer has designed a 30-watt amplifier with five microphone inputs which may be paralleled with an identical unit to furnish a total of ten microphone inputs (with 10 volume controls). The combined output of the paralleled amplifiers is, of course, 60 watts.



This portable system has a 35-W p.a. amplifier, a record player, a mike, two 12-in speakers in carrying case.

In some installations it is entirely feasible to connect five or more microphones across a single cable which feeds into an amplifier having only one microphone input. These microphones are wired through momentary press-to-talk switches which complete the microphone input circuit only while the switch is held down. In this arrangement only one microphone is live at a given time. As a rule, two microphones should not be paralleled for feeding into a single microphone input since mixing becomes impossible with the single available volume control. In addition, the sensitivity of each microphone is considerably reduced and the over-all signal-to-noise ratio deteriorates.

After determining the number of microphone inputs which the amplifier must provide, consideration must be given to the impedance of the microphones. When the length of microphone cable does not exceed about 50 feet, a high-impedance microphone may be used. If the microphone cable is run to lengths exceeding 50 feet, however, the capacitance of the high-impedance microphone cable attenuates the signal. To avoid this and possible pick-up of hum and noise, it is advisable to employ a low-impedance microphone with low-impedance microphone cable, and to convert the amplifier input to match the low-impedance signal. Conversion from high- to low-impedance microphone input is a relatively simple matter with many amplifier models since it consists simply of removing a shorting plug from the top of the amplifier chassis and substituting for it a plug-in transformer. This technique permits the microphone channel to be reconverted from low to high impedance at any later date. It also affords considerable flexibility in that a four-microphone-channel amplifier may be set up to work, for instance, with two high-impedance and two low-impedance microphones if this particular arrangement is required.

4. Auxiliary Inputs

In most sound systems it is often necessary to reproduce program material from tuners, record players, and tape recorders. Infrequently it is also desirable to distribute over the system music which is piped in over a leased 600-ohm telephone line—or tone signals generated by an oscillator. The latter may be purchased to produce either a siren tone (to alert personnel to an emergency) or a constant tone which designates time periods (lunch or coffee breaks). Many time clocks incorporate a set of contacts which can be used to activate the constant-tone oscillator at predetermined intervals; the siren tone oscillator is best keyed by a switch under the control of administrative personnel.

Although most p.a. amplifiers include one or two auxiliary inputs for high-impedance, high-level signals (for tuner or crystal phono cartridge), only a few provide a properly equalized low-level input for either a magnetic phono cartridge or a tape playback head. A balanced 600-ohm line input (suitable for connection to a telephone line over which "wired music" is piped) is afforded in any public-address amplifier by installing a small line transformer whose secondary plugs into the high-level auxiliary input.

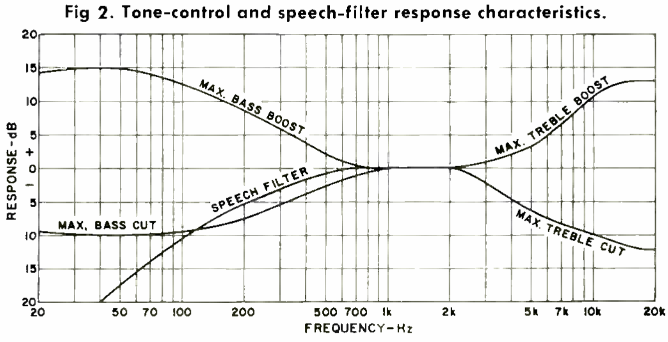
5. Output Impedance

To deliver its maximum rated output power, an amplifier's output impedance must be matched or equal to the loudspeaker impedance. In simple systems employing only a few loudspeakers, amplifier output taps of 4, 8, and 16 ohms usually permit proper matching. This is frequently the case in churches and auditoriums. In large systems where many loudspeakers are required and/or where loudspeakers must be driven to varying sound levels (20 watts into trumpet A, 5 watts into trumpet B, for example), a much more flexible arrangement is afforded by installing a line-matching transformer at each loudspeaker. These transformers, almost always of the constant-voltage type, are designed to connect across a 25- or 70-volt line from the amplifier. Most p.a. amplifiers include 25- and 70-volt output taps; hi-fi amplifiers, which are designed to drive only a limited number of speakers at voice-coil impedances, do not usually have such output-voltage taps.

There are applications in which it is essential to feed the output signal from an amplifier over a 600-ohm telephone line to a remote point, as in the case of a church service which is to be broadcast by a local radio station. The proper output level and impedance can be obtained by using the same line transformer as described under "Auxiliary Inputs." When turned around so that its secondary is connected to the 25-volt output tap of any amplifier, its primary will deliver a zero-level signal at 600 ohms which can then be used to transmit to a remote point.

To simplify tape recording of an historic or sentimentally important event (testimonial dinner, dedication, etc.) many amplifiers provide an output tap at the proper level and impedance. This output connection should precede the amplifier's tone controls so that recordings can always be made with a "flat" response. A tape recorded "flat" in this manner can be played back at a later date through an amplifier whose tone controls may be adjusted at will to produce the most pleasing sound, without affecting the original recording.

Fig 2. Tone-control and speech-filter response characteristics.

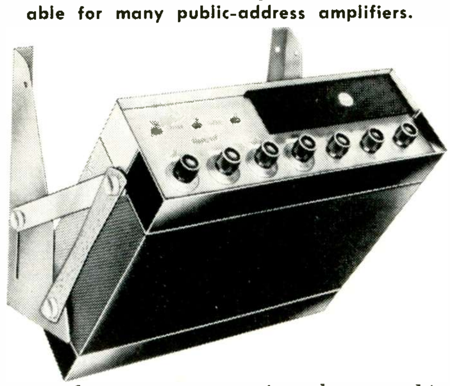


6. Tone Controls and Filters

Excessive reverberation (sound bouncing from wall to wall) can be severe enough in auditoriums and large rooms to seriously reduce the effectiveness of a sound system. Inasmuch as reverberation time is longer at the lower frequencies, the problem can usually be alleviated by employing a bass-cut tone control which attenuates frequencies below 300 Hz. A control which affords up to 10-dB attentuation at 50 Hz is entirely adequate for this purpose in most installations. The bass-cut tone control is of further value when re-entrant horns are used. Since diaphragms of horn driver units may be damaged by extreme excursions when reproducing high-level, low-frequency program material, it is standard practice to attenuate these frequencies (below 300 Hz) with the bass-cut control. Most p.a. amplifiers include separate bass and treble tone controls which are continuously variable from maximum boost to maximum attenuation, as shown in Fig. 2.

Some amplifiers also include a speech filter (not variable) which will attenuate low-frequency material as much as 20 dB at 40 Hz. Professional amplifiers, in addition, feature panel-calibrated variable low-frequency notch filters which may be adjusted to remove troublesome frequencies that produce audible hum, phono motor rumble, lectern thumps picked up by the microphone, etc. Fig. 3 shows a typical notch filter attenuation of 50 dB at 60 Hz—which does not materially affect the over-all balance of the amplifier's response to any great extent.

The mobile amplifier shown here is a 40-W unit which operates from 12-15 V d.c. Accessory unit is siren/fog-horn generator.



Convenient wall-mounting kits are available for many public-address amplifiers.

7. Power Source

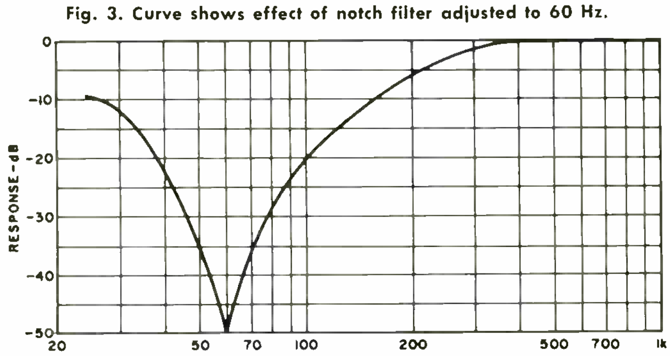
Not all p.a. amplifiers used indoors are powered from the 117-volt a.c. line. In recent years lecterns have been developed with built-in battery-operated amplifiers which eliminate unsightly extension cords. And last Fall's massive power failure in northeastern states did much to stimulate the use of amplifiers which could be operated in emergencies from a 12-volt battery as well as from the 117-volt a.c. line.

Mobile amplifiers are generally powered from a 12-volt battery but are sometimes called upon to perform double duty as 117-volt a.c. units. A variety of p.a. amplifiers is available (rated from 10 to 450 watts output) for battery operation. There are also several so-called "universal" models, with output ratings to 50 watts, which may be operated from either batteries or 117 volts a.c. The latter make excellent "fail-safe" sound systems in the event of black-outs and are logical choices for the rental operator who cannot afford to stock a very wide variety of p.a. models.

If the amplifier is to be installed abroad, it may have to be operated from 220-volt, 50-Hz power lines. A step-down transformer of adequate wattage rating will take care of the higher voltage but the amplifier's specifications should be checked to insure that the 50-Hz frequency will not cause excessive power-transformer heat rise.

Operators of helicopters, airplanes, police/fire vehicles, and boats are increasingly discovering the advantages of sound systems and several manufacturers produce battery-powered models (12 to 24 volts d.c.) for these applications.

Fig. 3. Curve shows effect of notch filter adjusted to 60 Hz.



8. Special Features

In addition to the more or less standard characteristics described up to this point, an amplifier will sometimes have to provide special features and functions. Typical of these are:

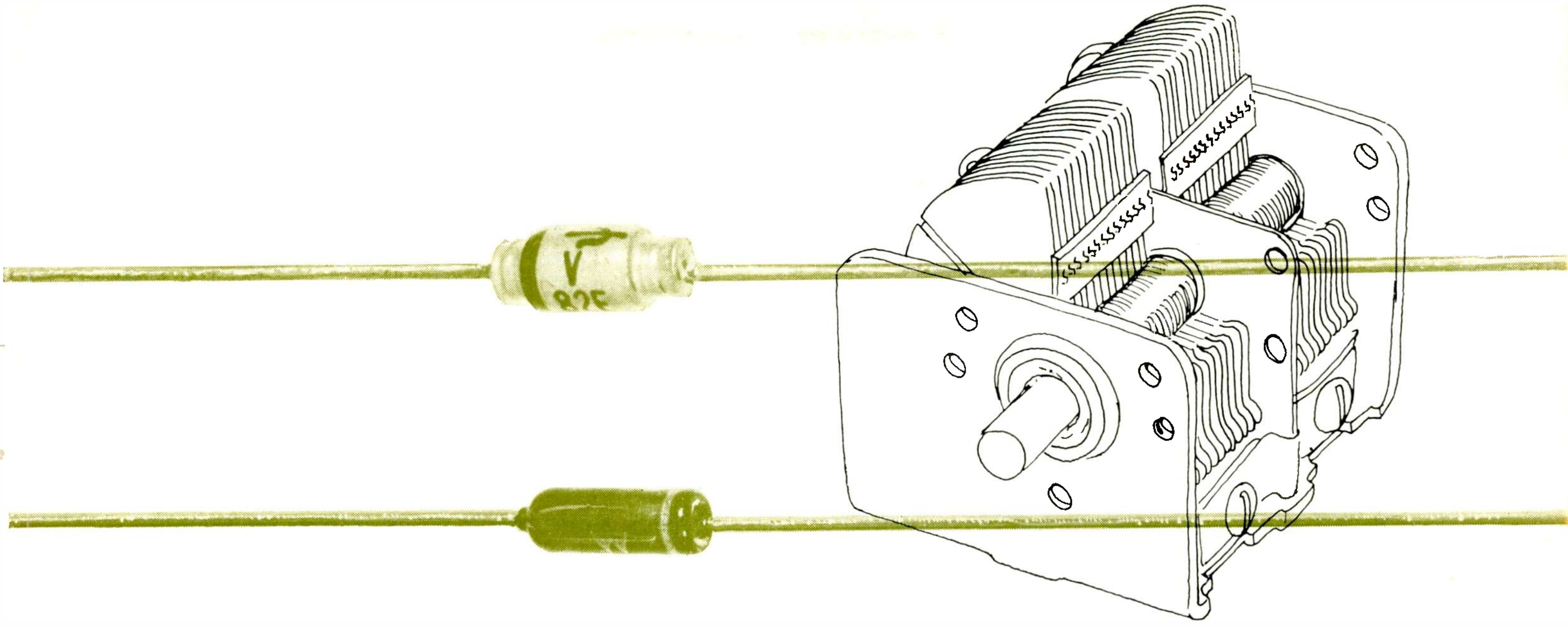
a. Remote Control of Volume: In many sound-system installations (such as in churches, theaters, auditoriums), it is desirable to control the volume of the sound output at some distance from the amplifier. To satisfy this special requirement, some amplifiers can be equipped with remote controllers which permit an operator to adjust the volume of each microphone and/or phono input channel from a distance as great as 2000 feet from the amplifier. In a typical church installation, for instance, it is standard practice to conceal the amplifier, but to bring out a remote volume controller to the rear of the church where the sound level may be adjusted quickly and without distracting the congregation.

b. Microphone Precedence: Factory, restaurant, and retail store sound systems are frequently installed for the primary purpose of distributing background music. When paging announcements are made over these systems, increased intelligibility may be realized by muting the music momentarily. To accomplish this simply, amplifiers are available with plug-in accessories (relay or light-dependent resistor devices) which can be activated by a momentary press-to-talk switch mounted on or near the microphone. The music is silenced during paging announcements by pressing the switch, then automatically redistributed to the speakers when the switch is released.

c. Monitor Panel: This panel-mounted accessory comes with a vu meter and/or small loudspeaker for visual and aural checking of the program quality and volume level. It is especially useful to the sound operator when the loudspeakers are installed at remote locations.

d. Limiter: A useful plug-in device for factory and retail store amplifiers is the limiter which aids in maintaining a pre-set output level. It is almost a necessity when several people, who regularly make paging announcements, speak into their microphones at different levels. All too frequently one individual's voice will be reproduced at a painfully high sound level while the others come through at inadequately low levels. The limiter assists considerably in maintaining a reasonably constant level for all announcements irrespective of signal input levels.

e. Master Volume Control: Multi-input amplifiers generally incorporate a master volume control in addition to the individual microphone and auxiliary volume controls. After three or more microphone signals have been carefully mixed for optimum blending of levels, the over-all amplifier output level can be (*Continued on page* 74)



Varactor Diode Applications

By DONALD E. LANCASTER

These special semiconductor diodes, which operate as high-"Q" electronically variable capacitors, are finding increasing uses in a.f.c. circuits, FM modulators, harmonic generators, and parametric amplifiers over a wide range of frequencies.

WHENEVER any *p-n* semiconductor junction is reversed-biased, a depletion layer is formed in which there are no excess electrons or holes. No conduction takes place in this region. As the reverse bias varies, so does this depletion layer, the layer becoming thicker with increasing reverse bias. The net effect is a high "Q," electronically variable capacitor. Whenever junction characteristics are optimized to yield this variable capacitance effect, a varactor diode results.

Due to their remarkable properties, varactor diodes now find extensive use everywhere from the audio frequencies to the outer reaches of the extreme microwave frequencies. A varactor is a non-microphonic, compact, electronically variable capacitor whose capacitance can be readily changed at a high rate of speed. It can directly frequency-modulate a signal. It has a non-linear capacitance characteristic, allowing varactors to serve as harmonic generators and parametric amplifiers. Most important, it is a reactance and not a resistance. Because of this, it is nearly lossless and essentially noiseless. Varactors are only a fraction of the size of conventional mechanically variable capacitors yet perform many tasks far better.

Commercially available varactors are amazingly diverse. They range in price from a little over a dollar each for a.f.c. varactors intended for FM receivers to exotic matched sets of parametric amplifier diodes costing thousands of dollars a pair. Low-frequency varactors are available with capacitances as high as .002 microfarad; some microwave devices have a maximum capacitance of only 0.4 picofarad. The power-handling capability ranges from 100 milliwatts or so for the small varactors to stud-mounted versions that can accept over a hundred watts of input r.f. power. Some are strictly low-voltage units having a breakdown voltage in the reverse direction of only −6 volts, while other, high-voltage, units may be rated as high as −300 volts and may have a maximum capacitance ratio on the order of 20:1 or higher.

Varactor Operation

A varactor is always operated somewhere between forward breakover and reverse breakdown. As the reverse bias increases, the junction capacitance *decreases*, but not in a linear manner. Many varactors will have their junction capacitance vary inversely as the square root of the reverse bias. This non-linearity is a two-edged sword. It means that bias-shaping circuitry is required to obtain large linear capacitance *vs* voltage control regions. This is highly desirable for frequency modulators and receiver-tuning applications. On the other hand, the two most important varactor applications—frequency multiplication and parametric amplification—*must* have a non-linear capacitance *vs* voltage characteristic. Both these applications are fundamentally impossible in a linear, time-invariant system.

The depletion layer is then the dielectric of a capacitor. As such, the varactor has a capacitance value and a "Q." Both are determined in the conventional manner, the capacitance being a function of the junction area, the thickness of the depletion layer (as determined by the reverse bias), and the dielectric constant. "Q" is defined as the ratio of reactance to resistance at a given frequency. To obtain high "Q," very low leakage is required. Because of this, silicon is used exclusively

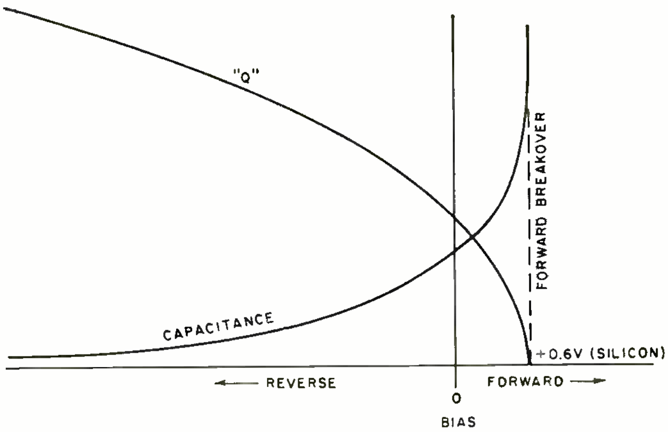


Fig. 1. Varactor capacitance and "Q" vary with bias voltage.

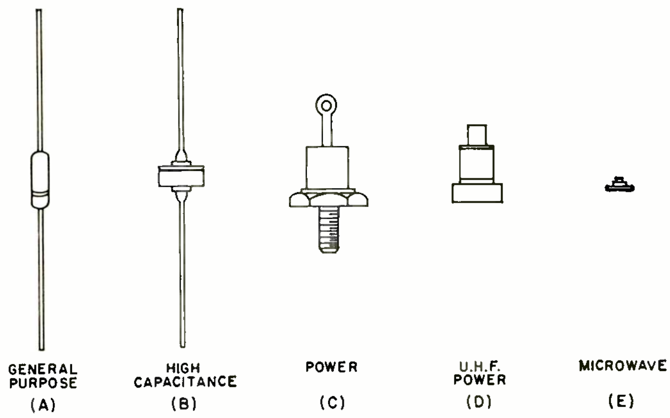


Fig. 2. Various types of varactor packages are shown here.

Table 1. A directory of manufacturers of varactor diodes.

MANUFACTURER	A	B	C	D	E
AIRBORNE ELECTRONIC LABS Richardson Rd., Colmar, Pa.	•			•	•
AMPEREX ELECTRONIC CORP. 230 Duffey Ave., Hicksville, L.I., N.Y.	•			•	
BENDIX CORP, SEMICONDUCTOR DIVISION South Street, Holmdel, N.J.	•		•	•	
COMPUTER DIODE CORP. 250 Garibaldi Ave., Lodi, N.J.	•				
EASTRON CORP. 25 Locust Street, Haverhill, Mass.	•	•	•		
FAIRCHILD SEMICONDUCTOR 545 Whisman Rd., Mountain View, Cal.	•				
HUGHES AIRCRAFT CO., SEMICONDUCTOR DIV. 500 Superior Ave., Newport Beach, Cal.	•	•			
ITT FEDERAL LABS 500 Washington Ave., Nutley, N.J.	•				
MOTOROLA SEMICONDUCTOR Box 955, Phoenix, Arizona 85001	•		•	•	•
MICRO STATE ELECTRONICS 152 Floral Ave., Murray Hill, N.J.				•	•
MICROWAVE ASSOCIATES Northwest Park, Burlington, Mass.		•	•	•	•
NUCLEONIC PRODUCTS CO. 3133 E. 12th St., Los Angeles, Cal.	•				
PHILCO SPECIAL PRODUCTS Lansdale Div., Lansdale, Pa.	•		•		•
RADIO CORPORATION OF AMERICA 415 S. Fifth St., Harrison, N.J.			•	•	•
RAYTHEON CO., SEMICONDUCTOR DIV. 350 Ellis St., Mountain View, Cal.	•				
SOLITRON DEVICES INC. 256 Oak Tree Rd., Tappan, N.Y.	•	•	•		
SYLVANIA ELECTRIC, SEMICONDUCTOR DIV. 100 Sylvan Rd., Woburn, Mass.			•	•	•
TEXAS INSTRUMENTS, SEMICONDUCTOR DIV. Box 5012, Dallas, Texas 75222	•		•		•
TRW/PSI SEMICONDUCTORS 14520 Aviation Blvd., Lawndale, Cal.	•	•	•		
VARIAN SOLID STATE Beverly 34, Mass.	•			•	•

A = General-purpose, low-frequency control varactors.
B = High capacitance, low-frequency varactors (68 pF or more).
C = High-power, low-frequency varactors (1 watt or more).
D = High-power, high-frequency varactors (1 watt or more; 100 MHz and higher).
E = Microwave devices (1 gigahertz and higher).

for all varactors, except for a few gallium-arsenide microwave devices. The finite "Q" implies a loss or a resistive component. This occurs due to the bulk resistivity of the semiconductor and appears as a small series resistance.

A figure of merit of any varactor is its *cut-off frequency*. This is the frequency at which "Q" $=1$. Put mathematically, "Q" $=X/R=1/2\pi fCR$ and $f_{cut-off}=1/2\pi RC$ where $f=$ frequency in Hz, $C=$ capacitance in farads, and $R=$ series resistance in ohms for some specified bias value.

Low-frequency "Q's" are at least 50, typically 200 to 400 for many units. Many microwave varactors have "Q's" so high they cannot be readily measured. Some manufacturers guarantee "Q's" of several thousand.

Fig. 1 shows how capacitance and "Q" vary with changing reverse bias. The junction capacitance tends to become infinitely great at the forward breakover voltage, for here the depletion layer approaches zero thickness. Unfortunately, the junction is conducting heavily at this point and has ceased being a capacitor. Because of this, the useful "Q" rapidly diminishes as forward breakover is approached. Obviously, if reverse breakdown is ever reached, the "Q" will also suddenly vanish. The greater the reverse bias, the greater the "Q" and the smaller the capacitance.

The choice of a reverse-bias operating point depends upon the application. For maximum capacitance swing, the varactor is normally biased halfway between zero and a value safely under reverse breakdown. For maximum capacitance *change* and greatest non-linearity, the varactor is biased near the forward region. In fact, some harmonic multipliers actually are momentarily driven into forward conduction briefly each cycle to produce strong harmonics. Operation at zero bias has an advantage in many circuits—no d.c. bias source is required. Finally, for maximum "Q" and greatest linearity, the varactor can be biased well out on the curve, perhaps within a few volts of reverse breakdown.

The actual biasing techniques will become apparent as we discuss applications. Since the varactor is always operating in the *reverse*-bias region, negligible current, and hence, negligible bias power are required. In this sense, a varactor is an extremely "high-gain" device, providing many control functions with only a few microwatts of control power.

Where a d.c. bias is used, a stable reference source must be obtained. If not, the junction capacitance will faithfully follow any drift or noise present with the bias source. A zener diode is often employed in order to provide a stable reference source when this is required.

Types of Varactors

There are five basic types of varactors, each with a fundamentally different package. These are shown in Table 1 and Fig. 2. The ordinary diode package of Fig. 2A finds use for general-purpose, low-power, low-frequency varactors. These are usually low-cost devices, rated at a few hundred milliwatts of power dissipation and having junction capacitances between 1 and 100 pF. These are used for any frequency where case and lead stray inductance and capacitance are not important, which usually restricts their use to under 500 MHz. For some low-frequency applications, more junction capacitance is required than will fit in this package. To increase junction capacitance, either a larger junction or multiple junctions may be employed. Both techniques find use. This results in the "fat" package of Fig. 2B. These devices range from 68 to 2000 pF and go as high as one or two watts of dissipation. Their main use is in low-frequency applications, such as audio phase shifters, AM broadcast-band applications, and delay lines.

The dissipation rating of any varactor is simply how much heat it can safely dissipate. In an ordinary diode, substantial heat is produced only in the forward-biased and reverse-breakdown regions. This heat is determined by multiplying the diode voltage by the d.c. diode current, producing the internal heat loss in watts. But no d.c. current can flow in a reverse-biased varactor (except for a trivial leakage current measured in nanoamperes). This is not true of an a.c. signal, since it will readily travel through the junction capacitance and series resistance of the reverse-biased varactor. The a.c. current traveling through the series resistance produces the heat loss that is the basis for the dissipation rating of the diode. The loss is given by I^2R_s where I is the instantaneous a.c. signal current and R_s is the equivalent series resistance. The peak values of this particular power can be substantial in some cases.

