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AUG. 1966

# Radio-Electronics™

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HUGO GERNSBACK, Editor-in-chief
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Test panel in research sub

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**RANGES**

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| DC Volts: | 0-2.5-10-50-250-1,000-5,000 at 20,000 ohms/volt. 0-0.25 at 100 microamperes. |
| AC Volts: | 0-3-10-50-250-1,000-5,000 at 5,000 ohms/volt. |
| Decibels: | −20 to +11, +21, +35, +49, +61, +75; "0" DB at 1 MW on 600 ohm line. |
| DC Microamperes: | 0-100 at 250 Mv. |
| DC Milliamperes: | 0-10-100-1,000 at 250 Mv. |
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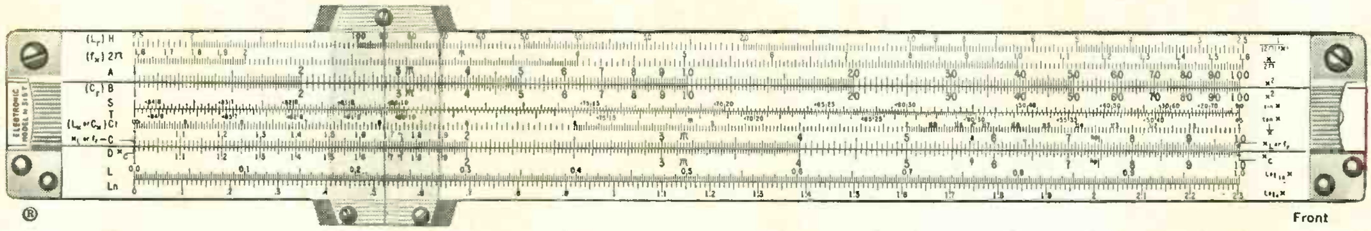
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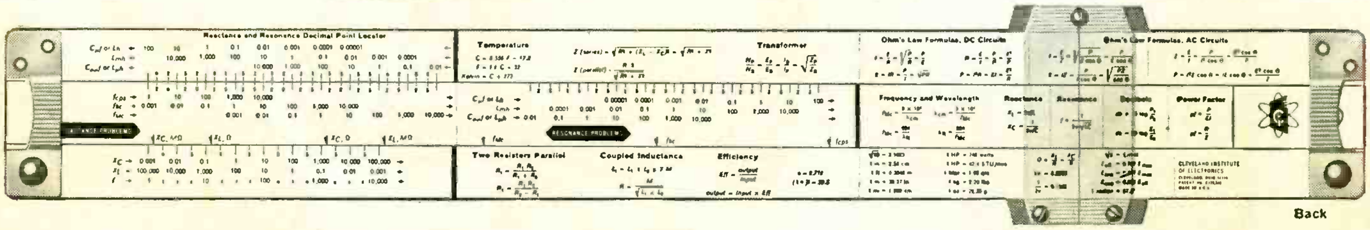
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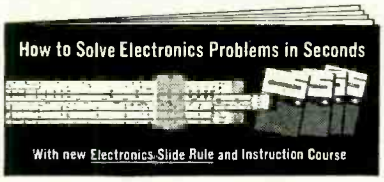

How to Solve Electronics Problems in Seconds
With new Electronics Slide Rule and Instruction Course

# Electronics' Role in Auto Safety

The most controversial news topic this year—next to Vietnam—has been Auto Safety. The arguments have been hot! Almost everyone has been blamed for our high accident rate: auto designers and builders