For applications where high r.f. signal levels are a problem, the power varactor package of Fig. 2C finds use. Some of these power varactors are rated at 25 watts and can easily handle r.f. power inputs of 100 watts. These are important in high-power multiplier chains, v.h.f. transmitters, and u.h.f. frequency multipliers. The practical upper frequency limit of this package is about 500 MHz of r.f. input. Heatsinking is usually provided by bolting the varactor to an aluminum or copper plate of reasonable size.

Above 500 MHz, the power varactor has to be streamlined to eliminate stray capacitance, residual inductance, and other parasitics, resulting in the u.h.f. power varactor package of Fig. 2D.

For microwave work, the least amount of circuit strays can drastically alter performance. Lead inductances of 5 nanohenrys can be intolerable, as can 0.1 pF of capacitance. Thus, the microwave "package" of Fig. 2E is not a package at all but merely a means of protecting the semiconductor and making contact with the circuit. These devices are used exclusively in stripline and waveguide circuitry. Some varactors have cut-off frequencies in excess of 500 GHz and find use at frequencies of 80 to 100 GHz. These varactors are truly tiny—some will fit in an ⅛-inch cube with room to spare.

Circuit Applications

One obvious application consists of using a varactor as a replacement for a conventional variable capacitor in a resonant circuit, as shown in Fig. 3. To allow proper biasing, a blocking capacitor (C) is added in series with the varactor. Biasing is by way of a high-value resistor and an r.f. bypass. As the d.c. bias on the varactor is changed, the depletion layer capacitance changes, which in turn changes the resonant frequency. If capacitor C in Fig. 3B is much larger than the junction capacitance, the series equivalent capacitance will essentially be that of the varactor itself.

There is a defect in this simple circuit. At any instant, the varactor sees a voltage that is the sum of the instantaneous signal and the d.c. bias value. If the signal is quite small, this is immaterial. But if the signal is large, it will itself bias the varactor differently on positive and negative cycles and cause severe distortion. This is eliminated by the balanced varactor circuit of Fig. 3C. Here, two varactors are used back to back. As the signal swings positive, it decreases the capacitance of

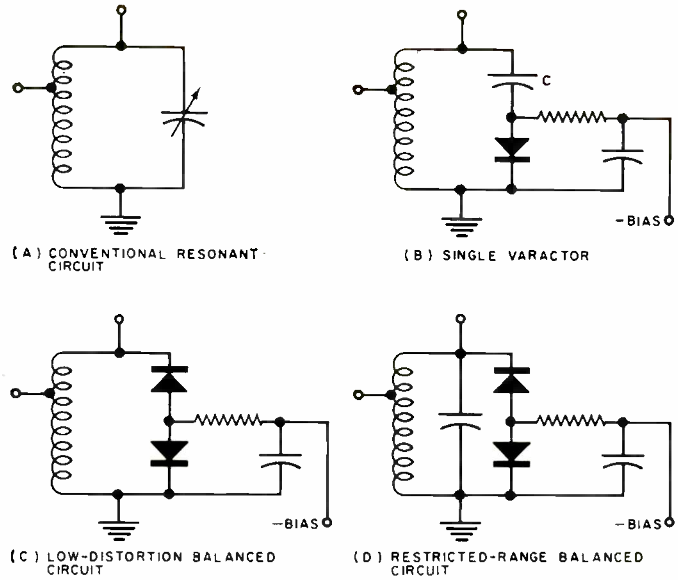


Fig. 3. The use of varactors in various tank circuits.

one varactor and increases the capacitance of the other one. The sum of the two series capacitors remains nearly constant, determined almost entirely by the bias and not the signal. Note that two series varactors have only half the junction capacitance of a single unit.

Sometimes it is desirable to just trim a resonant circuit instead of permitting the varactor to assume full frequency control. A shunt capacitor may be added as in Fig. 3D to give any desired control range. The ratios of shunt to junction capacitance determine the swing the varactor can produce.

The circuit in Fig. 3C is used for radio-receiver tuning. For a conventional AM receiver, the 365-pF tuning capacitor is replaced by two 700-pF varactors in the balanced connection. A d.c. source and potentiometer provide the tuning. In more elaborate circuits, a saw-tooth signal may be used for tuning, producing either a signal-seeking tuner or a spectrum analyzer, depending upon the rest of the circuit. Obvious advantages of this circuit are mechanical stability, small size, and ease of remote control.

Fig. 4 shows how a varactor is used to provide a.f.c. for an FM receiver. The varactor is normally biased at −4 volts with no input signal due to the base bias on the transistor. The input signal is derived from the d.c. output of the FM discriminator. If the local oscillator frequency is low, a positive d.c. output is produced at the discriminator which increases the reverse bias on the varactor, decreasing its capacitance and raising the local oscillator frequency. Similarly, a high oscillator frequency produces a negative error which is also corrected, thus locking the local oscillator to the input FM signal. This same technique is used in radar to provide signal-tracking filters, devices that follow an input signal regardless of its frequency drift or change. Voltage-tunable i.f. amplifiers work in much the same manner.

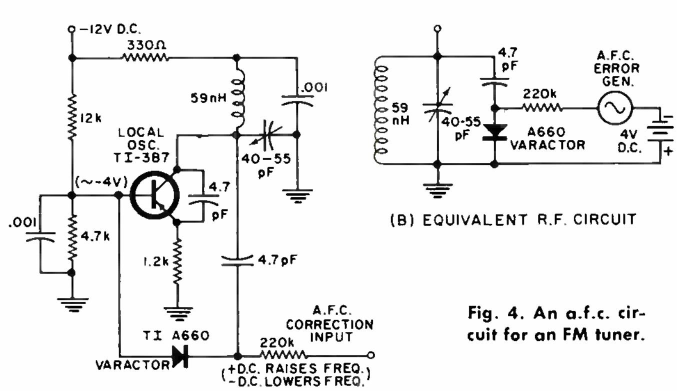


Fig. 4. An a.f.c. circuit for an FM tuner.

The basic resonant circuit becomes a sweep oscillator if a saw-tooth bias voltage is applied to the varactor. The output will be a swept frequency that follows the saw-tooth input. Distortion of the input saw-tooth will produce either a linear or a logarithmic sweep, useful in many test instruments.

Fig. 5 is a varactor v.c.o. (voltage-controlled oscillator) circuit. It produces a 25- to 35-MHz r.f. output in tune with a d.c. bias input of −2 to −39 volts. Distortion circuitry added to the bias input has produced a v.c.o. with better than 1% linearity over a 30% bandwidth.

Varactors can produce frequency modulation in an oscillator simply by being driven with audio. The choice of shunt capacitance, d.c. bias point, and modulation amplitude will determine the modulation index. This method is much simpler and more effective than conventional reactance modulators. It also produces very little residual AM, has a very high "Q," and requires only a tiny amount of modulation power.

Varactors can replace ordinary capacitors in many conventional networks, resulting in electrically variable phase shifters, delay lines, and low-pass filters, as well as high-pass, bandpass, and band-rejection networks. These may have operating frequencies anywhere from audio to microwave.

An efficient microwave switch, shown in Fig. 6, uses a single varactor series-connected in a coaxial transmission line. To turn the switch *off*, enough *forward* bias is introduced to cause the diode to conduct heavily. This places the internal lead inductance in *parallel* with the case capacitance, producing a high "Q" parallel-resonant circuit that blocks the band of frequencies of interest. *Reverse*-biasing the varactor puts the junction capacitance and the internal lead inductance in *series*, producing a *series*-resonant circuit that easily passes the frequencies of interest. Note that this circuit appears to be "backwards" from what a casual look at this circuit would reveal; the switch is "off" when the diode is conducting heavily. Shunt diode circuits also find use for varactors. Both circuits will readily switch in a fraction of a nanosecond with very little amount of control power.

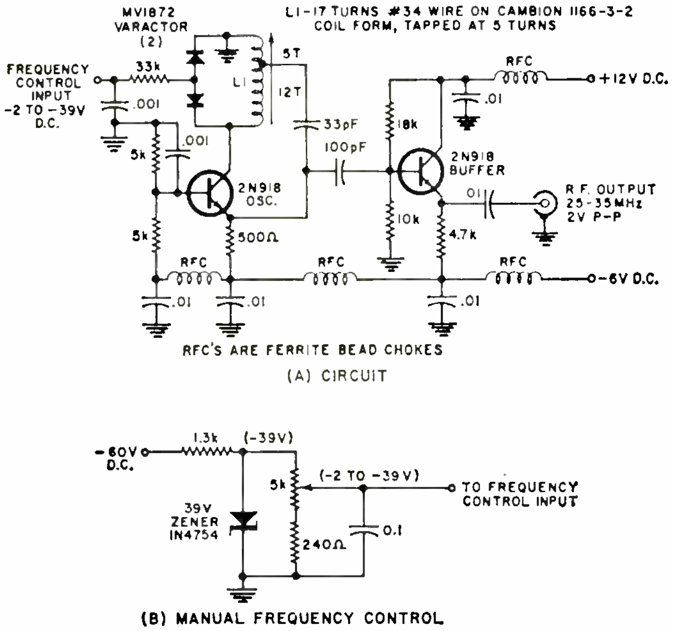


Fig. 5. Dual-varactor voltage-controlled oscillator circuit.

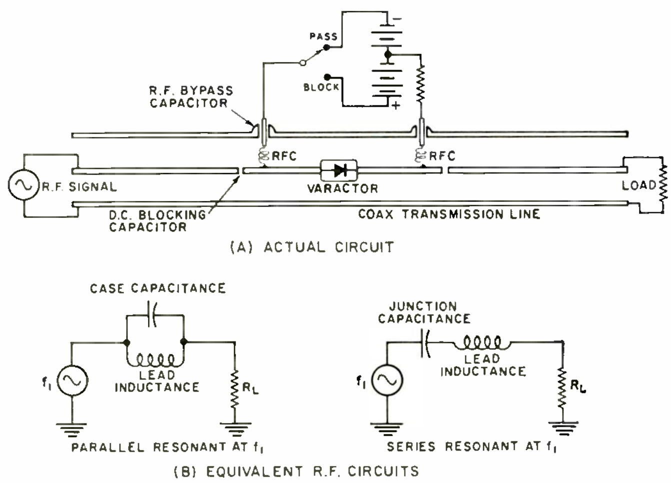


Fig. 6. A varactor microwave switch. With forward bias the signal is blocked (left); reverse bias passes signal (right).

Non-Linear Applications

None of the applications discussed so far have made use of the capability of a varactor to produce strong harmonics of an r.f. signal. The two most important applications make specific use of the varactor as a non-linear, time-varying reactance. These applications are frequency multipliers and parametric amplifiers.

Consider the frequency doubler of Fig. 7. This circuit consists of a signal source at frequency f_1, an ideal series-resonant circuit that will pass *only* f_1, a varactor, a second ideal series-resonant circuit that will pass *only* the second harmonic of f_1, and a load resistance. An input signal is delivered to the varactor at a frequency f_1. The varactor will change its junction capacitance as it is self-biased by f_1, producing a strong harmonic waveform that is time-varying to the tune of f_1. The only harmonic that is allowed to flow by the filter is the second. Therefore, practically all the power that goes into the input must be converted into second harmonic power at the output. The only losses are incurred in the small series resistance of the varactor and the finite "Q" of the filters.

Frequency multipliers of this type do not have an efficiency limitation nearly as severe as the $1/n$ efficiency limit that is rarely, if ever, achieved with non-linear resistance tube and transistor multipliers. Doublers (*Continued on page* 70)

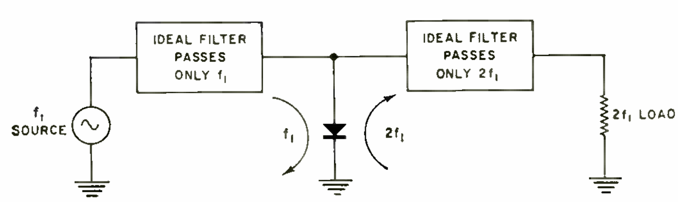
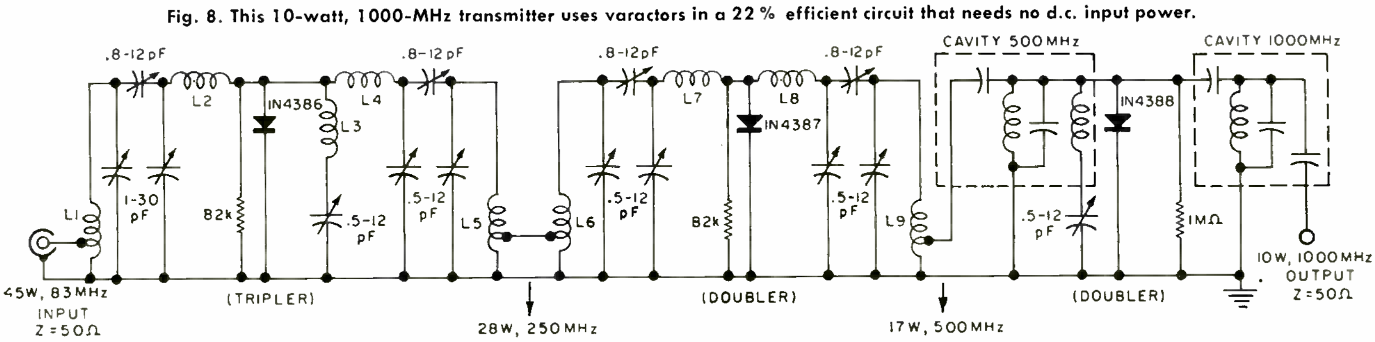


Fig. 7. A high-efficiency doubler using non-linearity of varactor.

Fig. 8. This 10-watt, 1000-MHz transmitter uses varactors in a 22% efficient circuit that needs no d.c. input power.



SAMPLING OSCILLOSCOPES

By SIDNEY L. SILVER

Signal sampling techniques permit laboratory-type oscilloscopes to extend their vertical bandpass capability up to the equivalent of 1000 MHz, thus allowing the measurement and display of extremely high-speed waveforms.

RECENT significant developments in the art of oscilloscope design have produced new measuring systems employing sampling techniques to extend the usefulness of existing oscilloscopes. In conventional scopes, the visual examination and analysis of waveforms in the ultra-high-frequency spectrum are impeded by the gain-bandwidth limitations of vertical deflection circuits and associated video amplifiers. Fast rise time, for example, is obtained at the expense of reduced amplifier gain and, conversely, high sensitivity is achieved at the expense of fast rise time. Furthermore, when a conventional scope is used to display extremely fast-changing signals of low amplitude, the trace becomes dim and the presentation may no longer be visible.

To offset these problems, pulse-sampling techniques are applied to existing scope circuitry whereby fast, repetitive waveforms in the gigacycle (thousand megacycle) range are converted into slow-speed signals of much lower frequency and of the same waveshape. This is accomplished by reconstructing the waveform of the original signal and displaying the information on a much slower sweep. By this means, high-speed pulses in the nanosecond (millimicrosecond) region are translated to a longer time base so that very wide bandwidth and high sensitivity can easily be simulated by conventional amplifiers and circuits. Moreover, the sampling process allows very slow speed scanning of the CRT display so that the recreated output waveform can be applied directly to an $X-Y$ recorder to make a permanent tracing of the signal being viewed. The resultant recording then gives the impression that the test setup had an extremely wide bandpass.

In a sampling scope, the CRT trace is independent of the repetition rate of the observed signal so that the presentation is bright and clearly visible, regardless of the waveform duty cycle. Since the duty cycle is independent of the degree of sweep expansion, a high amount of sweep magnification is possible without reducing the brightness, time-base calibration accuracy, or resolution of the display.

Sampling oscilloscopes have found wide application in the investigation of the properties and basic parameters of fast semiconductor devices. They provide, for example, a rapid, accurate means of determining the rise-time performance and pulse response of high-speed switching transistors, diodes, and computer memory elements. These instruments are particularly useful in the detailed studies of pulse shape (required in the evaluation of multiplier phototubes), transmission and delay lines, computer circuits, and radar systems. Other applications include flux measurements in fast memory cores and thin films, and analysis of coaxial cables and attenuators by observing the reflection of ultra-fast pulses that are being propagated within the line.

The Sampling Principle

Sampling is the electrical equivalent of the optical stroboscope principle used for the visual observation of rapid mechanical motion. This strobe-lighting technique appears to slow down the motion of the object and depends upon repetition of the observed phenomenon to reconstruct the apparent image. Similarly, the oscillographic sampling process requires that the input waveform be repetitive, although not necessarily periodic or occurring at a constant repetition rate.

Fig. 1 shows the synthesis of a recurring waveform in which the CRT display appears as a series of image-retaining dots rather than the continuous presentation of a conventional scope. The dots, which are uniformly spaced in time, are produced by high-speed sampling pulses which are superimposed on the input signal at discrete points along the contour of the waveform. Each time a sample is taken, the spot is moved horizontally along adjacent portions of the

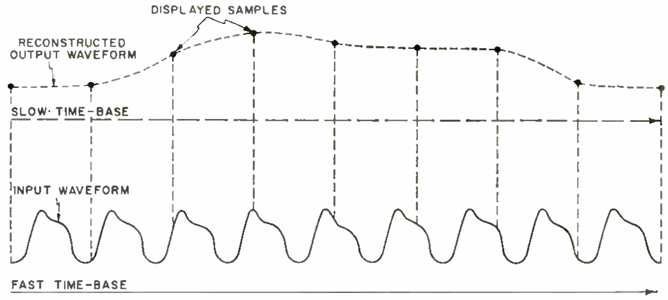
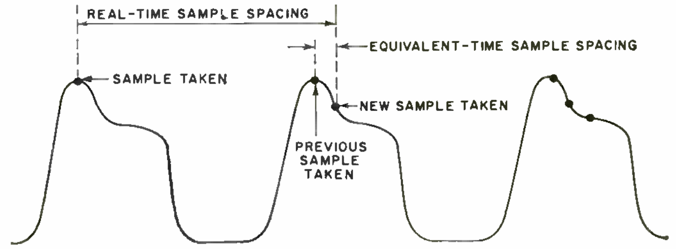


Fig. 1. Sampling technique displays a synthesized reproduction of the original signal and is similar to the stationary image of a rapidly spinning wheel produced by optical strobe.

Fig. 2. The relationship between real and equivalent time.



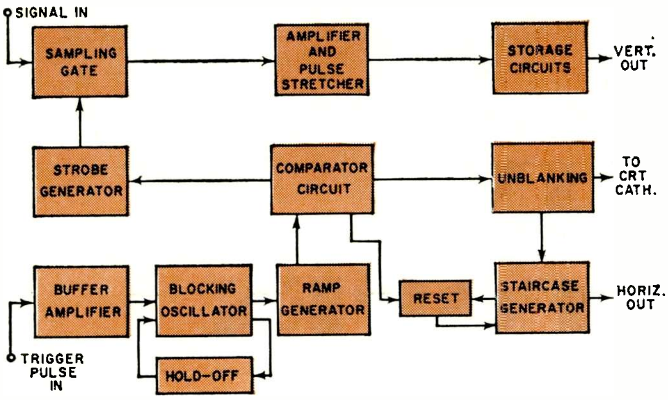


Fig. 3. Functional block diagram of a basic sampling system.

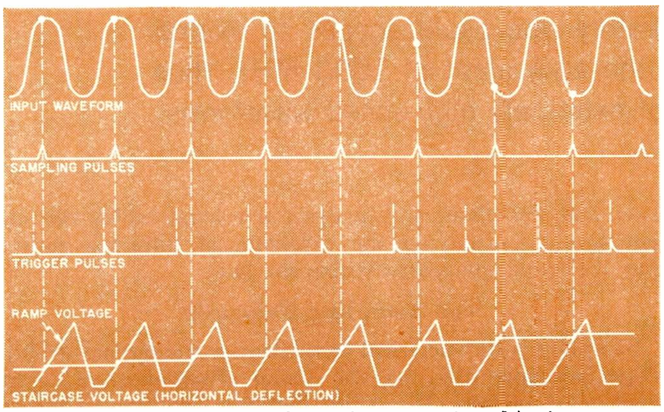
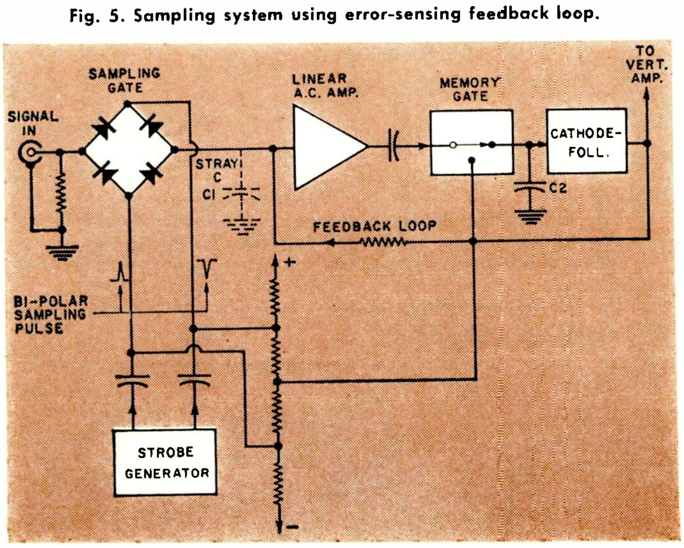


Fig. 4. Time-related waveforms show operation of basic sampling oscilloscope. Trigger is either external or internal.

waveform and is simultaneously repositioned vertically to the corresponding voltage amplitude of the signal. This process is continued until an exact reproduction of the original signal is traced sequentially across the CRT screen, and then the scan is repeated cyclically. In practice, a large number of dots forms the display (as many as 1000 samples being used to plot the waveform) so that the trace appears continuous and the waveshape is well-defined.

The sampling process, as shown in Fig. 2, involves a time transformation whereby a long interval of real time is used to display a short portion of sampled waveform. The real time between successive samples depends upon the repetition rate of the incoming signal, while the equivalent time is determined by the spacing of the samples along the signal. By slowly changing the relative time between the start of a signal event and the sampling interval, it is possible to slowly scan a fast signal so that a slow real-time horizontal sweep rate gives a display which represents an extremely fast sweep rate. Thus, in building up a composite picture of the input waveform, the visual presentation apparently gives the illusion that all samples are taken on a single pulse rather than a train of recurrent pulses.

Fig. 5. Sampling system using error-sensing feedback loop.



Over-All System

A basic consideration in the design of a sampling scope is a means of generating extremely narrow sampling pulses in order to operate a suitable gating circuit which can utilize the pulses to measure the amplitude of the input signal at the moment of sampling. It is also necessary to include a means of processing the information provided by the sampling gate so as to deliver to the CRT a vertical output signal which is proportional to the sampling-signal level. Another requirement is a means of controlling the position of the sampling pulses as a function of time in order to actuate the horizontal time-axis deflection in the CRT.

These objectives are met by the typical sampling-scope arrangement shown as a functional block diagram in Fig. 3. Initially, a trigger signal (derived internally or externally) initiates a series of events, as illustrated by the time-related waveforms of Fig. 4, which establishes the scanning process. The trigger is fed to a buffer isolation amplifier which initiates the operation of a blocking oscillator. A hold-off circuit monitors the blocking oscillator so that it does not respond to trigger signals until all circuits in the system have returned to their equilibrium states and the circuit is free to accept a new triggering event.

The output of the blocking oscillator is a flat-topped pulse with an extremely fast rise time, which initiates a ramp generator, in turn, produces a positive-going linear saw-tooth which ultimately controls the time base of the reconstructed waveform. This circuit operates by means of a staircase generator in conjunction with a voltage comparison, or comparator, device. When the instantaneous ramp voltage reaches the voltage level of the staircase, the comparator circuit fires and delivers a pulse to the strobe generator which, in turn, produces the sampling pulse. Immediately, the staircase advances one discrete step for each sampling pulse and simultaneously advances the *X* position of the CRT beam one increment of horizontal distance. When the staircase voltage reaches a sufficient level to deflect the CRT beam full screen, the voltage automatically resets itself to start a new scan.

At the peak of each sampling pulse, the CRT is unblanked, and the instantaneous pulse-height samples are mixed in a gating circuit with the vertical input signal during a preselected time period determined by the sampling rate. In operation, the sampling gate blocks the input signal during the time interval between samples but turns the signal on each time the strobe generator produces a sampling pulse. The resultant signal-modulated sample is amplified, lengthened or "stretched" in time, applied to the oscilloscope *Y* plates for vertical deflection, and traced out as a series of bright dots. See Fig. 8 for an example.

Signal Channel

In the sampling approach to u.h.f. measurements, there are two basic types of sampling processes employed in the signal circuit: the signal-proportioning system and the error-sensing feedback system. The signal-proportioning method is an open-loop configuration in which the vertical output is directly proportional to the input signal. Each sample is thus displayed independently so that the presentation is governed by the efficiency and gain of the signal circuitry. In the more sophisticated feedback system, the vertical output is adjusted in proportion to any change in level between consecutive samples. The sampling function thus determines whether a previously stored sample voltage must be appropriately modified to properly display a subsequent event.

Fig. 5 illustrates a typical error-sensing sampling technique used in modern sampling scopes. In this arrangement, the sampling gate is composed of four matched diodes, connected in a balanced bridge configuration, which operate as a high-speed switch. The gate is held open by reverse biasing which prevents the input signal from being passed to the amplifier. Sampling is accomplished by momentarily closing the gate with a pair of opposite-polarity pulses coupled from the strobe generator. This action forward biases the gate during the sampling interval and stores a very short pulse of current, proportional to the instantaneous signal amplitude, in the amplifier input stray capacitance ($C1$). Any voltage change at $C1$ is amplified, stretched to about ½ μsec, and applied through the memory gate to storage capacitor $C2$. To stabilize the feedback loop, the memory gate is held open only long enough to respond to the sampled signal.

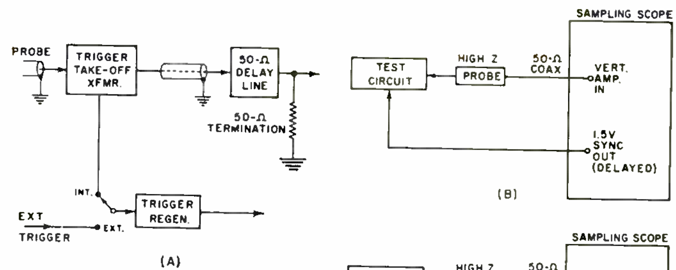
By means of the feedback system, the voltage level in the storage circuit is compared to the true level of the input signal at the time of the previous sample. If the stored level differs from the signal amplitude, an error signal is applied to the input of the system during the interval of the next sample and adjusts the stored output voltage to the appropriate new value. Thus, if the signal is the same for two consecutive samples, there is no change in the level of storage capacitor $C2$, no signal is fed through the amplifier, and the output voltage remains constant. By virtue of the over-all feedback loop, the error-sensing sampling system has excellent gain stability and a high degree of linearity.

Probing and Triggering

Generally, two basic types of input probes are used to couple the measuring signal to the vertical circuit of the sampling scope—the passive probe and the direct sampling probe. The passive probing technique shown in Fig. 6A generally includes a trigger pick-off circuit for internal triggering. To minimize reflections that can seriously distort the input waveform, the circuit is provided with a 50-ohm termination which is bridged by the high-impedance sampling gate located in the main instrument. In the internal triggering mode, a small portion of the input signal amplitude is extracted by a take-off transformer (6-dB insertion loss) to serve as the trigger signal for the sampling process. To view the leading edge of very fast pulses, an internal delay line may be included in the signal channel which will allow the triggering and time-base circuit to operate before the signal arrives at the sampling gate. The proper delay is provided by a high-quality 50-ohm coaxial cable (typically 50-nsec delay with 0.1-nsec rise time) capable of passing high-speed signals without distortion.

In the direct sampling probe, the input signal is introduced directly to the sampling circuit which is incorporated into the probe assembly. This arrangement permits the high input impedance (100,000 ohms shunted by 2 pF) to be preserved where it is important to minimize loading of the circuit under test. To achieve the required time spacing between the trigger and the signal, the test circuit may be excited by a sync-out pulse derived from the scope (Fig. 6B). An alternate arrangement, shown in Fig. 6C, utilizes an external delay line which is inserted between the signal source provided by a repetition rate generator and the circuit under test that the signal is triggering.

Triggering places demanding requirements on a sampling scope since the instrument must be capable of reliable synchronization from extremely narrow pulses of low amplitude and from signals of ultra high frequency. In practice, it is not necessary to trigger every occurrence of the input waveform so that signals at high repetition rates may be sampled at lower repetition rates. At frequencies up to 100 kHz, the



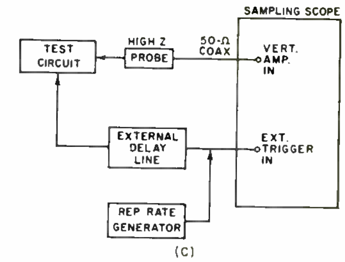


Fig. 6. (A) Synchronization by signal splitting in the internal trigger mode. (B) Delayed sync from scope. (C) Sync pulse produced by external generator.

scope samples the input signal on a pulse-by-pulse basis. Above 100 kHz, the hold-off circuit operates and provides synchronization on a subharmonic of the input waveform so that if the signal repeats more than 100,000 times per second, the trigger circuit automatically "locks" out interim triggers. Synchronization can then be achieved with trigger-signal repetition rates up to 100 MHz. For triggering on signals above 100 MHz, an additional countdown circuit provides a stable trigger wave train at a submultiple of the signal frequency in the 10-MHz range. The output is subsequently fed to the scope synchronizing circuit which, in turn, operates in the 100-kHz region. By this means, the scope timing system is locked in solidly on frequencies in the gigacycle range.

Performance Characteristics

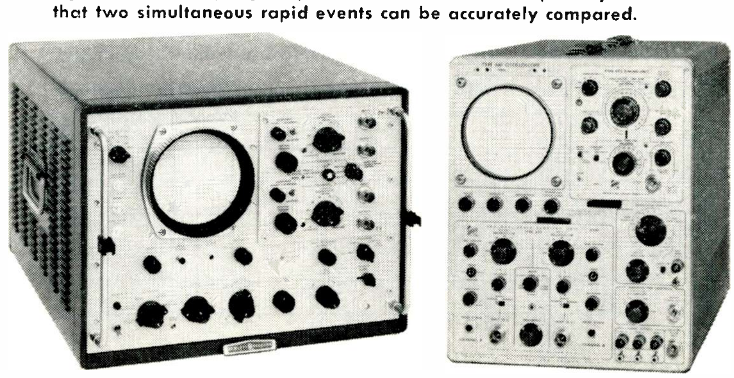
Modern sampling scopes generally consist of a main unit to carry the necessary power supplies and display circuitry along with plug-in modules for the vertical (and sometimes the horizontal) circuits. The plug-in concept provides a high degree of flexibility since the equipment can be conveniently updated at any time, thereby reducing obsolescence.

Fig. 7 shows a pair of commercially available sampling scopes equipped with a vertical amplifier plug-in unit designed for dual-channel operation. The dual-channel capability is obtained by using two independent sampling circuits which sample the respective inputs simultaneously. The information is electronically switched between the two channels, and both outputs are displayed on each sampling so that accurate time comparisons between the two events can be made.

These instruments are capable of displaying signals in the gigacycle range and can measure rise times down to several picoseconds (micromicroseconds).

A typical step response obtained from a fast tunnel diode pulse generator is shown in Fig. 8. In this oscillogram, the sweep speed is 100 psec/cm (*Continued on page* 72)

Fig. 7. Most sampling scopes have dual-channel capability so that two simultaneous rapid events can be accurately compared.



Microphones for Public Address

By PAUL K. FRANKLIN / Electro-Voice

Proper selection and correct placement of p.a. microphones are essential to good system performance. Important factors to consider are response, directivity, and the output level.

IN order to achieve the most satisfying results, microphones for public-address use must be precisely selected and correctly positioned. Determination of that "exactly correct" microphone and its best position *can* be made by persons who are not necessarily experts in this field.

The first requirement is an understanding of certain fundamental concepts and a careful application of the rules derived from them. The important microphone characteristics with which these concepts are concerned, and from which the rules are derived, fall into three basic categories: frequency response, directional characteristics, and output level.

Frequency Response

Microphone frequency response is a description of the manner in which a microphone "hears" sound. Such a description is portrayed graphically in a response curve. Fig. 1A illustrates such a curve—the ideal flat response that is highly desirable. Actually, however, no microphone is really this flat. Fig. 1B is really more representative of the modern, high-quality microphone having "smooth, wide-range" response.

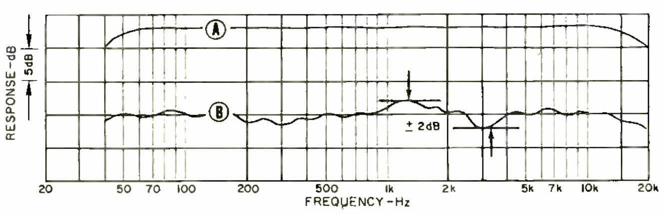
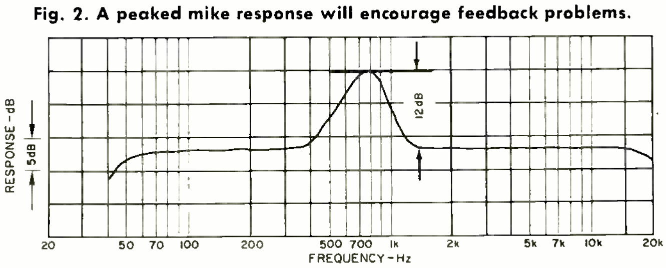


Fig. 1. Smooth, wide-range microphones are within 2 dB of flat.

Fig. 2. A peaked mike response will encourage feedback problems.



Note, however, that excursions of the curve above and below flat (or the stipulated reference value) are restricted to ±2 dB. Since 3 dB is close to the minimum change in level the human ear can perceive, tolerances shown in the curve indicate a microphone of excellent quality (in terms of frequency response). Deviations in microphones of lesser quality may exceed 5 or 6 dB.

Large excursions or major deviations in response, especially in the lower frequencies, tend to encourage system feedback, thus limiting performance of the public-address system. Economies effected through compromise with frequency response tolerances can be expensive.

Fig. 2 shows a hypothetical microphone response curve that illustrates the effects on total system performance of extreme excursions in microphone response. In this hypothetical situation, certain assumptions must be made to clearly emphasize the point. These assumptions are, basically, that actual response curves of auditoriums, speakers, and amplifiers are as flat as shown in Fig. 1A. The response peak might fall at any frequency (in practice, many such peaks will exist and at many frequencies), but for this discussion, we will arbitrarily center it at 800 Hz.

Note that in the illustration, the microphone sensitivity is 12 dB greater at the peak than is average for the microphone. Sound projected at 800 cycles per second by the speaker system will arrive at the microphone at a level 12 dB higher than the rest of the signal and will be amplified again, 12 dB higher. A closed loop has been created. The entire system will start oscillating and feedback will end the usefulness of the system until a change is made. Now note that if we eliminate that peak, the system might generate at least 12 dB more sound before the start of feedback. Since an increase of system output of 3 dB is equivalent to doubling the power at the speakers, it can be seen that elimination of extraneous response peaks in any component of the public-address system is critically important.

A second important characteristic of response is range—the higher and lower frequency limits within which the response is flat. A very wide-range response might be specified as 40 to 20,000 Hz. A specification for an excellent quality microphone might read "flat within ±2 dB, 40 to 20,000 Hz," Fig. 3A. It should be noted, however, that range of response does not, as such, denote microphone quality. A high-quality dynamic microphone specification might as easily read, "flat within ±2 dB, 60 to 10,000 Hz," Fig. 3B. Range is the design characteristic that is determined to meet requirements of a specific application. Range beyond specific requirements is not desirable. Transmissions of portions of the audio spectrum not required may actually degrade the signal.

Other important characteristics of response involve special shaping that is sometimes given to microphone response curves in order to satisfy particular acoustical requirements. Lavalier microphones, for example, are suspended from the neck of the user, and this position under the chin requires a reduced low-frequency response in order that the final signal will sound flat. In other situations, high-frequency response of the microphone may be deliberately deviated from flat in order to achieve a desired effect.

Directional Characteristics

The directional characteristic of a microphone is a description of its sensitivity to sound at specific angles away from the on-axis, or front, looking toward the zero position on a graph. A source of sound generating a signal always exactly at the same level of loudness and moving around the microphone would have to trace a pattern as shown in Fig. 4 in order to make a particular microphone generate a signal of constant amplitude. Note that several traces are actually made, one for each of several representative frequencies, to accurately describe the directional characteristics of the microphone. In general, curves taken at the higher frequencies show more directivity.

The best-known form of unidirectional characteristic is the cardioid, or heart-shaped pattern. The generally accepted definition of a cardioid pattern involves reduction at 90 degrees off-axis of 6 dB from the 0 degree reference value, and at least 20-dB reduction at 180 degrees (rear of microphone). Note, in particular, the significance of a 20-dB reduction in sensitivity at 180 degrees. This means 20 dB or more rejection of unwanted sound arriving at the rear, or virtual elimination of sensitivity to these undesired sounds.

An important refinement of the principles through which directional characteristics are achieved results in super-directional microphones. Combination of a cardioid pattern below about 1000 Hz with the extremely directional long, slotted tube (or distributed front opening) for higher frequencies, results in highly directional patterns. This increased directionality makes possible pickup with "on-mike" sound never before practical.

Selection of microphones in terms of directional characteristics is, then, the second phase in the process of determining the exact nature of the microphone required. The angle-of-acceptance concept (Fig. 5) illustrates a useful method of visualizing a microphone directional pattern. Note that the omnidirectional unit (A) shows nearly uniform sensitivity in all directions (300 degrees). The typical cardioid (B) is primarily sensitive through an angle of only 150 degrees, while the super-directional units narrow to angles of 80 and 40 degrees respectively, (C) and (D). Although the angles shown are represented as angles in a single plane, polar patterns for properly designed microphones are symmetrical about the major axes, hence the geometric figures described are actually cones. Thus a cone-of-acceptance concept is suggested—and is quite useful in determining microphone placement.

Output Level

The output level of a microphone is an expression of its performance in terms of value of signal generated under certain specific conditions. As a statement of performance, the output level defines basic reference values for the process of microphone selection.

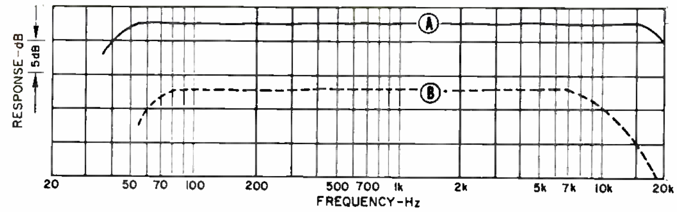


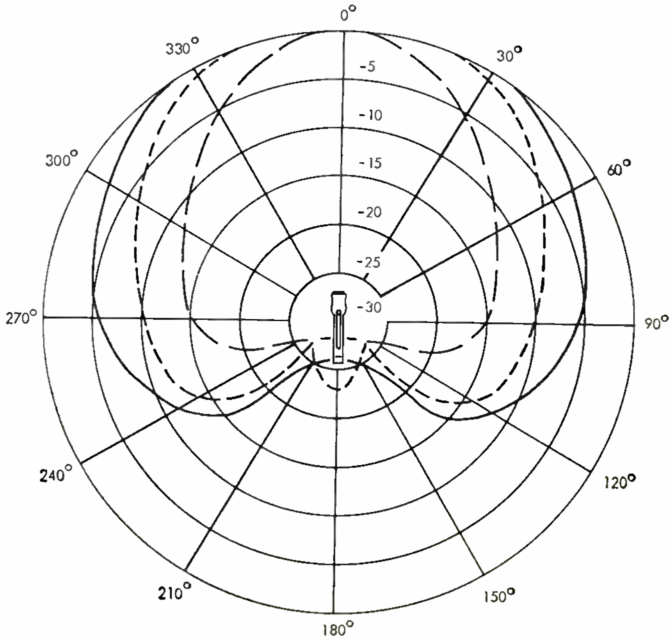
Fig. 3. Frequency range is not the only criterion of quality.

Microphone signal values may be stated in several ways—some of primary importance to design engineers, others of major usefulness to microphone users. High-impedance microphone performance is most frequently stated in terms of voltage. (Example: 0 dB = 1 volt/dyne/cm^2.) Low-impedance outputs, typically 50, 150, or 250 ohms, are commonly stated in terms of power generated. (Example: 0 dB = 1 mW/10 dynes/cm^2.)

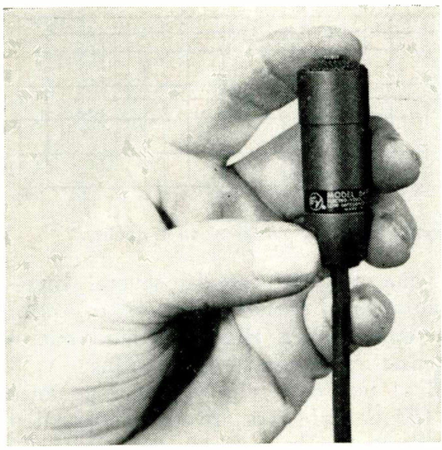
Note carefully that the meaningful statements to the microphone users are expressed as comparisons of one signal to another. A typical high-quality dynamic cardioid microphone output rating, for instance, might read, "output: −58 dB (0 dB = 1 mW/10 dynes/cm^2)." Additional information not normally emphasized in the list of specifications would include frequency of measurement—usually 250 cycles per second for low-impedance dynamics and 1000 cycles per second for some high-impedance microphones. The microphone rating is expressed in negative numbers, −58 dB, or 58 dB *below* the established zero reference value. Smaller negative numbers, therefore, indicate figures of greater output level.

Microphone output levels occur most frequently in the range of −55 to −60 dB. Therefore, the gain of typical amplifier input stages would be established to accommodate microphones having values of output level in this range. In turn, then, the specific microphone application dictates the type of unit required, in terms of the level of signal that must finally be available to the amplifier input. Recognizing that sound intensity level at the microphone reduces by 6 dB each time distance from the sound source doubles, it is apparent that a stage setup requiring placement of the microphone in the footlights would demand much greater initial output from the microphone to generate a signal comparable to another unit used much closer to the sound source. Thus, microphones intended for greater working distance would be designed for much higher output levels (−48 to −55 dB). Conversely,

Fig. 4. Typical directional characteristics of a microphone.



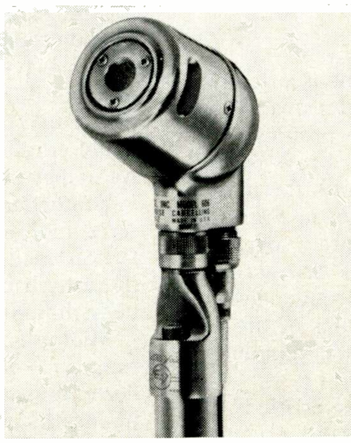
Scale: 5 Decibels Per Division



A

B

C



D

Typical dynamic microphones. (A) Miniature omnidirectional lavalier type. (B) Highly unidirectional type. (C) High-quality omnidirectional microphone designed especially for close talking. (D) Special noise-canceling mike.

microphones that are designed for close-talking applications could function satisfactorily with outputs of −60 dB or lower.

Selecting a Microphone

The process of selecting microphones for specific applications, then, can be reduced to a relatively simple, step-by-step procedure. First, determine the intended primary use, *i.e.*, for hand-held use or stand mounted. If hand-held, an omnidirectional pattern is indicated. (The usefulness of the directional pattern of a cardioid is generally defeated in hand-held use.) Consider the angle of acceptance required in this use. Which of the four choices is best suited in this case?

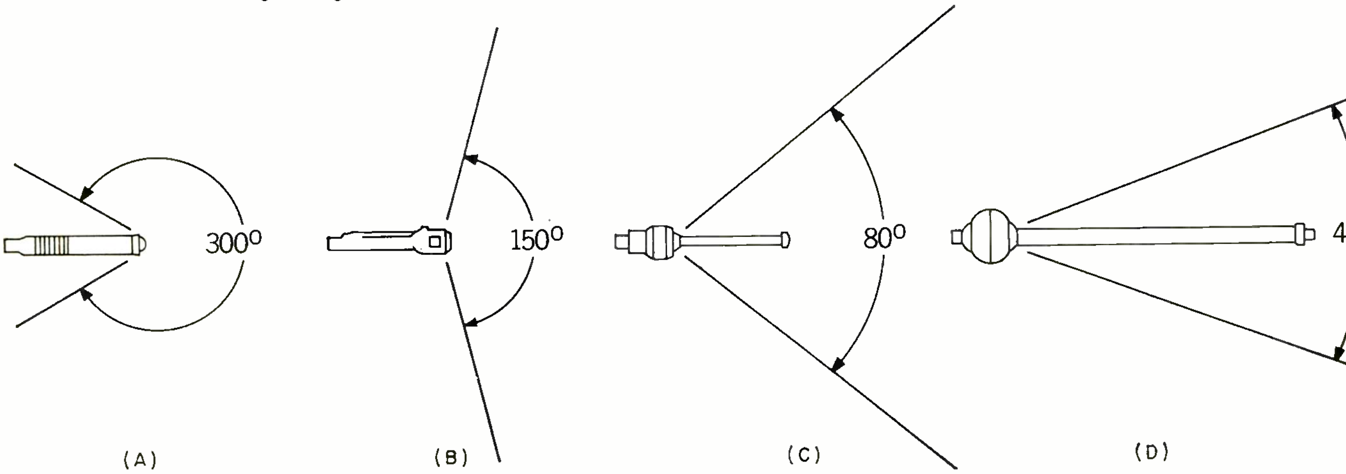
Notice, as evaluation proceeds, most indications are for a cardioid (unidirectional) pattern. In most instances, a cardioid pattern is actually the best choice and, in those few remaining instances, it would not be wrong. Certainly, for situations requiring greater working distance, a unidirectional pattern is essential in order that sensitivity to extraneous noises and reverberation can be reduced. Note how the requirements dictate choice—narrow angle of acceptance for increased working distance suggests highly directional units and also suggests high output level. Hence, the vast majority of microphones available are eliminated from consideration — choices are narrowed. Frequency response requirements, then, will probably reduce range of choice to one or two units.

Correct placement of microphones for a specific effect in a particular environment may seem difficult—yet it can be fairly easy. A clear understanding of the concepts covered in this discussion applied to the placement problem in an imaginative manner will go a long way. Judicious trial and error will then usually bring into focus the one best choice of position. This is a round-about way of emphasizing the point that, at best, microphone placement is a rather inexact science.

If a flashlight could be made whose beam angle could be varied in accordance with the angle of acceptance requirement, a useful tool for determining microphone position would have been created. For example, the 150-degree angle of the cardioid cone could be visualized easily using this concept. Theoretically, from all points within that cone and equidistant from the microphone, a constant level sound source would generate constant signal level from the microphone. In other words, imagine a vocal group on a stage, visualize the flashlight beam (set for the 150-degree cardioid) and move back until the light covers the group. At this point, set the cardioid microphone, angled slightly upward to minimize pickup of reflections of sound (reverberation) from vertical surfaces directly on-axis, and you have probably selected the nearly optimum position. Beyond this, only careful listening tests can refine your choice of position.

How do you pick up adequately the action of a stage production such as a play or musical? One approach that has been satisfactory on some occasions (here possible methods are limited by the performance (*Continued on page* 72)

Fig. 5. Angles of maximum response for various types of typical microphones are illustrated below.



JOHN FRYE

Citizens Band equipment is now getting sophisticated, but operating practices often leave something to be desired.

A HAM LOOKS AT CB

MAC, a little late for work, bustled through the front office of his radio-TV shop only to be brought up short in the door of the service department by the sight of a slender white rod weaving up and down just inches in front of his bifocals.

"Woops! Sorry, Boss," Barney called from the other end of the room as he swung the long fiberglass pole he was holding out of his employer's way.

"You really intend to throw the fish out on the bank," Mac said. "That rod must be fifteen feet long."

"Eighteen and a half," Barney corrected. He laid the large-diameter butt section on the floor and began unscrewing the slender whip part from the top of it. "It's a CB antenna, but I'll excuse you for calling it a fishing rod. I had it delivered here because Mom is visiting her sister for a few weeks and no one is home at our place during the daytime."

"Where are the radials?" Mac asked, peering through the long, empty cardboard tube in which the antenna had been shipped.

"Ain't any. That's the main reason I chose this type for mounting to the side of the pole supporting my tri-bander ham beam. A CB antenna on our house could legally project only twenty feet above the roof, but I can mount it as high as I like on 'the transmitting antenna structure of another authorized radio station,' so long as the height of the CB antenna does not exceed the height of the supporting structure. I'm confident a ground plane mounted up there beneath my tri-bander would foul up the beam's operation, especially on ten meters, which is quite close to the CB frequencies; but since all of this antenna will be at right angles to the horizontal beam elements, it should have little, if any, effect."

"How do you feed it?"

"Through this SO-239 connector mounted in the bottom end. The antenna is really a coaxial type. A piece of coax feeds up from the connector through the hollow base section, and the shield and inner conductor connect to the base and top section, respectively, at their junction. This arrangement prevents r.f. from appearing on the feedline and radiating so as to impair the antenna's desired low angle of radiation."

"Is this something new?"

"Not really. Coaxial antennas have been popular on v.h.f. and u.h.f. commercial frequencies for a long time, and hams have used them. CB manufacturers, though, have inclined more toward variations on the basic ground plane, possibly because the coaxial antenna presents some fabricating problems—especially if you make it chiefly of metal. The antenna must be well insulated at both the support at the bottom and at the center; yet these insulators must withstand considerable mechanical stress. The performance of the coaxial antenna, however, should equal that of any other basic circular-pattern type, and several companies are now marketing these no-radials 'stick'-type antennas.

"This one is a little unusual in that it is fabricated mostly of fiberglass. Both quarter-wave elements are spirally wound and embedded in this strong, flexible, insulating material. Advantages claimed for this type of construction are resistance to corrosion and a reduction in precipitation static through complete insulated covering of the metallic radiators."

"Worrying about precipitation static, huh? CB'ers really try to squeeze the last microwatt out of a received signal, don't they?"

"They have to. Remember that the power input to the final stage of a class-D CB station must not exceed 5 watts, while amateurs can—and many do—input a full kilowatt. Having to work with this low power has caused CB engineers to come up with some very fine equipment. Take antennas, for instance: the original ground plane with quarter-wave radiator and quarter-wave radials has proliferated into end-fed ½- and ⅝-wave radiators with impedance-matching transformers for end-feeding them and feedline-decoupling ground planes; wide-spaced flip-over yagis and horizontally stacked yagis; cubical quads; phased antennas with electronically rotated beams; and even rhombics and V-beams.

"And some CB transceivers can make the most of any tiny signal coming down the feedline. Sensitivity claims of ½ microvolt for 10 dB S/N ratio are not uncommon, and checks made with my noise generator convince me some of these claims are justified. Nuvistor r.f. stages and careful front-end design achieve a sensitivity hard to equal in a broad-spectrum, bandswitching communications receiver such as we hams use."

"It seems to me CB engineers do good stuff with transistors."

"Yes, that's where they really shine. Transistors are a natural for mobile CB transceivers because of low transmitting power requirements, low drain on the car battery, and the way transistors lend themselves to compact construction.

"I've followed the development of transistorized CB equipment right from the beginning, and I'll admit I was greatly disappointed in the first transistorized five-watter I examined. Transmitter output was below that of a tube transmitter even at normal temperatures, and this output fell off rapidly as the temperature approached zero. The receiver was worse. Selectivity was poor, the squelch had a kind of backlash effect that made precise setting of the level impossible, sensitivity was very mediocre, and the simple shunt-type noise limiter did a poor job on ignition noise. On 'Tune' the receiver was most unstable. The dial setting varied widely with a change in temperature, and the local oscillator was so sensitive to battery voltage that you could tune the receiver over two or three channels just by using the accelerator pedal!

"Then *Cadre* came out with its sophisticated 1.5-watt C-75 hand-held transceiver and showed what could be done with transistors. Close on the heels of this trailblazer came several fine transistorized five-watt units that corrected all the faults of the early transceivers. Epitaxial silicon mesa transistors in the transmitter section and silicon mesa transistors in critical receiver areas overcame the temperature problem. Zener diodes clamped voltages at sensitive points and rendered them independent of fluctuations of the car battery voltage. Double-conversion superheterodyne circuits greatly improved

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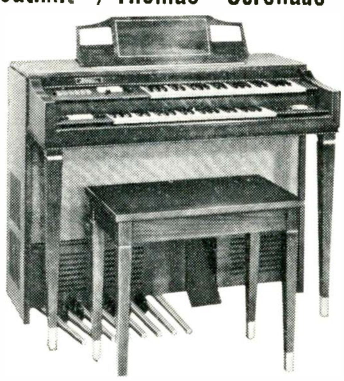

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over-all selectivity; and some transceivers, such as the *Lafayette* HB-500, employed a mechanical filter to achieve outstanding adjacent-channel selectivity. Other transceivers did the same thing with crystal filters.

"Exotic and effective noise-blanker circuits have been worked out to prevent ignition noise from degrading the excellent sensitivity achieved with recent high-gain, low-noise transistors. Squelch circuits work as smoothly as in tube-type transceivers. New a.g.c. circuits and modern transistors have been combined to overcome a serious problem in early transistorized equipment: overloading and cross-modulation by strong nearby signals. Another tough problem, how to modulate fully and linearly a transistorized r.f. amplifier, has been whipped. Yet most of these refinements can be had in remarkably small packages. For example, the *Johnson* "Messenger III" measures only $2\frac{3}{16}$" x $6\frac{3}{16}$" x $8\frac{3}{4}$"."

"Doesn't seem to leave much to be done in CB engineering."

"I wouldn't say that. *Johnson* just came out with a new SSB CB transceiver. Some people pooh-pooh SSB for CB use, but I'm not one of them. As a ham, I *know* how much more effective sideband is than AM, especially when the going is rough, as it is likely to be when working mobile-to-base. Recently my cousin, who is also a ham, took a month-long trip from here in northern Indiana down to the tip of Texas and then on around the Gulf into southern Florida. Both his mobile installation and my fixed station run less than 200 watts on SSB; yet we talked two and three times a day on the 20-, 40-, and 75-meter bands without missing a single schedule. We could never have done that on AM.

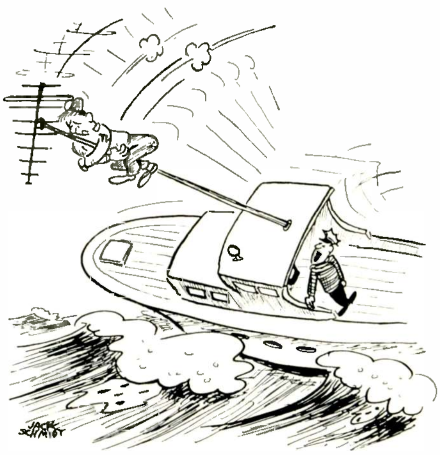
"Detractors of CB SSB complain that with it you can't talk to anyone except another station similarly equipped. I thought the chief purpose of CB equipment was to talk among your own units. If you want to go down the road talking illegally with Tom, Dick, and Harry, SSB is not for you; but if a mobile wants to maintain solid contact with its base station for receiving and transmitting substantial messages, SSB will do a better job than AM."

"It seems to me," Mac observed, "that CB borrowed heavily from ham radio in the beginning but now may be about to repay the debt. Much of the engineering that has been done on CB transceivers can be used almost 'as is' on transistorized ham gear. Now that high-power transistors have been developed, I fully expect to see completely solid-state ham transmitters with substantial outputs coming on the market in the near future. You already have hybrid transceivers that use transistors just about everywhere except in the r.f. final amplifier."

"I agree," Barney said. "Very compact solid-state transceivers for ham radio cannot be very far away. But getting back to CB, I think it is a pity operating practices are not keeping pace with engineering in that field. A friend of mine receives copies of 'Show Cause' notices sent out by the FCC, and looking over these is pretty depressing. For the life of me, I don't see why some CB operators can't realize what hams learned long ago: if you operate illegally, sooner or later 'Uncle' will catch up with you. What's more, he doesn't overlook some 'minor' infractions of the rules; he will cite you for any kind of illegal operation. I saw operators cited again and again for (1) not giving calls at the beginning and end of each transmission, (2) for giving calls incorrectly (you must say *KHD four-one-six-seven*, not *KHD forty-one, sixty-seven*), (3) for working another station outside the seven channels prescribed for this operation, (4) for having an antenna 20 feet above the ground level or 20 feet above the roof top, (5) for working skip, (6) for asking for signal-strength reports, (7) for talking longer than 5 minutes, (8) for not keeping silent for 5 minutes after an exchange, (9) for frequency deviation beyond tolerance—but why go on? Name any kind of forbidden operation and I can match it with an 'Order To Show Cause' issued by the FCC for that violation.

"I can't see why CB operators can't police themselves as hams do. We have our Official Observer Stations whose operators send out written notices to stations they hear violating some rule or regulation. We respect these notices and the people who send them because they very often keep us from getting a citation from the FCC. But in the CB magazines I have read, anything of this sort is disparagingly called 'rat-finking.'"

"Don't be too hard on the CB'ers," Mac advised. "Remember, it is still a new service and has growing pains. Personally, I have faith that eventually the Citizens Band will become a respected member of the radio family." ▲



"Now the picture is weak again. . . . ."

POWER MEGAPHONES

This type of p.a. system is highly portable and can be used where other types of p.a. systems cannot be easily operated.

THE introduction of the multiwatt power transistor with its low voltage requirements, printed circuits, and efficient small loudspeakers and microphones hastened the development of the power megaphone (sometimes called a "bullhorn"). This highly portable p.a. system mounts its microphone, power amplifier, speaker, and battery power supply, all within a small, relatively lightweight package.

Although mostly used by police and fire departments for traffic control, mob control, and rescue work, power megaphones are finding their way into boating where they are standard equipment aboard U.S. Coast Guard vessels; in construction where voice instructions must be heard over the sound of bulldozers and hydraulic drills; in schools where they are used as "voice savers" for athletic coaches and playground supervisors; and in resorts, camps, and beaches for paging and safety in water sports.

Two basic types of power megaphones are available: one is a semi-portable, somewhat heavier of the two types, whose microphone is separate from the amplifier. It is designed for long-range communications at high acoustic power and is usually provided with a shoulder strap for portability. The other is a relatively light-weight, hand-held unit with the amplifier, battery, and microphone mounted at the small end of the megaphone. Many of these hand-held units store their batteries within the hollow handle.

A typical high-power semi-portable power megaphone is the Model PP-1T of *LTV University* shown in Fig. 1 (left). This unit has an output of 25 watts, frequency response of 400 to 5000 Hz, and a useful range of about one mile. Speaker dispersion angle is 120°, weight is 13 pounds, and the unit requires 24-volts supplied by four lantern-type batteries.

A useful feature found in some of these models is the "talk/listen" mode. A flip of a switch converts this power megaphone into a sensitive, directional listening device finding ready application in marine use, fire and police service, and various rescue operations. In this mode, the loudspeaker and megaphone horn become the microphone, while the microphone becomes the earpiece.

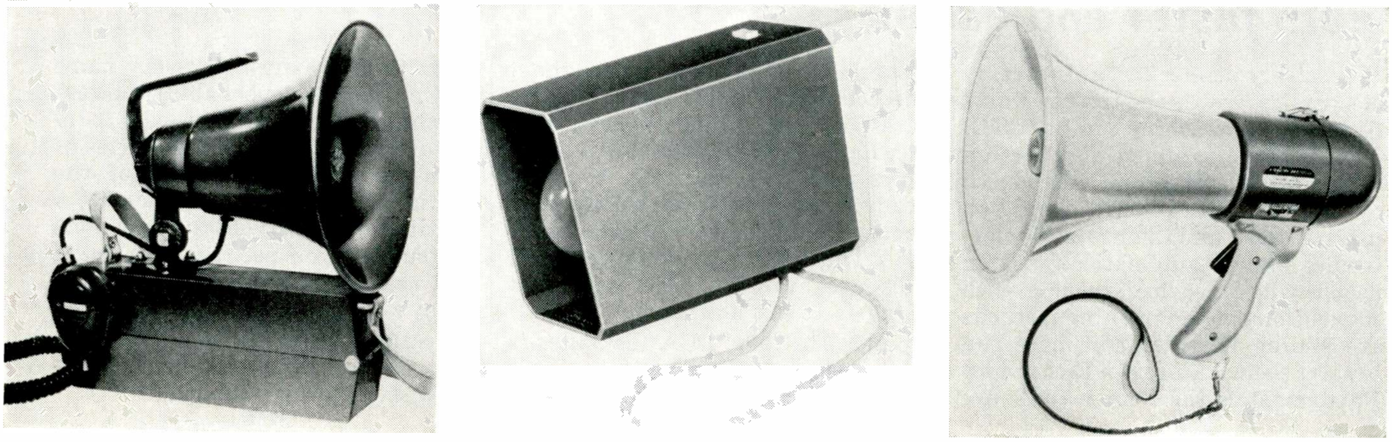
These types of power megaphones are usually provided with an auxiliary input connector so that an external microphone, AM/FM tuner, or a record or tape player can be used as the input signal. Usually, when used with an external signal source, operating the microphone switch automatically reduces the volume from the external source (usually 6 dB), so that voice messages can be clearly heard over the music background. Releasing the microphone switch brings the background music back to the original level. Many of these units are also provided with an attention-getting "siren"-type signal. This employs a positive-feedback loop around the amplifier that is activated by a push-button switch and produces a high-intensity, penetrating tone used for warning alerts, fog horn, or any necessary attention-getting demands.

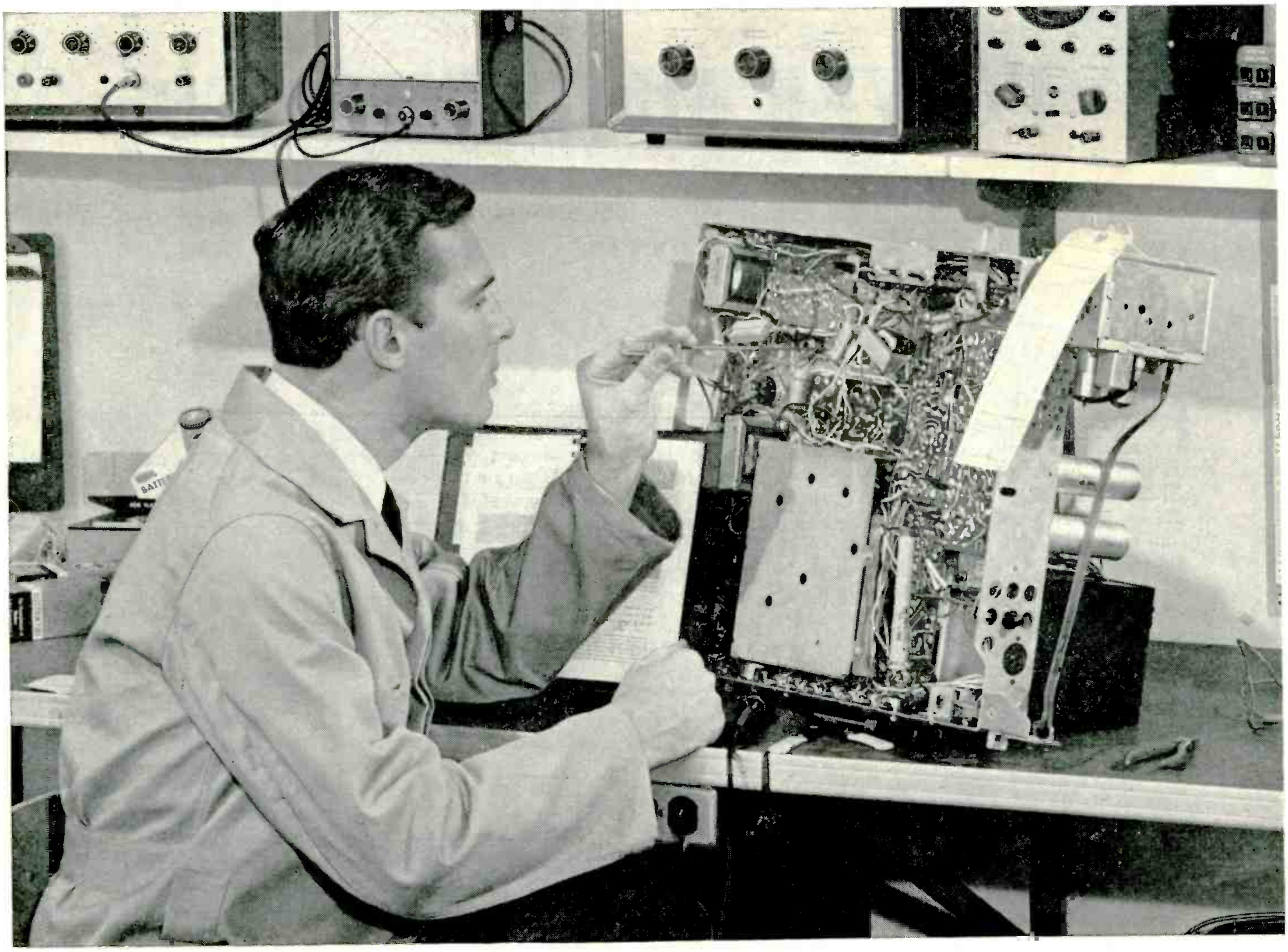
The hand-held, lightweight, familiar "bullhorn" is used for almost every situation involving crowd conditions where the loudspeaker must be mobile, or used in areas where conventional p.a. systems cannot reach. This type of electronic megaphone ranges from the three-transistor, 1-watt, 1½-pound MV-2 of *Fanon-Masco*, shown in Fig. 1 (center) that has about 150 yard range, to the five-transistor MV-16S unit shown in Fig. 1 (right) whose 16 watts of power output within a five-pound package produces a usable signal at 800 yards.

Although most power megaphones provide many continuous hours of operation using only a few flashlight-type "C" or "D" cells, some have provisions for coupling to an external power source such as a storage battery, or a battery eliminator for heavy-duty, long hours of sustained operation.

The horns themselves are usually made from high-impact plastic, or aluminum, as is the electronics and microphone cover, and the handles. When used with a waterproof microphone, these units are not adversely affected by practically any environmental extreme. ▲

Fig. 1. (Left) This 25-watt semi-portable power megaphone has a detachable microphone and range of one mile. (Center) Hand-held, lightweight, one-watt unit has range of 150 yards. (Right) 16-watt "bullhorn" has range in excess of 800 yards.





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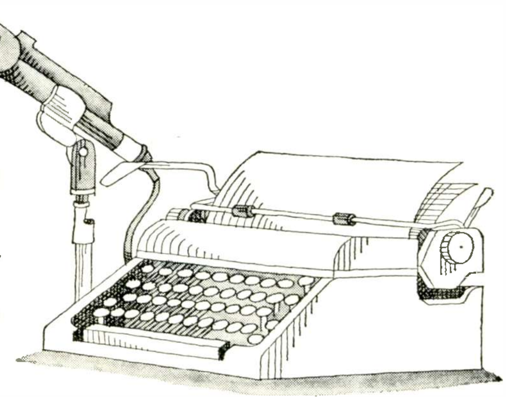


DURING the past few years, we have passed into the era of printed circuits and deposited transistors, resistors, and capacitors, until now it is very practical to deposit an entire circuit, including both active and passive components, on a single substrate. However, the power supply was always external and relatively bulky even with small-size batteries.

A recent paper prepared by three researchers at the Institute for Exploratory Research, Fort Monmouth, N.J., reported that while they were studying certain characteristics of compressed silver iodide powder carrying thin evaporated films of platinum and silver on opposite faces, they observed that this array exhibited battery-like behavior. The data they presented concerns the charge-discharge characteristics of a rechargeable, solid-electrolyte battery of solid silver iodide (the electrolyte), an evaporated film of silver (the anode), and an evaporated film of palladium (the cathode). This combination behaves just like a rechargeable cell having low internal resistance and unexpectedly high cell capacity.

The service life of these "printed batteries" is about 400 minutes per cm^2 of anode area across a one-megohm load while maintaining a closed-circuit voltage greater than one-half the original open-circuit voltage of 0.5 volt per cell. Arrays of cells have been recharged over 100 cycles with no apparent deterioration. The cells appear operable over the temperature range from −100°F to +240°F.

It has been suggested that this development opens the door for a new class of battery that can be "printed" directly on circuit boards, inside instrument cases, or within almost any package.

Woofer, Tweeter, Flamer

Hi-fi enthusiasts will be interested in a new loudspeaker approach reported by the Stanford Research Institute in which a flame is used both as an "amplifier" and "loudspeaker." Using this pyro-acoustic system, a human voice was amplified to a loudness many times greater than possible with conventional loudspeakers of the same power.

A stream of combustible gas is modulated as it passes through an orifice formed by a metal block and the diaphragm of a conventional loudspeaker. The modulated gas stream expands through a throat and passes through a wire-mesh flame holder. Combustion takes place completely and very close to the flame holder. Variation of the flame, caused by the modulated gas flow, imparts varying mechanical energy to the gas molecules of the combustion products. As the large changes in molecule motion follow those of the loudspeaker diaphragm, the result is amplified sound.

Mosquito Bitometer

Probably the farthest thing from electronics is being bitten by a wild mosquito. Now, a scientist at the *ITT Research Institute* has created an electronic device that not only tells when the mosquito bites but what kind of a bite and how the mosquito feeds.

Mosquito-borne diseases are transmitted primarily when a mosquito probes a host's skin and salivates before consuming blood. Previous methods of observing mosquito-biting action were chiefly visual and could not distinguish probing from actual engorgement of a host's blood.

The electrical circuit consists of a glass or cardboard container, holding one or more mosquitoes, covered with a fine-mesh bronze screen. An anesthetized mouse is placed on top of the screen. A wire is connected from the screen to one pole of a battery and the circuit from the other pole of the battery then passes through a current-flow recorder to the tail of the mouse. No current flows since the mouse is insulated from the screen by its hair.

When the mosquito attacks the mouse, it holds onto the screen and completes the circuit when it passes its proboscis through the fine mesh and into the mouse. The recorder then measures the current flow through the circuit.

Besides enabling a complete study of host-insect relationships for any species of biting or blood-sucking insects, the electrical device will permit testing insect-repellent effectiveness with high accuracy under natural conditions. ▲

P. A. Loudspeaker Principles

(*Continued from page 26*)

distribution of units, let us operate them at 5 watts input. Hence, ten of these units, uniformly distributed, would cover the area adequately.

As a quick alternate, suppose this same volume housed just a large automobile service station and, rather than spot coverage, a single wall-mounted medium-power projector would do the job. In this instance, the vertical line would drop down to the medium-power projector band. Then following the slope of the diagonal we arrive at about 30 watts of power required, which one of these projectors can handle easily.

SECTION 3— CONSTANT-VOLTAGE SYSTEM

Contrary to popular belief, constant-voltage systems do not eliminate the need for impedance matching. The impedance matching is done *automatically* by selecting the proper *power* taps. It is as simple as changing a light bulb in a lamp. The user does not worry about impedances when making the change, but the manufacturer of the bulb did. He knows he has a 120-volt line to contend with which the power company guarantees to be "constant" within limits. Knowing this voltage is constant, the light-bulb manufacturer simply makes the impedance of a 25-watt bulb such that it will draw this amount of power from the 120-volt line, or the impedance of a 50-watt bulb so that it will draw 50 watts of power. As long as the source voltage remains constant, and as specified, the bulb will draw its rated power.

So it is with the 70.7 (or 25)-volt constant-voltage system for p.a. use. The sound installer has had the impedance problem taken care of for him by the speaker manufacturer. The transformer that he ties onto the line and then connects to the speaker is marked in *wattage* inputs. There is no need to calculate impedances. If ten sound penetrators are to be used and each one is to take 5 watts, he simply selects the 5-watt tap on the primary of the transformer and ties it directly across the p.a. amplifier's output supply line. To add another speaker, simply adjust its power tap and put it directly across the line—just as you would use a 25-watt bulb in one socket and a 50-watt bulb in the other socket of a table lamp. It becomes just as easy to adjust the sound power into any one spot with complete disregard of the adjustment of any other speaker.

Of course, in using this system: (1) The total power supplied to all the speakers in the system must not exceed the amplifier rating. (2) The power rating of the matching transformer must be adequate for the power consumed by its associated speaker load. (3) Matching transformer secondaries must be terminated by an equivalent speaker load.

Up to the point where the amplifier is not delivering its full rated power, the use of this system results in an impedance mismatch on the amplifier. However, since we are not using the maximum output power from the amplifier, the mismatch can be readily tolerated. ▲

NEW TV PICTURE-TUBE SIZING RULES

NEW rules for advertising the "picture size" of TV receivers have been adopted by the Federal Trade Commission, effective July 1, 1966.

Starting on this date, only the actual size of the picture—not the dimensions of the CRT—when measured on a single plane can be used in advertising.

If any size other than the horizontal dimension is used, it must be accompanied by a clear and conspicuous statement showing how the measurements were made.

The FTC noted that CRT measurements invariably are larger than the actual picture size because some portion of the CRT screen is masked in an actual installation.

The FTC gave the following examples of proper and improper advertising claims for a picture that measures 20 inches diagonally, 19 inches horizontally, 15 inches vertically, and has an area of 262 square inches.

Proper

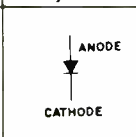
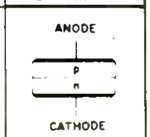
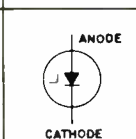
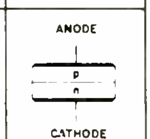
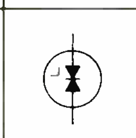
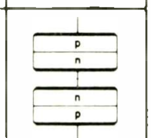
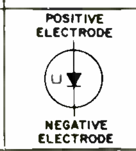
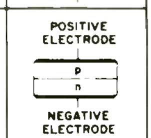
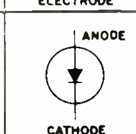
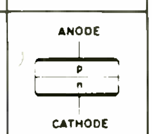
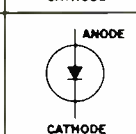
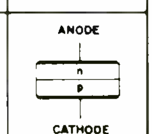
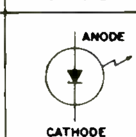
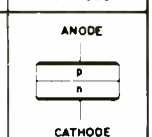
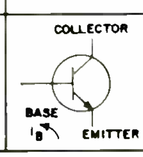
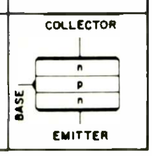
"20-inch picture measured diagonally."
"19-inch picture." ● "19 inch."
"19-inch by 15-inch picture." ● "262 square-inch picture."

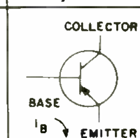
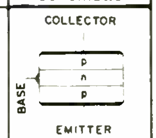
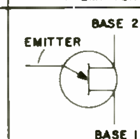
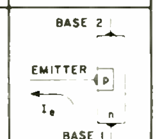
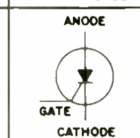
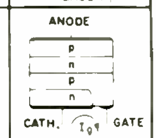
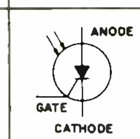
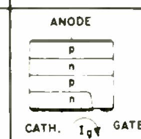
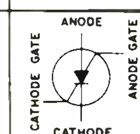
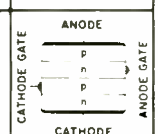
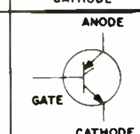
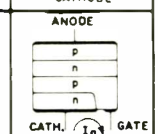
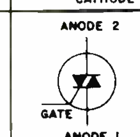
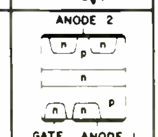
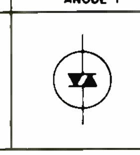
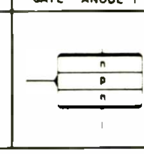
Improper

"21-inch set." ● "21-inch diagonal set."
"21-inch over-all diagonal—262-square-inch picture."
"(Brand Name) 21." ▲

MAJOR SEMICONDUCTOR COMPONENTS

The following table of the major semiconductor components, along with their commonly used circuit symbols and junction schematics, was taken from the General Electric "Entertainment Semiconductor Almanac." Note that in all cases the direction of current flow indicated on the various circuits is for electron movement.

Name of Device	Circuit Symbol	Commonly Used Junction Schematic
Diode or Rectifier		
Avalanche (Zener) Diode		
Thyrector		
Tunnel Diode		
Snap Diode or Step Recovery Diode		
Back Diode		
Light Emitting Diode		
n-p-n Transistor		

Name of Device	Circuit Symbol	Commonly Used Junction Schematic
p-n-p Transistor		
Unijunction Transistor (UJT)		
Silicon Controlled Rectifier (SCR)		
Light Activated SCR* (LASCR)		
Silicon Controlled Switch* (SCS)		
Gate Turn-off Switch (GTO)		
Triac		
Diac Trigger		

*Light Activated SCS also possible.

LOW-PROFILE U.H.F. ANTENNA

Similar to a quarter-wave monopole, this new design is 2.5 electrical degrees high.

A NEW type of low-profile transmission-line antenna has been unveiled by *Motorola* engineers. The radiation pattern of this new antenna is comparable to that of a quarter-wave monopole, even though the low-profile antenna is mounted only 2.5 electrical degrees above a ground plane.

This new design is used to avoid the losses usually associated with transmission lines and coupling networks between the transmitter output and the antenna system. Average radiated power is 6 to 8 dB greater than equivalent non-integrated antenna and amplifier.

As shown in the diagram below, the antenna consists of a quarter-wave length of wire, formed into a figure-8 shape and mounted 2.5 electrical degrees above a ground plane.

Each end of the antenna is r.f. shorted to ground through a coaxial type feed-through capacitor.

Antenna tuning to half-wave resonance is made by adjusting the length of the stub connected to the midpoint of the antenna and positioned to run parallel with it.

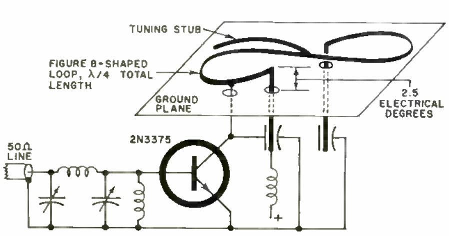
Impedance matching to the transistor is by positioning the transistor collector connection along the antenna.

The equivalent circuit of the antenna is a sharply tuned parallel-resonant circuit having a "*Q*" of about 100, which is controlled by the spacing of the antenna above the ground plane.

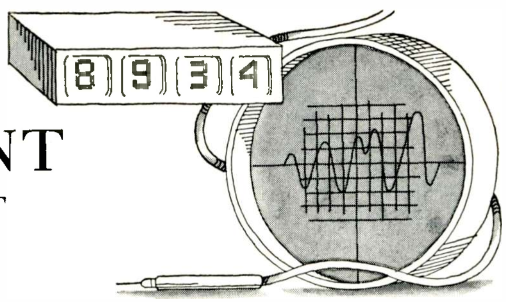
The input r.f. power is matched to the transistor through a *pi* network. To remove any possible feedback between the radiated power from the antenna and the output transistor, each is mounted on opposite sides of the ground plane.

The new antenna has a high tolerance to metal objects in close proximity. Various objects, such as quarter- and half-wave rods were placed within one inch of the antenna without appreciable detuning effects.

In the actual experimental circuit, a frequency of 300 MHz was used with all dimensions scaled accordingly. ▲



TEST EQUIPMENT
PRODUCT REPORT

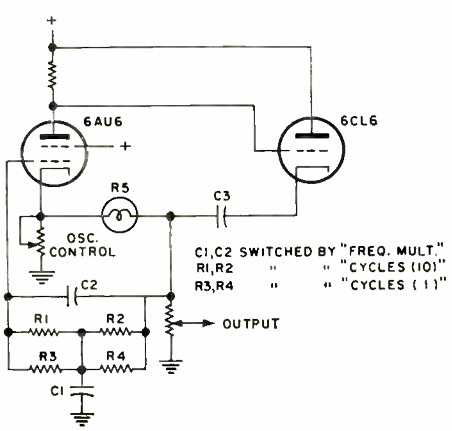


Eico Model 378 Audio Generator

For a copy of manufacturer's brochure, circle No. 25 on Reader Service Card.

THE new *Eico* Model 378 produces a very low distortion sine-wave signal over a very wide range of frequencies. It is useful for testing audio amplifiers for gain and frequency response, as a signal source for bridge measurements, for modulating r.f. signal generators, or for any other application where a stable, accurate audio sine wave must be used. The frequency-determining elements are not continuously variable but are set by three switches that insert combinations of 1% resistors and 2% capacitors making up the frequency-selecting network. This method of tuning permits repeatable, accurate setting of any frequency from 1 Hz to 110 kHz, to two significant figures.

The output level of this instrument can be set with great accuracy between 0 and 10 volts r.m.s. (or between −70 and +22 dB) as read on a 4½-inch 2% meter. Hence, it is not necessary to monitor the output of the generator with an audio voltmeter in order to maintain an absolutely constant output over a wide range of frequencies. Below 1-volt output, the instrument has a switch-selected, internal 600-ohm load that can be disconnected if desired.



The oscillator uses a 6AU6 voltage amplifier coupled directly to a triode-connected 6CL6 cathode follower (see diagram). Phasing of the circuit is such that regenerative (positive) feedback is coupled from the 6CL6 cathode to the 6AU6 cathode *via* C3 and the tungsten-filament lamp *R5*. At the same time, degenerative (negative) feedback is coupled from the 6CL6 cathode through the switch-selected, frequency-sensitive, capacitor-shunted "T" network. This network has maximum attenuation at the specific frequency to which it is tuned; hence, it cuts off the negative feedback at this frequency and permits sine-wave oscillations to occur.

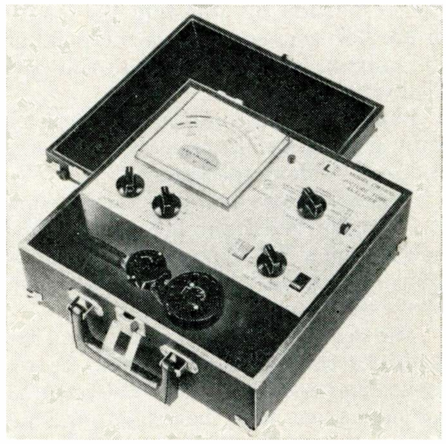
These oscillations would build up to an amplitude sufficient to cause distortion except for the action of the positive-feedback loop. The resistance of the lamp filament in this loop increases with increasing signal amplitude. This reduces the amount of positive feedback which reduces the amplitude of the output. If output tends to go down, the lamp resistance also goes down and increases the amplitude of the output. In this manner, *R5* stabilizes the current flow through the circuit and keeps the amplitude of the output quite constant over a wide range of frequencies. Incidentally, the voltage applied to the lamp (a 3-watt, 117-volt bulb) is far below its normal operating voltage so that the filament does not even glow faintly.

Output is fed to a continuously variable control and then to an eight-step attenuator. A metering circuit is included here to measure the output voltage being generated by the instrument. This circuit uses a 200-μA meter in a bridge circuit that employs a pair of crystal diodes along with a third shunting diode to compensate for low-level non-linearity of the meter. When the generator is properly terminated, the meter and the attenuator switch will indicate the actual signal level between the output and ground terminals.

The output distortion of the unit is less than 0.1% throughout the audio range, while the frequency accuracy is within 5% over the entire range. The generator is available in kit form at $49.95 or factory-wired at $69.95. ▲

Lectrotech CRT-100 Picture-Tube Tester

For a copy of manufacturer's brochure, circle No. 26 on Reader Service Card.

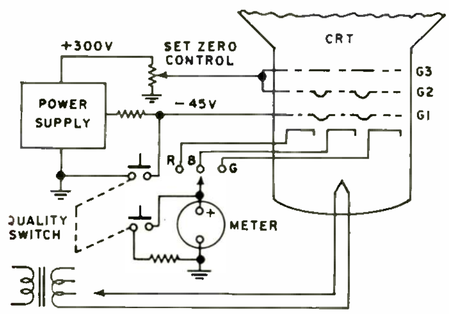


THE new Model CRT-100 picture-tube tester, recently introduced by *Lectrotech*, is designed to test all color-TV and black-and-white picture tubes as well as to remove shorts and operate as a rejuvenator.

In testing a color tube properly, it is necessary to establish a standard set of conditions that simulates the operating conditions within the receiver. This cannot be done too accurately by applying an arbitrary grid-2 voltage and then testing for emission. A somewhat different technique is used in this tester. A fixed negative bias is applied between grid and cathode of the gun under test. Then the *G2* voltage is adjusted until the tube begins to conduct. This normalizes the gun to a standard cut-off voltage which simulates the operating conditions in a color receiver. The negative bias is then removed and a zero bias emission test is performed with quality read directly on a meter. This test checks a tube at the two extremes of its operating conditions (maximum and minimum emission).

Grid-cathode leakage is measured by means of a sensitive microammeter. This is done because very small grid currents (more than about 10 μA) may be sufficient to cause trouble; it was felt that neon lamp indicators were insufficiently accurate and stable to make such sensitive measurements. A neon lamp indicator is used, however, to detect heat-cathode leakage.

Rejuvenation is accomplished by a momentary application of a high-energy



potential to burn out particle shorts. There are three stages of rejuvenation available.

The CRT-100 comes complete with a portable carrying case and all necessary sockets and cables. It is available at electronics distributors for $89.50. ▲

Ballantine Model 353 Digital Voltmeter

For a copy of manufacturer's brochure, circle No. 155 *on Reader Service Card.*

A NEW all-solid-state d.c. digital voltmeter that will sell for just under $500 has been announced by *Ballantine Laboratories.* This would not be outstanding except that the accuracy is ±0.02% of reading or ±0.01% of full scale and the instrument has four-digit readout with overranging to five digits. In addition, the last place may be interpolated, thus providing, in effect, five digits with overrange to six.

The primary application of the meter is to replace the multi-knob manual-balance voltmeter that takes so much time to use. A four- or five-digit manual-balance instrument may take as many as eight or nine operations in order to obtain the answer whereas this instrument takes only two.

The instrument is an electromechanical device in which the voltage to be measured is compared to the voltage developed across a potentiometer in the reference circuit. A motor drives the movable arm of the potentiometer and

a four-digit counter until the voltage to be measured is equal to that from the potentiometer. The potentiometer is wound linearly; hence, any fraction of the potentiometer voltage will correspond to the same fraction of full range on the counter.

Model 353 has been designed to make accurate d.c. voltage measurements from 0 to ±1000 volts (in five ranges) with only two manual motions as follows: (1) Set mode switch to "Normal" and note voltage. (2) Set mode switch to the position of the first digit of the voltage just read. The instrument will then read out the voltage to four digits, with overrange to five, and, in addition, one more digit may be obtained by interpolation. The instrument has a constant input resistance of 10 megohms for all ranges and modes. The high accuracy of the instrument is due to the submerging of inherent errors so that they become a tiny part of the whole measurement.

Some of the design features that help speed up measurements and reduce personnel errors are: use of an automatic display of "mV" for millivolts or "V" for volts with the decimal point located automatically; a red light to indicate overrange or wrong polarity; large, well-lighted digits; provision for a foot-operated switch for a "read" or "hold" function in addition to a hand-operated toggle switch on the front panel.

The small size of the unit (7.8″ wide x 6.1″ high x 10.2″ deep) means that it uses little of the valuable bench or shelf space around an operator. ▲

"Take it easy, Chum, or I'll let you rust!"

ELECTRONIC SPEECHMAKER

A COMBINATION of computer and electronic techniques is now enabling hundreds of stockbrokers in the New York metropolitan area to pick up their office phones, even simultaneously, dial a digital code, and receive the latest stock quotations from the American Stock Exchange in the form of an electronically synthesized human voice, all without uttering a single verbal request for the information.

The basic Speechmaker, built by the *Cognitronics Corp.* and shown in Fig. 1, consists of a $7\frac{7}{8}$-inch diameter, photographic film audio memory drum having a total of 64 tracks (63 audio and one for timing). The audio tracks, similar to those used in motion-picture systems, are composed of 26 tracks each containing one spoken letter of the alphabet, with the remainder of the tracks containing the individual spoken numbers from zero to nine, all necessary fractions, and a selection of key words (bid, asked, open, closed, etc.), as used in stock transactions.

A light source and an aperture provide a narrow light beam that is directed through the variable-density audio tracks, where the beam is modulated by each track and detected by a photocell. The outputs of the photocells are amplified for application to the telephone line.

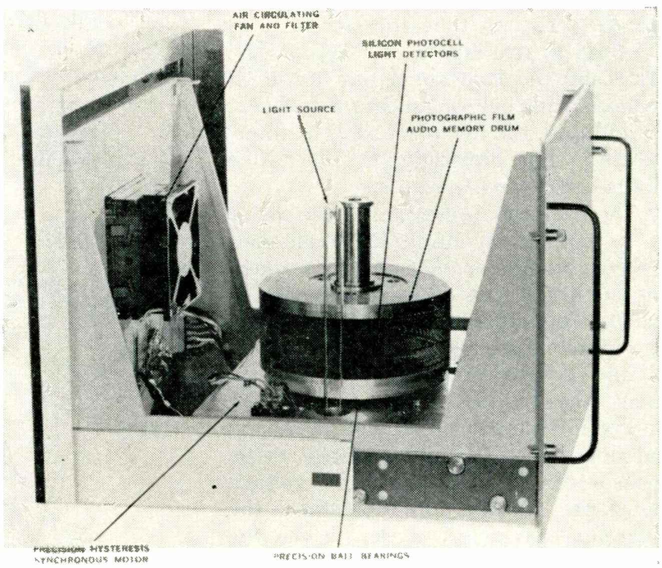
As the film drum rotates about the photocells at 1.6 revolutions per second, the individual letters, words, numbers, and fractions are extracted at the rate of 400 milliseconds per word. This speed maintains a high degree of voice fidelity in the completed phrases.

With the proper selection of track sequence, it is possible to create a synthesized vocal response that will cover any combination of words and numbers usually found on a stock ticker.

The computer system associated with the Speechmaker is arranged so that when a stockbroker dials the digits for a particular stock, an electronic selection circuit chooses the appropriate audio tracks and arranges them in the proper sequence (such as found on a stock ticker). The computer stores all numerical information on a magnetic drum that is continuously updated with the latest trading information.

The over-all system can handle 1200 inquiries a minute, up to 72,000 an hour, during the average business day. ▲

Fig. 1. As the drum rotates, the variable-density tracks modulate the light beams passing to the individual photocells.



LASERS ARE NOW BIG BUSINESS

LASERS—long referred to as an R&D "adventure"—actually accounted for over $97 million worth of business during 1965. Surprisingly, 41 percent of this was direct manufacturing activity. This significant finding, along with many other pertinent facts about the laser market was revealed recently by Patrick J. McGovern, president of the *International Data Corporation.*

According to Mr. McGovern, the size and distribution of the laser market, have for the first time, been established by a detailed market study. The basis of the study was a comprehensive survey of the 1000 organizations both in the U.S. and abroad, known, or thought to be involved in laser activities. A few of the more salient facts are:

At least 367 organizations are doing laser and/or laser-related work. Of these, 257 are industrial companies, 75 are non-profit concerns (universities, institutes, foundations, hospitals, museums, and the like), and 35 are government civilian and military agencies.

A breakdown of the 257 industrial companies according to primary activity shows that 151 are engaged more extensively in the manufacturing area and 95 in R&D, 9 are almost exclusively applications oriented, and 2 have made a business of providing consultation.

Total laser expenditure by the 367 organizations for 1965 was $97.1 million. Of this amount, $40 million (41.2%) was spent in the manufacturing and sales area, $42.1 million (43.3%) on R&D, $13.1 million (13.5%) on applications studies, and $1.9 million (2%) on consultation services.

Total amount spent by manufacturing oriented companies was $51.9 million (53.4%), by R&D oriented companies $21.1 million (21.7%), by application oriented companies $1.3 million (1.3%), by consultation oriented companies $150,000 (0.2%), by non-profit organizations $12.4 million (12.8%), and by government civilian and military agencies $10.3 million (10.6%).

The study report also includes the names, contact data, and a description of the activity of all 367 organizations engaged in laser work, product and R&D area listings for ready reference, listing of the prices of many laser and laser-related products, a tabulation of the marketing information provided by respondents to the survey questionnaire, and a description of user need.

Copies of "Laser Marketers' and Buyers Guide," at a cost of $8, are available from *International Data Corporation,* 355 Walnut Street, Newtonville, Mass. 02160. ▲

Varactor Diode Applications

(Continued from page 46)

with over 90% efficiency and 50% efficient octuplers are readily achieved and require no power except the input signal. Any order harmonic may be produced by proper filtering. By allowing certain other harmonics to flow and then multiply each other, efficiencies may be markedly increased.

The present practical limitations of this technique are about 25 watts of r.f. output at 1 GHz and 2.5 watts at 10 GHz. Useful harmonic power may be obtained at 100 GHz in special circuits.

Fig. 8 is a typical circuit. It is a 1-GHz, 10-watt transmitter driven from a 45-watt, 83-MHz source. This gives a 22% efficiency after a multiplication of twelve. The three varactors have a total cost of around $125. This is considerably more economical than any other present solid-state technique. Note that no d.c. power is required by the circuit as the varactors derive a self-bias from the r.f. input. The size, power, and reliability advantage over tube circuits is obvious.

This type of circuit finds use in v.h.f. and u.h.f. solid-state transmitters and signal sources. A second type of circuit uses higher order multiplication to allow a low-frequency (25 to 50 MHz) crystal to produce a stable reference microwave frequency, perhaps at 10 or 24 GHz. This is often used to phase-lock klystrons, backward-wave oscillators, and other tubes, producing substantial, precisely controlled microwave power.

A mutation of the multiplier produces an interesting circuit. Suppose we ignore the second harmonic power and look at the *input* to the multiplier. There is a sharp, well-defined threshold below which a varactor multiplier will not operate. Above this threshold, the input voltage remains constant, *independent of the input power*. This is because all power above the threshold is immediately converted into the second harmonic. This results in an effective microwave limiter with over 20 dB of dynamic range. Fig. 9 gives details. By using high "Q" circuits (usually cavities), the limiter's output is essentially flat.

Parametric amplifiers have purposely been saved for last. To attempt to cover these amplifiers in a few lines would be, to say the least, a gross oversimplification. Interested readers are urged to look up "Semiconductor Diode Parametric Amplifiers" by Blackwell & Kotzebue, published by *Prentice Hall*, Englewood Cliffs, New Jersey (1961) for details. Suffice it to say that parametric amplification is a means of using a readily available signal to reinforce a much weaker one. This is accomplished by interaction of the two signals in the time-varying reactance of a varactor diode or two. One form of paramp uses a local "pump" signal of precisely twice the input signal frequency to increase the amplitude of the input. This is in exactly the same manner as a child on a swing will "pump" the swing twice each cycle to increase its amplitude.

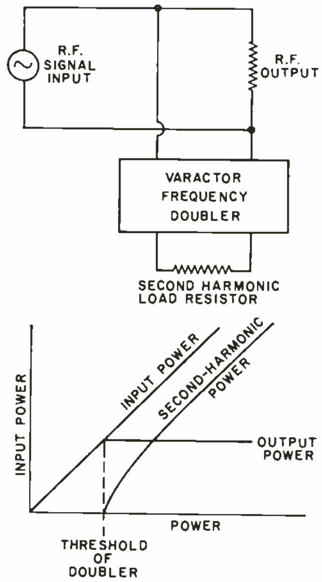


Fig. 9. R.F. limiting with varactor circuit.

The big advantage is low noise. Paramps have room-temperature noise figures that are well below any conventional devices; a one- or two-decibel noise figure is typical. This is possible because the varactor is a reactance and not a resistance. A pure reactance produces no thermal noise, but all resistances, biasing networks, transistors, and tubes do. This is of utmost importance when dealing with weak radar returns, miniscule satellite TV signals, radio astronomy, and many other applications where the last ounce of signal must be obtained without further degrading an already low signal-to-noise ratio.

Varactor paramps are useful from 200 MHz to the outer reaches of the extreme microwaves. They are now the only practical means of forming extremely low noise amplifiers at reasonable temperatures over this entire frequency range. ▲

"Please, Doc, don't tell me I'm color blind! I just paid $800 for a color-TV set!"

AUDIO PEAK FACTOR

PEAK factor, also called "form factor" or "peak allowance," means the number that would be added to the program volume in vu in order to determine a dBm level which would produce the same *peak* power. Although erroneous, peak factor is stated in dB.

Let us take an example of how to determine peak factor. Assume that a vu meter and its attenuator are connected across a line carrying program material and that the meter pointer deflects as high as −2 on the vu scale. The attenuator is set to +30 vu. Volume level of the program line is +28 vu. Now let us also connect an oscilloscope across the line and mark on its face the observed program peaks. Next, remove the program from the line and substitute an audio sine-wave generator. Bring up the level of the generator until the peaks of the sine waves come up to the marks previously made on the scope face. Vary the attenuator setting until the vu meter again indicates near "0" on its scale. If, for example, the meter indicates −1 and the attenuator reads +40, the generator is producing +39 dBm (dBm, not vu, because of the steady-state sine wave). The number 11 must be added to the previously obtained 28 to get 39, so peak factor is 11 dB.

This factor of 11 dB is fairly typical. It will be seen that peak factor depends upon several variables such as program material, microphone technique, studio acoustics, etc. Bland music usually shows a factor of about 8 dB. Medium-miked speech shows 10 dB or so. Percussive music in a dead studio will show over 20 dB. A close-miked xylophone reaches 40 dB. Generally, factors over 20 dB can be observed only with unusual program content in a system (including microphone) with extreme bandwidth.

It is fortunate that the human ear does not object to occasional clipping of program peaks, or else amplifiers would have to be much larger for many applications. AM radio stations and networks allow only about 10 dB factor, and peak clipping occurs often. If the amplifiers clip cleanly, with blocking or base-line displacement, the sound is acceptable. Magnetic tape recorders, even the best of studio machines, saturate on peaks quite regularly. The peaks cannot be said to be "clipped" on magnetic recorders, as the overload characteristic is "soft"; however, peak distortion is severe. For sound-reinforcement purposes, reproduction is generally satisfactory if the volume of the amplifier (in vu) is kept at least 10 dB below the amplifier maximum rating (in dBm).

This information appeared in the first issue of *Langevin* Engineering Letter. ▲

Sampling Oscilloscopes

(*Continued from page* 49)

and the rise time displayed is 60 psec.

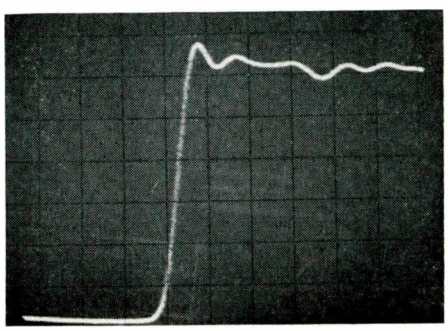
The most important specification of a sampling scope is the rise-time characteristic which determines the minimum pulse duration that the instrument can handle. Since the rise time can be no greater than the sample time, the width of the sampling pulse must be as short as possible.

A useful parameter is the sampling efficiency (α) which is a measure of the sampling response of the system and which is defined as $\alpha(\text{dB}) = E_{xample}/\Delta E_{input}$. By observing the sampling efficiency while changing the frequency of the input signal, it is possible to determine the bandwidth of the scope.

Another significant parameter is the loop gain, which refers to the product of the sampling efficiency and the amplifier gain in the sampling circuit. Normally, the loop gain is optimized to unity so that each sample is accurately displayed, independent of sampling density. However, in cases where the signal has random noise, reduced loop gain acts to minimize the noise carried by the signal. For this reason, sampling scopes are provided with a smoothing capability which selects the desired loop gain by altering either the sampling efficiency or amplifier gain. When the loop gain is adjusted to other than unity, however, the measured rise time of the input signal will vary with changes in sampling density. The resultant error is insignificant at high sampling densities.

Sampling density refers to the number of samples or dots taken per unit equivalent time. If, for example, the sweep rate is 5 nsec per division when taking 200 samples per division, the sampling density is then 40 samples per nsec equivalent time. For normal viewing, it is desirable to have as many dots on the trace as possible for maximum resolution. At low pulse repetition rates, however, it is necessary to reduce the scan time so that the beam recurrence rate is high enough to prevent trace flicker. For this reason, a sampling-density control is employed to vary the amplitude of each step in the staircase circuit and provide a continuous selection from 50 to 1000 samples per trace. Thus, an optimum balance between resolution and flicker can be easily achieved.

Fig. 8. Typical step response shows a 60-picosecond rise time with clarity.



The ability of modern sampling oscilloscopes to process signal information in equivalent and real time represents an important advance in microwave measurement. While the versatility of the sampling technique has not yet been fully exploited, at the present state-of-the-art the method offers unique solutions to many high-speed pulse problems. ▲

Microphones for P.A.

(*Continued from page* 52)

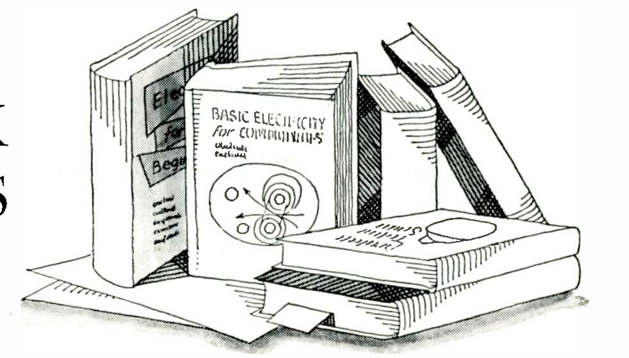
of the rest of the public-address system) is the use of super-directional microphones evenly spaced across the stage at footlight level. Remember, cone angle is 80 degrees so, ideally, the microphone should be angled upward at least 40 degrees. Properly spaced, the pickup can be very uniform and on mike.

In most applications, the undirectional microphone is easiest to use effectively and the omnidirectional unit the most difficult. Special situations, however, require the use of the omnidirectional. Where hand-held microphones are necessary for stage or interview work, in particular, the advantages of the cardioid are usually defeated because of position and here the omnidirectional designed especially for hand-held close-up use comes into its own. Because the sound source is very close to the microphone, the level of sound from the speakers and the level of extraneous sounds in the room are low in comparison. Hence, although omnidirectional, such a unit can be used in public address without undue concern for feedback.

In a few rare instances, such as with certain sporting events, the situation requires placement of microphones very close to the system speakers operating at high level. Ordinary microphones, and even the finest of the highly directional units described, may not be satisfactory. In such event, a differential (noise-canceling) microphone may be the answer. A true noise-canceling type must be worked very closely—in fact, with the face touching the unit. Properly used, however, the noise-canceling type can be extremely effective in preventing feedback as well as for paging use in high-noise areas.

In summary then, useful guidelines have been presented and fundamental concepts enunciated by means of which requirements can be defined. A logical sequence of consideration coupled with imagination will usually reduce the problems to a level that can be readily handled successfully. ▲

BOOK REVIEWS



"MAGNETIC TAPE RECORDING" by Dr. Skipworth W. Athey. Published by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. 326 pages. Price $1.25.

NASA has announced the release of a comprehensive survey of techniques and developments in magnetic tape recording, written by a former director of *Ampex Corp.'s* research laboratory.

The book includes chapters on recording technology ranging from the more elaborate ground-based systems to those used on satellites in space. It covers work done in NASA centers and commercial concerns in recent years and includes an appendix of standard references in the tape recording field.

* * *

"JOHN DIEBOLD: BREAKING THE CONFINES OF THE POSSIBLE" by Wilbur Cross. Published by *James H. Heineman, Inc.*, 60 East 42nd Street, New York, N.Y. 10017. 293 pages. Price $6.50.

This is the fourth volume in this publisher's series "The Future Makers" and the first to deal with a technical subject through the life of one of its "prophets"—John Diebold—who has been dubbed the "high priest of automation."

By using the life of John Diebold as a springboard, the book points out how automation is far more than the application of computers and electronic devices and more than a technological development. Automation is explained as a concept and as a philosophy which must be understood if one wishes to appreciate and understand how it affects our social, intellectual, moral, and spiritual values.

The book covers the impact of automation on the tools and concepts of education, job re-education, the use of leisure time, instant "newspapers" in the home through television, robot housekeepers, medical diagnoses, and military defense, among other subjects.

* * *

"MOST-OFTEN-NEEDED 1966 TELEVISION SERVICING INFORMATION" compiled by M. N. Beitman. Published by *Supreme Publications*, 1760 Balsam Road, Highland Park, Ill. 192 pages. Price $3.00. Soft cover.

This is Volume 25 in this publisher's series of servicing information manuals and like the earlier volumes includes a schematic, alignment data, special service notes, and chassis views of 1966 models in the lines of such firms as *Admiral, Emerson, General Electric, Magnavox, Motorola, Philco, RCA Victor, Sears, Roebuck and Co., Sony, Sharp, Sylvania, Westinghouse,* and *Zenith.*

* * *

"BASIC ELECTRICITY FOR ELECTRONICS" by Robert G. Middleton & Milton Goldstein. Published by *Holt, Rinehart and Winston, Inc.*, New York. 681 pages. Price $9.95.

This is a beginner's book for those who plan to make electronics their vocation or avocation. The text is divided into 23 chapters which range from a basic explanation of electronics and electricity, through the laws of voltage, current, and power to a discussion of vacuum tubes and semiconductors, filters, and network theorems.

The authors' style is informal and, where possible, they have avoided the mathematical approach to the subject under discussion. Fifteen appendices have been included to provide a number of the reference and working tools needed by the student. These include color-code tables, log tables, tables of square roots and squares, etc.

For those wishing to study electronics on their own, this book would be entirely suitable. There are questions and problems appended to each chapter so the student can check his understanding (answers to both the questions and problems are provided). The book would serve equally well as an elementary text for junior colleges, technical institutes, and other beginning-level courses.

* * *

"ELECTRONIC DRAFTING AND DESIGN" by Nicholas M. Raskhodoff. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 584 pages. Price $15.95.

This lavishly illustrated, up-to-date volume presents a broad coverage of components, materials, graphic symbols, standards, industrial diagrams, wiring harnesses, printed circuits, reference designations, and electronic equipment design. Assuming that the user has a knowledge of conventional drawing practices, this volume presents a comprehensive view of military electronic equipment specifications and design, latest information on such subjects as flexible printed cables, modular packaging, adhesive bonding, solid-state component packaging, and multilayer printed wiring boards. In addition, there are over 50 tables containing information on mechanical fasteners, copper-wire dimensions, abbreviations of wire colors, abbreviations of drafting terms, and rivet dimensions.

For those in drafting who wish to up-grade their skills to embrace the fast-moving and lucrative electronic drafting field, this book should do the trick. It would also be of help to electronic circuit designers to enable them to specify correctly what they require in the way of circuit drawings.

* * *

"BOOLEAN ALGEBRA" prepared under the direction of Oswald Wolf. John Buchholz, John Spiech, and Henry Shleuder, *Federal Electric Corporation.* Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 246 pages. Price $11.00.

This is a programmed manual designed to be used by the student studying on his own. The material is presented in such a way that it is directly applicable to the field of computer logic design. The text features a linear programmed format and provides every element required to acquire complete mastery of the subject, using as illustrative bases, switching circuits, logical equations, and word problems to amplify the basic discussions.

The mathematical discussions throughout the text are applied to the key factor in the field—computer circuitry—the formal and informal methods which allow the selection of the simpler of two circuits.

* * *

"BASIC MICROWAVES" by Bernard Berkowitz. Published by *Hayden Book Company, Inc.*, New York. 163 pages. Price $3.95. Soft cover.

Here, at last, is a truly "basic" text on microwaves—one that doesn't assume that the student is familiar with calculus, the theory of transmission lines, or with Maxwell's equations. The author begins his discussion with the familiar wave phenomena and carries on from there. The six chapters progress naturally from a discussion of waves in free space, waves interacting with matter, antenna theory, types of antennas, and transmission lines to microwave components.

The exposition is informal and the text material is lavishly dotted with sketches, line drawings, tables, charts, photographs, and graphs. Each chapter concludes with a summary and a group of questions regarding the material covered in the chapter. A glossary of symbols used in the text is included. ▲

Selecting P.A. Amplifier

(*Continued from page 42*)

changed most easily by using the master volume control—which changes the levels of all input signals simultaneously. This control does not disturb the relative settings of the individual input controls.

9. Mounting and Portability

Most packaged p.a. amplifiers are furnished complete with protective enclosures which are suitable for table or shelf mounting. When the amplifier is to be operated with a record player, tuner, and/or tape recorder in a fixed installation, the greatest amount of protection will be provided by installing these components in a cabinet rack, which is available in different heights. To expedite assembly in a cabinet rack, many amplifier manufacturers sell rack panels which are pre-cut and screened to permit easy indentification of all controls. After the rack panel has been attached to the amplifier (a relatively simple job), the complete assembly is then inserted in the cabinet and bolted. Panel widths are a standard 19″; heights vary from 3½″ to 8¾″.

Much more frequently a need exists for carrying the amplifier and associated components from place to place. To facilitate handling with minimum damage to the equipment, manufacturers market carrying cases which can hold, in addition to the amplifier, 1 or 2 12″ loudspeakers with cables, a microphone with its cable, and a record player. Complete portable systems of this kind can be easily transported by one man and quickly set up at the job site. Since some amplifiers are too large to fit into any case, the carrying case and amplifier dimensions should be checked for compatibility before the amplifier is purchased.

Also available is a professional utility carrying case on rubber casters in which can be neatly stored virtually a complete sound system—except for the speakers. This case holds an amplifier, two floor-mounting adjustable microphone stands and bases, several microphones, and a very considerable amount of associated cables. Its use greatly reduces the confusion and labor connected with the set-up of most portable sound systems and helps to create an atmosphere of professionalism and competence.

Wall-mounting kits ingeniously solve the sometimes perplexing question of where to locate the amplifier when a table or shelf is not available. These sheet-metal kits attach without difficulty to a wall; hinged arms, to which the amplifier is easily secured, swing up to hold it flat against the wall when not in use. When lowered for operation, the amplifier is secured at a convenient angle.

10. Accessories

The number of accessories which are available for packaged p.a. amplifiers is too large to permit full coverage in this article. But since they can increase the usefulness of an amplifier—usually at a very nominal cost—it is important that the sound-system installer have some knowledge of what they are and what they can accomplish.

As a general rule, higher priced amplifiers provide for the addition of the greatest number of accessories. Economy-priced models, however, are usually designed to accept only the most important of these accessories—some of which are described below.

a. Phono Top. This consists of a 3- or 4-speed phono motor, turntable, and tonearm mounted on a small chassis which is easily attached to the amplifier's enclosure. Most 117-volt a.c. amplifiers, as well as some 12-volt d.c. mobile models, can be equipped with these useful phono tops.

b. Plug-in Microphone Transformers. Separate transformers are offered for microphones whose impedances are 50, 500, or 150-250 ohms. The latter impedance is by far the most widely used in p.a. work.

c. Carrying Cases.
d. Wall-Mounting Kit.
e. Rack-Panel Kits.
f. Remote Volume Controller.
g. Microphone Precedence.
h. Monitor Panel.
i. Limiter.

j. Locking Plates. To prevent unauthorized hands from tampering with amplifier controls which have been carefully adjusted, manufacturers offer a protective plate which may be secured over the front panel and locked with a key. The controls cannot be reached until authorized personnel remove the plate with a key. This accessory is important for multi-microphone installations in a church, theater, or auditorium where controls must be carefully pre-set during rehearsals or preliminary test periods. Incidentally, some manufacturers provide adjustable indicators or pointers for the various level controls to show their proper settings, once these have been determined by the operator.

11. Cost

In selecting an amplifier for a sound system, cost is not as important a factor as it might seem at first glance. Usually the difference in price between the least expensive amplifier which will do the job and a much higher quality unit is relatively small when considered in relation to the over-all outlay for the complete sound system. A few manufacturers offer deluxe as well as economy lines. In some instances, there is no sacrifice of reliability in the economy line, but the features are more limited and the over-all performance somewhat below that of the deluxe line. Careful examination of the catalogue data will enable the purchaser to make intelligent comparisons to determine whether the lower priced unit will be adequate. Obviously, an amplifier should be selected for its ability to meet a certain set of requirements. To purchase an amplifier with capabilities that are considerably above the requirements of a particular job is certainly uneconomical.

Careful consideration should also be given to the quality of the loudspeakers and microphones with which it will be used. All too often, the purchaser overlooks the interrelationship of the components and installs a sound system in which only one component of poor quality establishes an over-all level of poor quality for the entire system. No improvement in sound quality will result from installing a high-priced amplifier with low-quality loudspeakers and microphones. On the other hand, if these are high-quality components designed with wide frequency response capabilities, it makes sense to purchase a comparable amplifier with a good power response curve. ▲

Chroma Demodulation

(*Continued from page 37*)

that a color test signal be available because in the absence of a color sync burst there will be no output from the "injection-locked" oscillator of the CTC-19. The test signal burst frequency must be very close to the correct value or else the alignment made with the color bar generator will not be right when a color-TV broadcast is received. One of the advantages of the CTC-19 circuit is easier alignment and simpler tint control operation.

The CTC-19 color sync circuit can be considered more reliable since it contains fewer tubes and other parts which can fail.

Similar comparisons can be made between the two color-killer circuits. Here, the only real difference is that the CTC-19 omits the phase detector and depends on the output of the crystal ringing circuit to "know" whether a color or monochrome broadcast is being received. There is no difference in the adjustment or in the operation of the killer amplifier and bias circuit.

As to performance under interference and various noise conditions, the CTC-17 type of circuit has been proven for at least five years, while the field experience with the new CTC-19 is still insufficient to form a judgment. According to laboratory tests certainly the CTC-19 color sync circuit should perform quite well. ▲

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SOLID-STATE HOME TEMPERATURE CONTROLLER

By JAMES A. PALMER
Sperry Rand Corp., Univac Div.

Design of a thermistor-bridge system that senses both outdoor and indoor air temperatures and matches indoor temperature to predetermined "comfort curve" within one-tenth of a degree.

THE object of any home heating system is not simply to keep the indoor temperature constant, but rather to keep the people inside the home comfortable during the winter, irrespective of the temperature outdoors. There are many factors that contribute to a person's feeling of warmth in a heated home, and yet only one of these factors is considered by the traditional simple thermostat—the indoor air temperature. This article describes a home temperature controller that senses both indoor and outdoor air temperature and essentially matches the indoor temperature to a predetermined "comfort curve."

Of the factors that determine a person's feeling of warmth or cold, ambient air temperature is undoubtedly the most important. Another factor that is nearly as important, however, is the temperature of the objects surrounding the person. Since all objects that are not at absolute zero temperature radiate heat, a person in a home receives heat from other people, furniture, floors, walls, ceilings, and any other object near him. The feeling of comfort is determined by the difference between the heat radiated from the body and the heat received by the body from surrounding objects. If the temperature of these objects remains constant, a person near them remains comfortable as long as the indoor air temperature is kept constant at some level near 70°F.

Thermostat Limitations

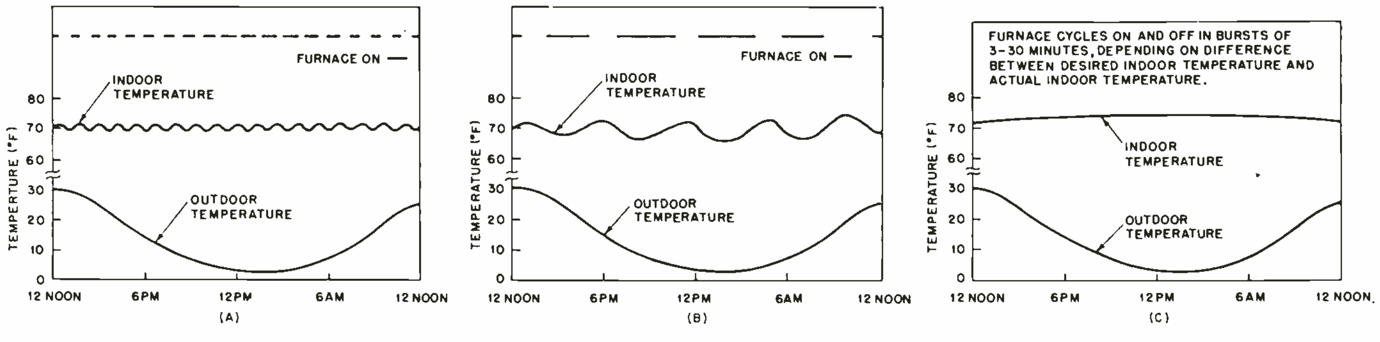
If all the objects in a home remain at a constant temperature (by some miracle) so that all the heating system has to do is keep the indoor temperature constant, a good simple thermostat could, at best, keep us somewhat comfortable only some of the time (see Fig. 1A). The reason is threefold.

First, even good thermostats can have a dead zone of about two degrees. For example, a typical thermostat set at 70° turns on at about 69° and off at about 71°. This causes moments of slight discomfort at the peaks of the temperature excursions. (*Some thermostats incorporate a built-in "heat-anticipator" feature in the form of a low-value resistor whose heat opens the thermostat contacts before the room temperature rises. Such thermostats have a very low differential; or difference between cut-in and cut-out temperatures. The differential of such thermostats is commonly a fraction of a degree.—Editor*)

Second, all heating systems have a certain delay between the time the thermostat turns on and the time the temperature stops decreasing (and between the time the thermostat turns off and the time the temperature stops increasing). This delay can vary from a minute or two in a good forced-air system to an hour or more in some radiant-slab systems. The result is overshoot, in both directions, which adds to the two-degree spread caused by the thermostat characteristics. Fig. 1B shows the extreme overshoot present in a system with a long thermal time constant.

Third, the thermostat senses only the indoor temperature, allowing the outdoor air to severely change its rate of extraction of heat from the structural members of the home before the indoor temperature changes and the furnace is

Fig. 1. Typical characteristics of (A) short time constant heating system controlled by a simple thermostat, (B) long time constant heating system controlled by simple thermostat, and (C) heating system controlled by circuit described.



turned on or off to compensate. Consequently, the overshoot gets worse as the outdoor temperature changes rapidly. It is not uncommon for the air temperature of a radiant-slab-heated home to change as much as five or six degrees during an abrupt change in outdoor temperature.

Another disadvantage of the simple thermostat is that there is usually only one per level in a home. Thus, the temperature at one centrally located point determines the heat supplied to the entire level. For example, if the thermostat for the ground level is in the living room, the heat supplied to the whole ground level is a function of the living-room temperature, and if a number of people in the living room cause its temperature to rise, the thermostat might turn off and stop the heat flow to the other ground-level rooms.

In short, the simple thermostat is a somewhat marginal control mechanism, and it becomes increasingly inadequate as the thermal time constant of a home heating system gets longer.

Compounding the situation is the decrease in the temperature of the windows and outside walls as the outdoor temperature drops. When they get colder, they radiate less heat, causing a person near them to feel chilly even though the temperature around him has not changed. This phenomenon has been termed the cold-wall effect, and it can be compensated by increasing the temperature of the indoor air as the walls get colder.

An adequate home temperature controller must therefore (1) have a negligible dead zone, (2) minimize the effects of the system's thermal time constant, (3) sense the outdoor temperature to "anticipate" changes in heat demand before the indoor temperature changes, (4) sense the indoor temperature at a number of separate points on each level (or in each separately supplied zone), and (5) scale the indoor temperature upwards as the outdoor temperature decreases to compensate for the cold-wall effect.

The controller described in this article holds the indoor temperature to within ±0.1 degree of a predetermined curve, as shown in Fig. 1C. Since the controller compensates for the thermal time constant of the system, these particular performance characteristics can be achieved with virtually any type of home or heating system.

Thermistor-Bridge System

The controller is shown in block form in Fig. 2. The heart of the circuit is the thermistor sensing bridge. This bridge determines the curve that the indoor temperature must follow as a function of outdoor temperature. The bridge thermistors are located both indoors and out, and the bridge balances only when the proper temperature relationship exists. When the bridge is out of balance, it produces an error signal that is subsequently amplified and detected. If the unbalance is caused by the indoor temperature being too low, the phase of the error signal is such that the relay closes and turns on the furnace.

Because the bridge contains outdoor elements, changes in outdoor temperature can turn the furnace on or off before there is any measurable change in indoor temperature.

At the instant the furnace turns on, a separate electric heater (a resistor) supplies heat to one of the thermistors in the bridge through a relatively short time constant path. This causes the bridge to return to balance (and the furnace to turn off) before the indoor temperature actually rises to the balance point. During the following few minutes, either the furnace-supplied heat reaches the bridge and keeps it in balance, or the bridge cools off and unbalances, turning on the furnace again. The degree of bridge unbalance determines the length of time that the furnace stays on; the over-all effect is to eliminate upward overshoot of indoor temperature.

Two thermistors in the bridge are geographically separated in the home so that the indoor temperature is sensed as the average of the temperature in two different rooms.

The bridge-balance curve, illustrated in Fig. 3, indicates the degree to which the indoor temperature is scaled as a function of the outdoor temperature. At outdoor temperatures above −20°, the indoor temperature rises approximately one degree for every 15-degree drop in outdoor temperature.

The bridge is not designed to operate satisfactorily at outdoor temperatures below −20°. In areas where lower temperatures occur, a separate thermostat should be placed in series with the controller to prevent the indoor temperature from soaring to uncomfortably hot levels in bitter cold weather. The shape of the curve was chosen after much experimentation with different bridge configurations. A potentiometer is provided in the bridge in order to set the absolute indoor temperature exactly, however, its effect on the shape of the curve is negligible.

Circuit Operation

Fig. 4 shows the complete schematic diagram of the controller. The bridge is excited by three volts a.c. from one half of the secondary of *T1*. The temperature control, *R2*, determines the temperature at which indoor thermistors *TH4* and *TH5* balance the bridge.

Thermistors *TH2* and *TH3* are both mounted outdoors, but *TH2* is the element that actually senses the outdoor temperature. The temperature of *TH3* does not affect bridge balance; it determines the amount of unbalance caused by changes in the temperature of *TH2*. Without *TH3*, the bridge-balance curve is much flatter at higher outdoor temperatures and rises rapidly below 10°. Resistors *R3* and *R4* essentially center-tap *TH3* and must be closely matched to give the curve of Fig. 3.

Cycler thermistor *TH1* is thermally coupled to resistor R_c, which is heated by a.c. line voltage from the furnace circuits. It is the heat from R_c that makes *TH1* prematurely balance the bridge and turn off the furnace.

The bridge error signal is capacitively coupled to the input of the error amplifier. Capacitor *C3* bypasses any high-frequency noise (particularly r.f. from nearby radio stations) that may be picked up by the long, unshielded thermistor wires. Transistor *Q1* is operated with an unbypassed emitter resistor, which lowers its voltage amplification to about 8 but raises

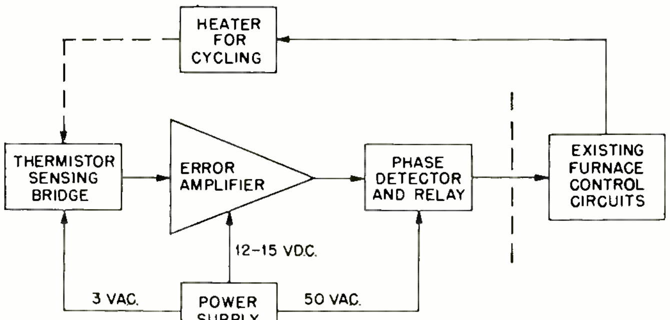
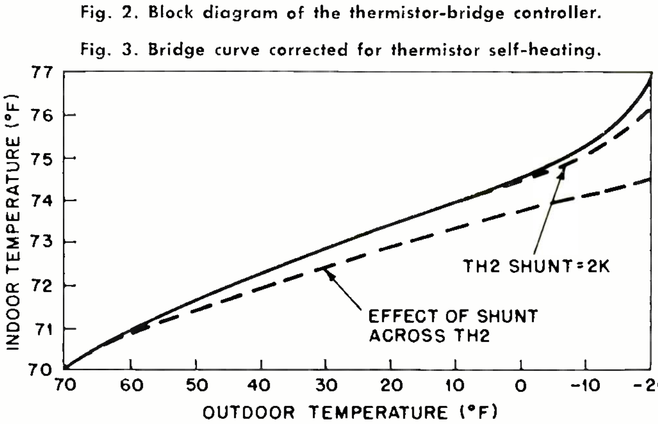


Fig. 2. Block diagram of the thermistor-bridge controller.

Fig. 3. Bridge curve corrected for thermistor self-heating.



its input impedance to prevent loading the bridge too heavily. Its output is applied to emitter follower $Q2$, which is direct-coupled to the base of transistor $Q3$. The bulk of the necessary voltage amplification is accomplished by transistor $Q3$.

Transistors $Q4$ and $Q5$ are cascaded emitter followers that drive the low and complex gate impedance of the SCR. The bias circuit of $Q4$ holds both transistors cut off except during the positive half cycles of the error signal. This keeps the gate terminal of the SCR at ground when no error signal is present and prevents any random firing. This gate circuit allows virtually any low-current SCR with the proper voltage rating to be used successfully.

The SCR, in combination with the relay in its anode circuit, forms the system's phase detector. The supply voltage applied to resistor $R21$ is half-wave rectified, but unfiltered, 60-Hz a.c., which forms the reference signal for phase detection. Each positive peak is approximately 72 volts in amplitude. The SCR can fire and energize the relay only when the error signal swings positive at the same instant that the reference signal swings positive. Diode $D1$ is placed in the circuit only to limit the peak negative voltage applied to the SCR anode. Resistors $R19$ and $R20$ and capacitors $C7$ and $C8$ are r.f. suppressors and should be mounted as close as possible to the silicon controlled rectifier.

The circuit of $R22$, $C11$, and $R23$ provides d.c. feedback to set the dead zone of the controller. When the relay energizes, the bias on $Q4$ is increased to a little more than one tenth of a volt. This essentially increases the error signal delivered to the SCR gate by the same amount, thus keeping the relay energized until the peak error voltage decreases by slightly more than that amount.

With the circuit values given, the controller's dead zone is approximately 0.006°F (indoors), which has proved to be near the minimum limit for stable operation. Smaller dead zones cause the system to click on and off rapidly when the indoor temperature is drifting around the turn-on level. Further improvements in stability can be achieved, with corresponding losses in sensitivity, by reducing the error amplifier's gain. Every 50% gain reduction results in halving the sensitivity and doubling the dead zone. There is considerable latitude in this matter, however, since even a 70% gain reduction leaves the dead zone at 0.02°, 100 times superior to that of the simple thermostat when it acts as controller.

The d.c. feedback also determines the controller's independence of line-voltage variations. The components shown permit stable operation during voltage depressions as great as 10%. (A prime cause of severe line dips is the starting load of a typical oil furnace.)

The power supply is designed to provide the voltages required at the lowest possible cost. Two 6.3-volt filament transformers are used, one of which must have a center-tapped secondary. One half of this secondary provides a "floating" source of excitation voltage for the bridge, as well as primary voltage for $T2$. Using the entire 6.3 volts for bridge excitation is not recommended, as this causes excessive self-heating of the indoor thermistors and changes the bridge characteristics.

With three volts on its primary (the 6.3-volt winding is used as the primary), $T2$ provides approximately 50 volts r.m.s. to $D1$ and to $R25$ which feeds the d.c. supply. Zener diode $D3$ is used to limit the maximum value of the d.c. to about 15 volts and is required because the voltage regulation of a supply of this type is a bit loose (to say the least) under varying load conditions.

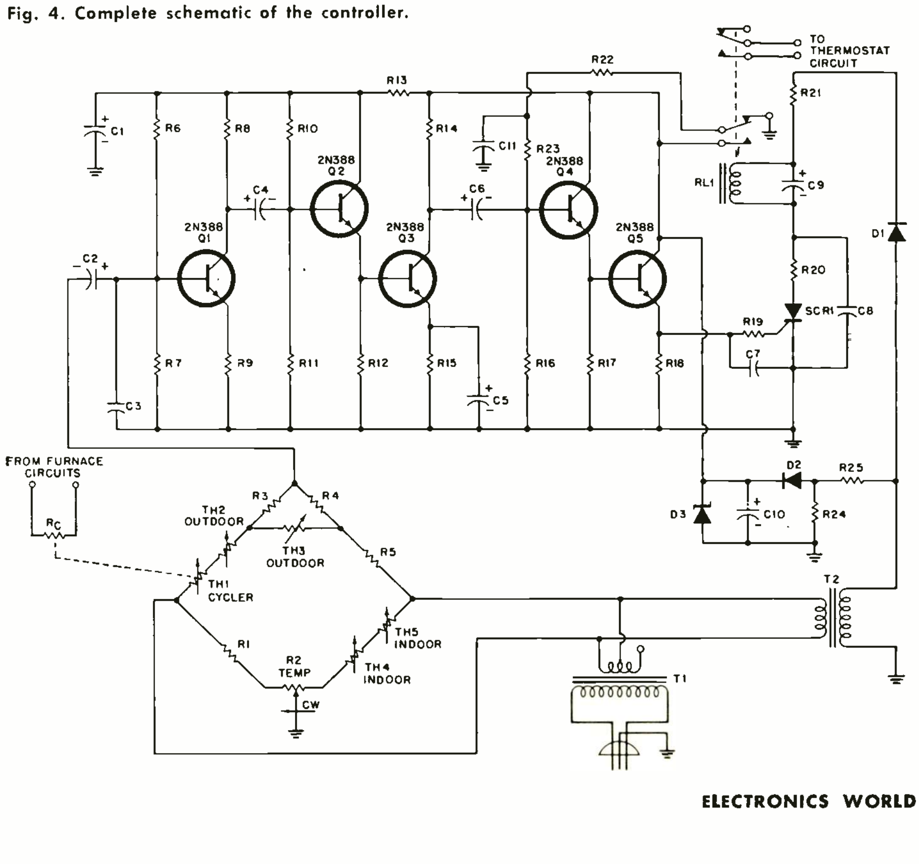
There are only a few subtleties which must be given special attention during construction of this unit. For the most part, no trouble should be encountered if good engineering practices are employed.

The temperature control, $R2$, can be mounted along with $TH4$ in an old thermostat case to form an attractive wall unit. The other indoor thermistor, $TH5$, should be mounted on an interior wall of some other room in the same heating zone. The outdoor thermistors, $TH2$ and $TH3$, should be sealed in a weatherproof case and mounted (preferably on the north side of the house) in a shady spot at least 12 inches from any heated wall. The author's are in a flat-black-painted baby food jar bolted to the underside of a wide eave. In no case should any of the thermistors be attached to heat sinks, as this can increase their response time to intolerable levels. Resistors $R3$ and $R4$ are relatively high in value and should be mounted on the amplifier chassis rather than outdoors with $TH3$ to reduce stray pickup in the long leads.

Most of the low-frequency stray pickup emanates from 60-Hz power lines, but it is largely the third harmonic of the

R1—47 ohm, ½ W res., ±5%
R2—10 ohm linear pot
R3,R4—5000 ohm, ½ W matched res., ±1%
R5—56 ohm, ½ W res., ±5%
R6,R10—180,000 ohm, ½ W res., ±10%
R7,R11—22,000 ohm, ½ W res., ±10%
R8,R14—6200 ohm, ½ W res. ±10%
R9—750 ohm, ½ W res., ±10%
R12,R16—56,000 ohm, ½ W res., ±10%
R13,R15—1000 ohm, ½ W res., ±10%
R17—47,000 ohm, ½ W res., ±10%
R18—10,000 ohm, ½ W res., ±10%
R19—300 ohm, ½ W res., ±10%
R20—12 ohm, ½ W res., ±10%
R21—470 ohm, ½ W res., ±10%
R22,R23—2.2 megohm, ½ W res., ±10%
R24—1250 ohm, ½ W res., ±10%
R25—1800 ohm, 2 W res., ±10%
Rc—Cycling resistor (see text)
C1—50 µF, 25 V elec. capacitor
C2,C4,C6—6.8 µF, 15 V elec. capacitor
C3—.02 µF, 100 V disc ceramic capacitor
C5—100 µF, 15 V elec. capacitor
C7,C8—.002 µF, 200 V disc ceramic capacitor
C9—20 µF, 150 V elec. capacitor
C10—500 µF, 25 V elec. capacitor
C11—.05 µF, 100 V paper capacitor
D1,D2—Silicon diode, 200 p.i.v., 200 mA
D3—Zener diode, 15 V, 400 mW (1N965 or equiv.)
RL1—D.p.d.t. relay, 10,000 ohm coil (Potter & Brumfield KCP11)
SCR1—Silicon controlled rect. (G-E C6B or equiv. 200 V, 0.6 A) See text.
T1—Filament trans., 6.3 V c.t. @ 1 A
T2—Filament trans., 6.3 V @ 1 A (connected as step-up trans.)
TH1,TH2,TH4,TH5—Thermistor, 25 ohm, −3.9%/°C (Fenwal MB13J1)
TH3—Thermistor, 500 ohm, −4.4%/°C (Fenwal LA25L2)
Q1,Q2,Q3,Q4,Q5—2N388

Fig. 4. Complete schematic of the controller.



power frequency and can't be "cancelled out" by slightly unbalancing the bridge. Consequently, twisted pairs are recommended for the long thermistor leads. The ultimate noise content of the error signal should be less than 0.2 volt peak at the emitter of $Q4$ for reliable operation. This level is easily attainable with a little care in thermistor wiring.

The unit should be bench-tested before either the relay or the cycler resistor is attached to the furnace circuit. During bench testing, the thermistors should all be at the same ambient temperature and the unit should be allowed to warm up for at least two minutes.

The only problem likely to occur is an over-all reversal of the desired action. The relay closes as the wiper of $R2$ is moved toward $TH4$ rather than toward $R1$. This can be remedied by reversing the leads to the primary of $T2$.

Sensitivity can be tested at the bench by first balancing the bridge with $R2$ while checking for a null at the base of $Q4$. The relay should then energize when you back away from the bench for a minute or two, removing your radiated body heat from $TH4$ and $TH5$. The relay should de-energize when you walk up near the thermistors and stand there for a few moments.

The controller is connected into the furnace control circuit by simply connecting the normally open contacts of $RL1$ in place of the former thermostat. If it is desired to retain the former thermostat as an upper-limit switch, connect the contacts of relay $RL1$ in series with it.

The cycler can be fabricated from any rigid vertical tube about 1½ inches in diameter and 6 or 8 inches long. Mount the thermistor a few inches *above* R_c. Since the characteristics of the cycler must be tailored to the thermal time constant of the entire heating system, the value of R_c can only be found experimentally.

First, with furnace power off, connect the cycler's resistor leads to the line-voltage point that actually causes heat to be supplied to the home. This could be the fan motor in some forced-air systems or the circulator motor in some forced-hot-water systems.

Next, connect a 25,000-ohm, 10-watt rheostat in series with R_c. Start with a 5000-ohm, 5-watt resistor for R_c and, over a period of a few days, adjust the rheostat until a satisfactory cycle duration is achieved. (As a starting point, when the outdoor temperature is about 30° below the indoor temperature, a well-adjusted cycler should have 3 to 8 minutes on-time for a forced-air or baseboard-radiator system, and 12 to 20 minutes on-time for a radiant-slab system. This is usually accomplished with resistor dissipations of 5 watts to as little as 0.1 watt.)

When a satisfactory cycle duration is achieved, measure the voltage across R_c with the furnace operating and calculate the amount of power it is dissipating. Then select a resistor that dissipates an equal amount of power with 117 volts across it and make a permanent installation without the rheostat.

It may be more convenient to connect R_c to the 24-volt a.c. furnace-control voltage. In such cases, a similar procedure can be used with lower valued resistors.

The bridge curve shown in Fig. 3 may be too steep for some well-insulated homes. The indoor temperature can be made less dependent upon outdoor temperature by shunting $TH2$ with a fixed resistor. A shunt value of 2000 ohms causes a change in the curve only below approximately zero degrees, while values between 200 and 1000 ohms affect virtually the entire curve. Shunt values below 200 ohms flatten the curve too severely and are not recommended.

The basic idea for this controller is by no means original. A unit similar in concept was described by Harry W. Lawson in the November, 1953 issue of this publication (then called *Radio & Television News*). Today's solid-state unit is a natural evolutionary outcome of earlier devices, with significant improvements made in stability, reliability, and bridge characteristics. ▲

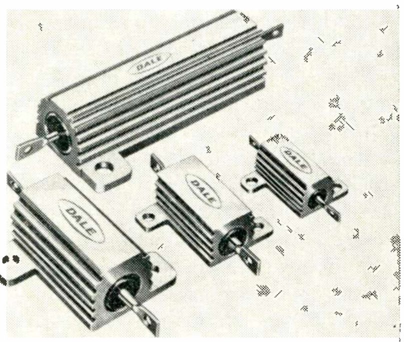
NEW PRODUCTS & LITERATURE

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

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

HIGH-RELIABILITY WIREWOUNDS

A new series of high-reliability housed power wirewound resistors is being marketed as the ARH line. Made according to the specifications of MIL-R-39009 and MIL-R-18546D, the new ARH series includes four models rated at 5, 10, 15, and 30 watts. Resistance range is 0.1 ohm to



39,200 ohms. Tolerance is 1% and temperature coefficient is from 30 to 100 ppm, depending on resistance range.

The units use high-purity alumina cores molded inside a finned aluminum housing which screw mounts to the chassis, giving excellent shock and vibration protection. The units are especially suited for use in space applications where heat is transferred primarily by conduction and/or radiation. Dale

Circle No. 126 on Reader Service Card

MICROMINIATURE READOUTS

A sixteen-segment, incandescent light-bar arrangement which permits numeric, alphabetic, and symbol displays all within less space than a quarter-inch cube has been released as the "Alpha-Lite."

The new unit is a modular device, allowing for plug-in rows, vertical or horizontal. Hermetic versions of any combinations of letters and numbers are available. Encoders for all types of logic input will be available to mate with the "Alpha-Lite."

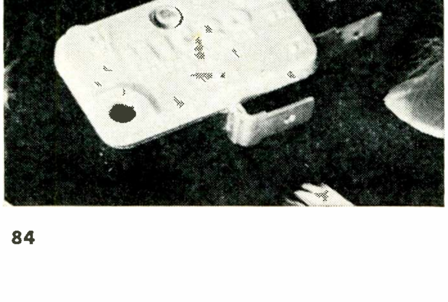
Brightness is controllable for various ambient light conditions by varying input voltages. Character height is 0.200", over-all height is 0.290", over-all width is 0.200", and depth is 0.200". Pinlites

Circle No. 127 on Reader Service Card

LOW-FORCE SWITCH

A new, low-force V3 switch, especially suited to applications in data-processing equipment, vending machines, appliances, coin-operated washers, and other devices where compact precision switches are needed, has been introduced as the V3-1100.

The new switch features small size, long mechanical life, and an operating force of less than 3 ounces. Also featured are quick-disconnect terminals for easy wiring, high-strength melamine plastic cases, and a choice of s.p.d.t., s.p.n.c., or s.p.n.o. circuits with high-quality silver contacts. The new switch carries UL and CSA ratings. The company will supply full specifications on request. Micro Switch



Circle No. 128 on Reader Service Card

LIGHT-EMITTING DIODES

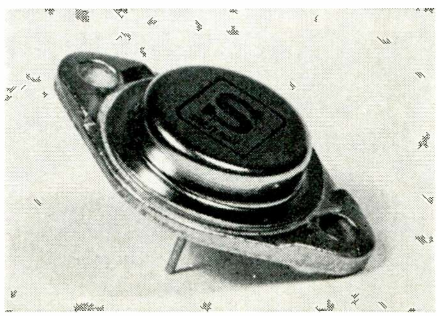
Light-emitting diodes, with wavelengths in the visible and infrared range have recently been introduced as the LED-7 and LED-8. Two gallium-phosphide diodes, in TO-46 header with transparent glass windows, will operate in a typical indicator light application. Pulsed at 100 milliamperes by a suitably biased, integrated circuit, the diodes will flash on for 2/10th of a second and off ½ second.

The red and green diodes have approximate wavelengths of 7000 and 5600 angstroms and exhibit excellent high monochromatic characteristics. Their short rise time to full emission rate and resistance to high in-rush current make them suitable for applications requiring a miniature visible light source in a miniature package. General Electric

Circle No. 129 on Reader Service Card

HIGH-VOLTAGE SILICONS

A new line of high-voltage silicon power transistors, series MHT 7201 through MHT 7205, is now available. These 10-ampere planar "n-p-n"



transistors feature V_{CEO} sustaining voltages from 200 V to 325 V. They are offered in the TO-3 package and have a frequency response of 50 MHz and a C_{OB} of 150 pF.

The new units are designed especially for use in high-voltage inverters and switching regulators, TV deflection circuits, as well as all line-voltage switching and amplifier applications. Solitron

Circle No. 130 on Reader Service Card

50,000-MILE IGNITION SYSTEM

An automotive ignition system which carries a 50,000-mile warranty has been introduced as the CD-65. This breakerless capacitor-discharge ignition system eliminates contact problems and rubbing block wear by eliminating the breaker points. In addition, pickup gap setting is not critical (gap changes of 0.020 inch will not affect timing). This eliminates the need for any wear adjustments for the life of the engine. Firing is consistent and accurate within one degree, according to the manufacturer.

The system uses an electronic-type proximity pickup method which is not speed-sensitive. Even when low battery or cold weather conditions reduce cranking voltage to as little as 4 volts, essentially full output is maintained. The system is well suited to applications involving extended low-speed operation and less than one-third ampere is required for ignition-system operation at idle. It is unaffected by ambient temperatures up to 212°F, permitting direct mounting on the engine block in many installations. Prestolite

Circle No. 1 on Reader Service Card

COLOR-PATTERN GENERATOR

A low-cost, solid-state color pattern generator, the 'Lo-Boy," is now being marketed for service technicians and experimental applications. The instrument is battery operated and features unique timing circuits to speed the operation. The CG10 provides the five basic patterns used

in convergence; ten standard RCA-type color bars, individual horizontal and vertical lines, crosshatch, and adjustable size white dots.

The unit is powered by long-life "C" cells that are replaceable from the outside of the unit. The battery voltage is regulated to provide maximum stability over the entire life of the batteries. Sencore

Circle No. 2 on Reader Service Card

SENSITIVE-GATE TRIACS

Low-cost electronic control of household appliances has been made possible by the development of two new sensitive-gate Triacs, TA2892 and TA2893. These low current, bi-directional a.c. switches have a typical triggering current of 1 mA (3 mA maximum), have symmetrical gate-triggering current requirements in all four firing modes, and a 2.5-A (r.m.s.) rating.

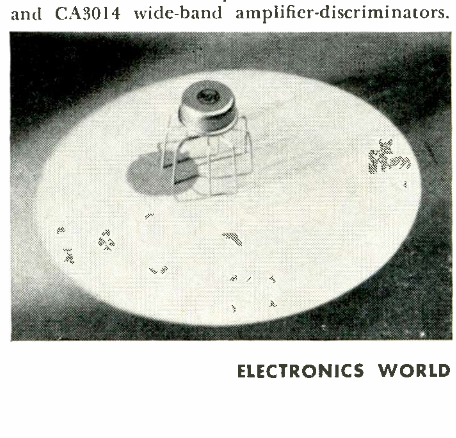
Because fewer components are required (both active and passive), circuit reliability and reduced cost can be achieved. The Triacs are housed in a standard TO-5 package which permits the designer to effect circuit miniaturization as required.

Technical data parameters will be supplied by the manufacturer on request. RCA Electronic Components

Circle No. 131 on Reader Service Card

LINEAR INTEGRATED CIRCUITS

Four new "economy-line" linear integrated circuits for use in FM sound systems and other commercial and industrial equipment applications have been introduced as the CA3011 and CA3012 wide-band amplifiers and the CA3013 and CA3014 wide-band amplifier-discriminators.



Each of the devices is packaged in a single TO-5 transistor-type case no larger than an aspirin tablet.

The CA3013 and CA3014 have 12 transistors, 12 diodes, and 15 resistors on a single chip or a total of 39 components, 24 of them active devices. According to the company, these devices offer excellent performance between 100 kHz and 20 MHz, offer 75 dB typical power gain at 4.5 MHz, have exceptional limiting characteristics, and an AM rejection of greater than 50 dB at 4.5 MHz. RCA Electronic Components

Circle No. 132 on Reader Service Card

HIGH-VOLTAGE A.C./D.C. CALIBRATOR

A high-voltage a.c.-d.c. calibrator, the Model 421A, whose output is 0 to 1110 volts a.c., either r.m.s. or peak-to-peak at 400 or 1000 Hz, and 0 to 110 volts d.c., is currently available.

The desired output is set with three knobs to 4 significant figures in a left-to-right digital readout. Accuracy is 0.15% to 110 volts then drops to 0.3% at 1000 volts. Particular attention has been paid to stability variations: a ±10% line-voltage change affects the output voltage by less than 0.05%. The effect of ambient temperature is less than 0.005%/°C for 25°C ±10°C.

The new calibrator is being offered in both portable and rack versions. Ballantine

Circle No. 133 on Reader Service Card

INDUSTRIAL-HEATING TRIODE

An axial ceramic, conical industrial triode designed for use in dielectric and other industrial heating applications has been introduced as the YD1160. It is fully rated to 160 MHz, the highest frequency without derating for any industrial power triode on the market, according to the manufacturer. When derated, the tube can be operated to 250 MHz. This enables the YD1160 to treat those low-loss materials which cannot be sufficiently heated at lower frequencies.

Under typical operating conditions as a class-C industrial oscillator, the tube has a power output

of 8.2 kW at 82% efficiency, with a plate voltage of 5 kV. Full specifications are available on request. Amperex

Circle No. 134 on Reader Service Card

RECHARGEABLE BATTERY

A high-energy, miniaturized, rechargeable 2 ampere-hour battery has been recently introduced as the "Silcad" (silver-cadmium) power pack.

The three-cell module design can fulfill numerous power and packaging demands, according to the company. It is rugged and leak-resistant and can withstand adverse environment, shock, and vibration. The new battery provides a high- or low-rate discharge capability, flat discharge voltage, and fast recharges. It can be designed to meet special requirements for maximum capacity output, maximum life, or optimum voltage. Yardney

Circle No. 135 on Reader Service Card

82-CHANNEL CABLE FOR COLOR

A new cable designed specifically to improve color-TV reception on all-channel color receivers is being introduced as the "82 Channel Coloraxial Cable." According to the company, the outstanding feature of the new cable is its exceptionally low loss—about half that of ordinary RG-59/U coax.

The new cable is packaged in handy lengths, with coaxial fittings and a weatherboot attached. Length of the cable is not critical, since a few feet can be coiled behind the TV set with no degradation of picture quality. Currently the cable is available in 50-, 75-, and 100-foot lengths. Jerrold

Circle No. 3 on Reader Service Card

ANTENNA COUPLERS

To facilitate coupling of separate v.h.f., u.h.f., and FM antennas in mixed signal areas, two new couplers for rotorless installations have been introduced as the Models CA-314 and CA-312.

The CA-314 will couple three separate antennas on the same mast, providing a single downlead into the home or building. The v.h.f. circuitry is a.c. passive to allow use of a preamplifier on the v.h.f. antenna if desired.

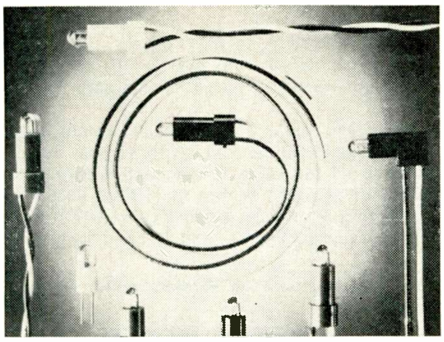
For areas where separate antennas are used for the high- and low-v.h.f. bands, the CA-312 is suggested. It couples a low-band (channel 2-6 and FM) antenna, a high-band (channel 7-13) antenna, and a u.h.f. antenna in order to run a single downlead. A splitter is then used at the receiver. Winegard

Circle No. 4 on Reader Service Card

SUBMINIATURE LAMPS FOR COMPUTERS

A new development in subminiature incandescent lamps—the integrally molded base—has been announced. The integrally molded-base lamp, designed specifically for computer applications, differs from the conventional lamp in that it employs a plastic base molded to a standard bulb. It replaces not only the separately attached metal base but also the mated socket.

CIRCLE NO. 107 ON READER SERVICE CARD



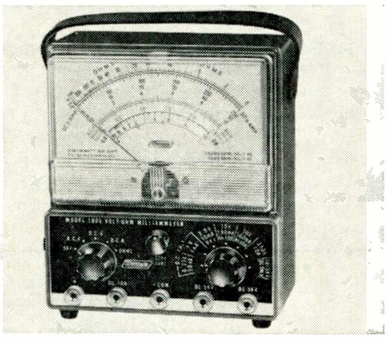
With the new lamps there is no bulb and socket separation; all leads are internally sealed against corrosion while exposed leads can be of corrosive-resistant material; since the base is its own socket, an additional connection is eliminated; and color coding is possible. Tung-Sol

Circle No. 136 on Reader Service Card

SERVICE V.O.M.

The Model 1800 v.o.m. has been designed for all types of servicing work—troubleshooting color and black-and-white TV, radios, hi-fi gear, and communications equipment.

Housed in a portable, high-impact durable case, the instrument features a large, full-view, easy-to-read 6-inch meter. The unit will measure



a.c. volts in six ranges; d.c. volts in eight ranges; d.c. current in six ranges, output decibels in four ranges; and resistance in three ranges. Accuracy is ±2%. Mercury

Circle No. 5 on Reader Service Card

HI-FI—AUDIO PRODUCTS

WEATHERPROOFED SPEAKER

The MO-2 weatherproofed speaker has been designed for use in mobile communications with two-way radio transceivers and medium-power, mobile p.a. amplifiers. Compactly sized for mounting in limited space, the MO-2 is designed to fit between automobile grille and radiator, in engine compartment, under the dashboard or anywhere where concealed installation or minimum obstruction is needed. A reinforced, welded steel bracket insures fail-safe mounting. All metal parts are treated for corrosion resistance prior to final finishing with specially fomulated melamine enamel.

Frequency response is 300 to 13,000 Hz, power is 25 watts, and impedance is 8 ohms. The sound level is 122 dB measured on a 4-foot axis at rated power. Dispersion is 130 degrees. The unit measures 6⅝" wide x 8" high x 4³⁄₁₆" deep. Atlas Sound

Circle No. 6 on Reader Service Card

LOUDSPEAKER DRIVERS

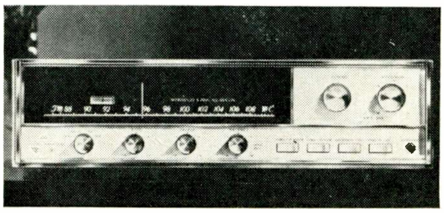
For those who enjoy building their cabinets or for custom installations, a new line of "Grenadier" speaker drivers in three individual models is available. The 9000/15W is a 15" woofer styled for enclosures from 3 to 8 cubic feet. The 8000/12W is a 12" woofer designed to fit between studs in dry walls; it produces solid bass in areas as small as 1.5 cubic feet. The 9000/MHX is a mid-frequency/high-frequency driver which is 10 3/4" on its longest side and features full-presence mid-range radiator, an ultrasonic domed tweeter, and a die-cast full-dispersion acoustic lens. Frequency response is 450-20,000 Hz over-all; mid-range is 450 to 5,000 Hz; and tweeter is 5000-20,000 Hz. Empire Scientific

Circle No. 7 on Reader Service Card

130-WATT FM-STEREO RECEIVER

The Model S-8800 FM-stereo receiver is rated at 130 watts music power at 4 ohms and 100 watts at 8 ohms. It incorporates the same FM tuner circuitry as the firm's S-3300 all-silicon FM-stereo tuner and achieves an FM sensitivity of 1.6 μV (IHF). A specially designed dual automatic-gain control system maintains proper selectivity under the strongest signal conditions.

The receiver also features noise-gated FM stereo/mono switching, instant indicator-light



identification of FM-stereo programming, a professional-type zero-center FM tuning meter, a front-panel stereo headphone jack, and rocker switching for tape monitor, noise filter, loudness contour, and speaker switching.

IM distortion is 0.1% at 10 watts or less; power bandwidth is 12-35,000 Hz at 1% distortion; FM signal-to-noise is 70 dB, and capture ratio is 2.2 dB. FM stability is 0.01% ±10 kHz. The circuit uses 40 silicon transistors and 14 silicon diodes and rectifiers. Chassis size is 16½" x 14" x 4½". Sherwood

Circle No. 8 on Reader Service Card

PAGING/INTERCOM UNIT

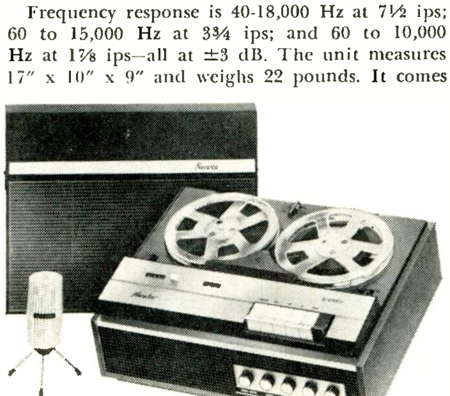
Speakers may be combined with intercom units to provide a versatile sound and communications system serving many needs in a recently introduced paging-intercom system. The master unit may be used with the telephone on its top to save desk space. In addition to the usual slave units (which can initiate calls to the master), various combinations of speakers and sound columns may be connected for paging and public announcements. The system will operate on batteries or on 110-120 volts a.c., using an adapter. A hold button frees the hands during use. American Geloso

Circle No. 9 on Reader Service Card

THREE-SPEED TAPE RECORDER

The "Continental 420" is a three-speed stereo tape recorder with a broad range of professional features, including multiplay and sound-on-sound facilities. The unit is housed in a slim-line teak case; provides for mixing, monitoring, and parallel playback operations; features four-track operation with ganged stereo controls which eliminate the need for dual knobs for recording and playback; a cardioid moving-coil stereo microphone; a "magic ribbon" modulation indicator; and a four-digit tape counter with automatic reset.

Frequency response is 40-18,000 Hz at 7½ ips; 60 to 15,000 Hz at 3¾ ips; and 60 to 10,000 Hz at 1⅞ ips—all at ±3 dB. The unit measures 17" x 10" x 9" and weighs 22 pounds. It comes



complete with three patch cords, demonstration tape, and empty reel. Available accessories include a foot-pedal control, headphones, telephone pickup coil, and dual microphone adapter. Norelco

Circle No. 10 on Reader Service Card

STEREO AMPLIFIER KIT

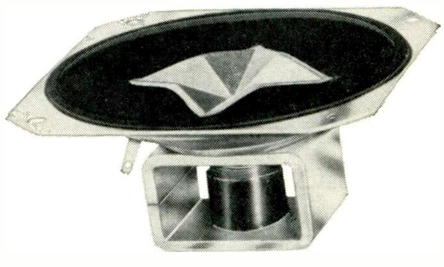
A 30-watt stereo amplifier in kit form is now being offered as the Model KT-60. Spacious component layout and simple step-by-step instructions make this unit suitable for assembly by beginners. The circuit features built-in equalized preamplifiers, d.c. on the filaments in the preamp stages, and four pairs of stereo inputs: magnetic and ceramic cartridges, tuner, and auxiliary.

The full 30-watt output may be switched to either speaker by means of slide switches on the front panel. The unit also has an a.c. receptacle on the rear of the chassis and a red indicator light on the front panel. Rated power output is 25 watts r.m.s., 12½ watts r.m.s. per channel; IHF 30 watts, 15 watts per channel. Frequency response is 20-60,000 Hz ±1.5 dB at 1 watt. Controls include bass cut, treble boost or cut, and loudness. The amplifier measures 12 5/8" x 11 5/8" x 5¼" over-all. It will operate from 110-125 V, 50-60 Hz a.c. Lafayette

Circle No. 11 on Reader Service Card

WIDE-ANGLE H.F. TWEETER

Specifically designed for radio, TV, and other entertainment applications, the Model T-4 tweeter includes a carefully designed propagator



which enhances the response characteristics and extends the high-frequency cut-off.

Eight radiating non-parallel faces project the sound into a wide-angle pattern closely resembling a compression horn. Oxford

Circle No. 12 on Reader Service Card

SOLID-STATE MONO RECORDER

A solid-state mono tape recorder, the Wollensak 1500SS, has been introduced as the transistorized counterpart of the firm's vacuum-tube Model 1500. The new unit features all-transistor circuitry for instant operation and exceptional long-life reliability. A vu recording meter has also been included. The recorder comes complete with blank tape, self-threading takeup reel, dynamic microphone, and accessory cords. 3M

Circle No. 13 on Reader Service Card

SEMICONDUCTOR PHONO CARTRIDGES

A new line of semiconductor transducers designed for the low-priced, high-volume OEM phonograph market has been introduced in three versions: standard stereo, miniature stereo, and standard mono.

The 2TAF-SG standard mono unit has a stylus force of 6 grams, tracking ability at 5 grams, and maximum d.c. excitation of 16 mA; the 43T standard stereo stylus force is also 6 grams, tracking ability 5 grams, and excitation 16 mA; while the 51T miniature stereo has a stylus force of 3 grams, tracking ability at 1.5 grams, and d.c. excitation of 16 mA. The standard stereo cartridge has a double sapphire needle, while the other two models have sapphire and diamond needles. Sonotone

Circle No. 137 on Reader Service Card

PORTABLE TAPE RECORDER

The new Model 300 is a compact (3" x 9" x 10"), solid-state, full-fidelity recorder which permits recording in both forward and re-

verse directions by a turn of a single lever. "Reverse-A-Track" eliminates reel changing and doubles continuous recording and playback time to three hours or more on a single standard reel of tape.

The solid-state electronics of the Model 300 also include a new automatic record-control compression circuit which eliminates the need for manual adjustment of recording levels. It automatically records sounds from different distances at the same level. Also featured is a new automatic power-selector circuit which disconnects the batteries when the unit is used on household current.

Tape speeds are 1 7/8 and 3 3/4 ips, frequency range is 60 to 10,000 Hz at 3 3/4 ips, power sources are six "C" cells or external a.c.; and the machine will handle standard reels up to 4". Concord

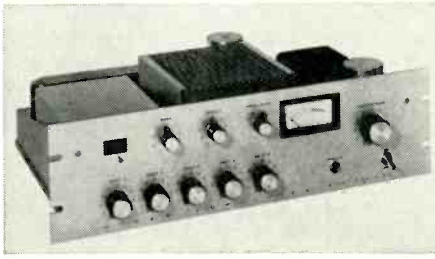
Circle No. 14 on Reader Service Card

FIVE-CHANNEL MIXER/AMPLIFIER

A new all-solid-state, five-channel, 50-watt mixer-amplifier is being marketed as the Model CMA-5-50. The new unit combines on a single chassis a mixer with five individually level-controlled input channels and a 50-watt power amplifier. In its rack-mounting configuration it is intended for use in churches, auditoriums, stadiums, and other permanent locations. In its optional portable case, it is readily transportable by traveling groups.

The input channels are modular plug-in circuit cards. Any of three available types of channel can be plugged into any of the five inputs. Available are low-level microphone input with RIAA equalization and high-level input. Desired balance among the five inputs is achieved by individually infinitely variable controls on all of the five channels.

The amplifier provides 50 watts into an 8-ohm load at 20 volts. Also available are units for 25- and 70.7-volt line outputs. Frequency response is within 1½ dB from 20 to 20,000 Hz. Maximum



gain is 95 dB on low-level inputs and 65 dB on high-level inputs. R.T. Bozak

Circle No. 15 on Reader Service Card

CB-HAM-COMMUNICATIONS

MARINE-BAND CONVERTER

The new "Monitor" converts an ordinary domestic or foreign-car radio into a marine-band receiver with a flick of a switch. This compact,

4½" x 1" x 2½" unit weighs just 6 ounces and can be installed in 10 minutes.

The operator may tune to ship-to-ship broadcasts, receive marine weather reports, Coast Guard emergency signals, and monitor marine operators. Time checks are instantly available by tuning to station WWV.

The unit comes complete with battery and easy-to-follow installation instructions. A calibration chart which shows how the car radio can be tuned for specific marine frequencies is also included. Pearce-Simpson

Circle No. 16 on Reader Service Card

25-CHANNEL CB UNIT

The "Comstat 25" is a low-priced transceiver which features 23 CB channels plus the two emergency "H.E.L.P." channels. The unit utilizes a frequency-synthesizer circuit to provide crystal control for all 25 channels on both receive and transmit functions. The dual-conversion receiver has a sensitivity of 0.8 μV. Selectivity is 6 kHz at 26 dB down. An easy-to-read illuminated tuning dial and "S" meter facilitate operation.

The transmitter features an advanced range-boost circuit which increases average modulation, effectively increasing range. The unit incorporates a built-in TVI antenna trap, 117-volt a.c., and transistorized 12-volt d.c. mobile supply. The circuit uses ten tubes, two transistors, and nine diodes. The transceiver comes with all crystals, a deluxe mobile mounting bracket, and rugged ceramic push-to-talk microphone. Size is 12" wide x 5" high x 8¼" deep. Lafayette

Circle No. 17 on Reader Service Card

CB MOBILE RADIOTELEPHONE

A new all-solid-state CB mobile two-way radio is now being marketed as the "Pace I." This six-channel set can be used with the "H.E.L.P." plan, with up to five more channels available by installling the proper crystals.

Designed to transmit up to 20 miles over normal terrain, the circuit provides 3½ watts of

CIRCLE NO. 88 ON READER SERVICE CARD

power output boosted by automatic speech compression. The unique double-conversion receiver section, with shaped audio response and heavy-duty side-mounted speaker, is said to bring in even weak and distant stations.

Other features include a lifetime glass fiber circuit board, instant operation, all-silicon-transistor design, adjustable squelch control, automatic noise clipping, and provision for adding public-address capability. Pace

Circle No. 18 on Reader Service Card

MANUFACTURERS' LITERATURE

POTENTIOMETER CATALOGUE

A new 120-page catalogue covering a complete line of trimming potentiometers, precision potentiometers, and counting dials has been published.

Detailed listings of electrical, mechanical, and environmental characteristics are supplied, along with cutaway drawings and dimensional diagrams. Amphenol Controls Div.

Circle No. 138 on Reader Service Card

AMPLIFIER BOOKLET

A new 8-page 1966 catalogue describing a complete line of solid-state amplifiers and kits is now available. In addition to product listings, the illustrated booklet includes sections explaining important amplifier specifications and amplifier terminology. Acoustech

Circle No. 19 on Reader Service Card

RELAY MAINTENANCE

Information on relay terminology, what tool to use, adjustment of the armature assembly, gaging, and current values and timing for all types of relays is contained in a new 20-page illustrated booklet entitled "How to Adjust and Maintain Relays." P. K. Neuses

Circle No. 20 on Reader Service Card

TANTALUM CAPACITORS

Complete technical information on Type STA solid tantalum capacitors is supplied in a new 8-page catalogue. Application data, specifications, and ratings are given, along with typical performance curves. Elpac

Circle No. 139 on Reader Service Card

ELECTRONIC COUNTERS

A complete line of analog instruments and electronic solid-state counters is described and illustrated in a new 24-page illustrated catalogue. Products covered include frequency-to-d.c. converters, frequency meters, multiple-frequency standards, counter-timers, bidirectional counters, and preset counters. Anadex

Circle No. 140 on Reader Service Card

PHOTOCONTROLLED LIGHTING

A new 4-page illustrated flier entitled "Basics of Photocontrolled Lighting" has been released. Designed as an aid to electrical contractors, distributors, and specifiers of photoelectric controls, the brochure discusses types of controls, selection factors, testing the control after installation, and installation procedures. Precision Multiple Controls

Circle No. 141 on Reader Service Card

COLORIMETER BROCHURE

Information on the "Evelyn" photoelectric colorimeter for quantitative chemical analysis is contained in a new catalogue (No. D2128). The instrument is used in chemical, biomedical, and metallurgical laboratories for both routine and control work. Honeywell

Circle No. 21 on Reader Service Card

SWITCH CATALOGUE

A new 8-page illustrated folder (Bulletin 78/79-101) covering a complete line of slide and rocker switches is now available. Information is arranged in easy-to-follow chart and outline form. Stackpole

Circle No. 142 on Reader Service Card

VIDEO SWITCHING

Information on video switching systems is presented in a new 4-page illustrated bulletin (No. 6-382). Typical closed-circuit and broadcast studio setups are described, and complete specifications for switching matrix units and switcher control and remote control modules are given. Cohu

Circle No. 143 on Reader Service Card

RECTANGULAR PILOT LIGHTS

Complete construction details on the "Line-O-Lite" line of rectangular neon indicator lights is given in a new illustrated data sheet. Four standard lenses are available as well as a variety of colors and bezel finishes. Industrial Devices

Circle No. 144 on Reader Service Card

GLASS CAPACITORS

Technical information on series CY60 and CY70 medium-power glass-dielectric transmitting capacitors is contained in a new 4-page illustrated folder (reference file CE-1.03).

The capacitors are used in power amplifiers, low-power transmitters, and in grid, plate, coupling, tank, and bypass functions. Because of their small size and minimum weight, they are also suitable for airborne equipment and mobile transmitters. Corning Electronic Components

Circle No. 145 on Reader Service Card

CONNECTOR CATALOGUE

A complete line of r.f. coaxial-cable connectors, adapters, receptacles, and plugs is described in a new 36-page catalogue (No. 6). Over 300 items are listed in the plastic-bound publication, and cross-references to government-designated connectors are provided. Star-Tronics

Circle No. 146 on Reader Service Card

MINIATURE R.F. CONNECTORS

Information on Series 2900 miniature r.f. coaxial connectors and accessories is offered in a new 4-page brochure. Designed to mate with OSM, BRM, and others, the connectors provide extremely low v.s.w.r. and are made of gold-plated stainless steel for long life and dependable operation.

Complete cable assembly instructions are given in the booklet. General RF Fittings

Circle No. 147 on Reader Service Card

TEST EQUIPMENT

A complete line of test equipment designed specifically for the cable-distribution industry is presented in a new 8-page illustrated booklet. Included are sweep generators, transformers, fixed and variable attenuators, connectors, a u.h.f./v.h.f. field-strength meter, a v.h.f. return loss bridge, and a delay line.

Supplied with the booklet is a 4-page reference chart which contains typical test setups, a dBmV-microvolt chart, a return loss v.s.w.r. chart, and transformation formulas. Blonder-Tongue

Circle No. 148 on Reader Service Card

COMPACTRONS

Complete technical information on more than 90 compactrons is contained in a new 20-page condensed catalogue (ETG-3983). Intended for use by designers of TV and audio communications products, the booklet lists general and maximum ratings along with characteristics and typical operation. Basing diagrams and outline drawings are also included.

Supplied with the catalogue is a 4-page supplement (ETG-3983-1 which covers 16 additional compactrons. General Electric

Circle No. 149 on Reader Service Card

CARTRIDGE REPLACEMENT

A new 24-page 1966 cartridge replacement manual is now available. The booklet is divided into two sections: Section I provides cross-references to cartridges manufactured by more than 50 competitors, while Section II lists replacements according to the phonograph model numbers of over 100 companies.

In addition, the manual (No. SAC-25) contains a cartridge performance specifications chart. Sonotone

Circle No. 22 on Reader Service Card

RELAY CATALOGUE

Miniature and subminiature, telephone-type, power, sensitive, magnetic-latching, coaxial, time-delay, and general-purpose relays are described and illustrated in a new 64-page catalogue (No. 1165). Full operating characteristics, electrical specifications, and mounting data are given for the more than 40 different types of relays and timing devices covered in the publication. Allied Control

Circle No. 150 on Reader Service Card

R.F. STRIP-LINE PC'S

Step-by-step processing and fabrication techniques for manufacturing r.f. strip-line circuit boards are covered in detail in a new 4-page illustrated brochure. A comparison of coaxial cable with flat-strip transmission line is also provided. Colbuk Div. of Bureau of Engraving, Inc.

Circle No. 151 on Reader Service Card

DIGITAL MEASURING SYSTEM

A new 6-page illustrated technical brochure describing a new low-cost digital measuring system has been released. The system consists of Model DMS-3200 main frame and four plug-in units—a d.c. voltmeter, 1-Hz counter, ohmmeter, and capacitance meter. Hickok

Circle No. 152 on Reader Service Card

TAPE-HEAD BROCHURE

A complete line of magnetic-tape recording heads is described in a new 10-page catalogue. Twenty-four types of erase heads, record/playback heads, and combination heads that record, play back, and erase are illustrated with their physical configurations and electrical characteristics. Michigan Magnetics

Circle No. 153 on Reader Service Card

GLASS CAPACITORS

Test data on Type CY glass capacitors is now available in a new 8-page booklet (No. 110565). Tests include shock, high-frequency vibration, temperature cycling, immersion, moisture resistance, lead strength, and length of life. Westinghouse

Circle No. 154 on Reader Service Card

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GENERAL INFORMATION: First word in all ads set in bold caps at no extra charge. Additional words may be set in bold caps at 10¢ extra per word. All copy subject to publisher's approval. **Closing Date:** 1st of the 2nd preceding month (for example, March issue closes January 1st.) **Send order and remittance to: Hal Cymes** ELECTRONICS WORLD, One Park Avenue, New York, New York 10016

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CANADIANS—Giant Surplus Bargain Packed Catalogs. Electronics. Hi-Fi, Shortwave, Amateur, Citizens Radio. Rush $1.00 (Refunded). ETCO. Dept. Z, Box 741, Montreal, Canada.

RESISTORS precision carbon-deposit. Guaranteed 1% accuracy, ½ watt 8¢. 1 watt 12¢. 2 watt 15¢. Rock Distributing Co., 902 Corwin Road, Rochester 10, N.Y.

NEW supersensitive transistor locators detect buried gold, silver, coins. Kits, assembled models. $19.95 up. Free catalog. Relco-A22, Box 10563, Houston 18, Texas.

JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266, Spokane, Washington 99207.

WEBBER Labs. Transistorized converter kit $5.00. Two models using car radio 30-50Mc or 100-200Mc, one Mc spread. Easily constructed. Webber, 72 Cottage, Lynn, Mass.

ACHTUNG! Das machine is nicht fur Gerfingerpoken und mittengraben. Is easy schnappen der Springenwerk, blowenfusen und poppencorken mit spitzensparken. Ist nicht fur gewerken by das Dummkopfen. Das rubbernecken sightseeren keepen hands in das pockets. Relaxen und watch das Blinkenlights. This attractive, brass metal plaque only $2.00 ea. ppd. Southwest Agents, Dept. E, P.O. Box 12283, Fort Worth, Texas 76116.

CANADIANS, transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics (Dept. EW), P.O. Box 1437 Winnipeg, Manitoba, Canada.

TRANSISTORS—Miniature Electronic Parts. Send for Free Catalog. Electronic Control Design Company, P. O. Box 1432M, Plainfield, N.J.

METERS—Surplus, new, used, panel and portable. Send for list. Hanchett, Box 5577, Riverside, Calif. 92507.

TRANSISTORIZED Products Importers catalog. $1.00. Intercontinental. CPO 1717, Tokyo, Japan.

MESHNA'S TRANSISTORIZED CONVERTER KIT $4.50 Two models——converts car radio to receive 30-50 mc or 100-200 mc (one mc tuning). Meshna, Lynn, Mass. 01901.

SECURITY ELECTRONICS introduces its **NEW** 1966 line of **SURVEILLANCE EQUIPMENT.** Improved **NEW** designs for maximum performance and greater value. **FREE DETAILS.** Security Electronics-EW, 11 East 43rd St., New York, N.Y. 10017.

R.F. CONVERTERS World's largest selection. Also CCTV cameras, transmitters, etc. Lowest factory prices. Catalog 10¢. Vanguard, 196-23 Jamaica Ave., Hollis, N.Y. 11423.

SAFEGUARD PRIVACY! New instrument detects electronic "bugs," wire-tapping and snooping devices. Free information. Dee Equipment, Box 7263-7, Houston 8, Texas.

CONVERT any television to sensitive big-screen oscilloscope. Only minor changes required. No electronic experience necessary. Illustrated plans, $2.00. Relco-A22, Box 10563, Houston 18, Texas.

ELECTRONIC DEVICES—Kits or assembled. For **CAR, HOME** and **BOAT.** Catalog Free. **EARN MONEY** selling these useful items. Write for details. Electronic Products Co., Dept. F, Box 8485, St. Louis, Mo. 63132.

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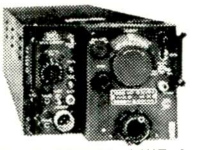

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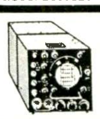

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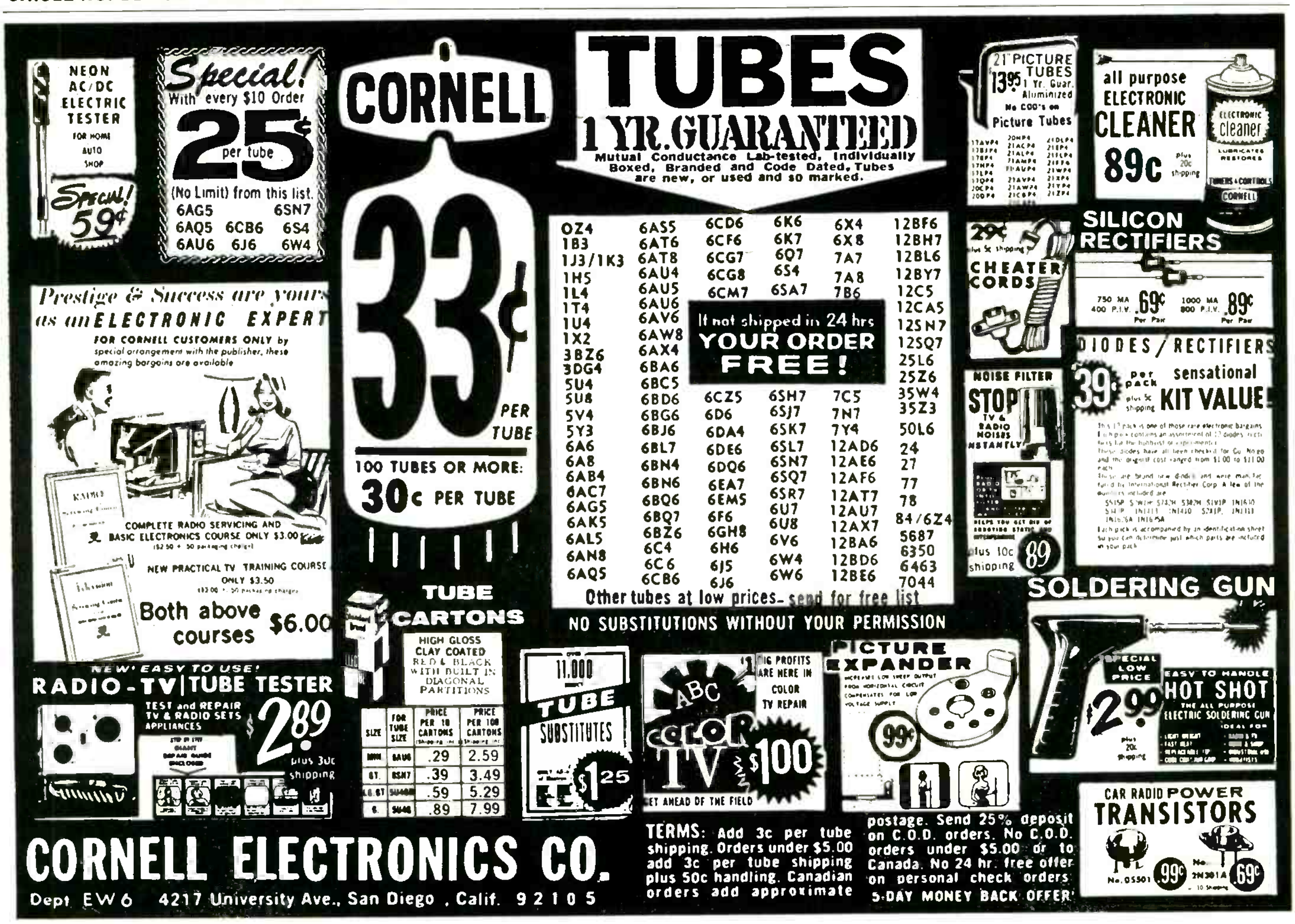

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YOUR EMPLOYMENT INFORMATION advertising will be seen and responded to by more than 196,000 **ELECTRONICS WORLD** buyers. Place your copy in these columns in the next available issue, August, on sale July 19th. Deadline is June 8th, so send copy and payment soon to: Hal Cymes, Classified Advertising Mgr. **ELECTRONICS WORLD**, One Park Avenue, New York, New York 10016

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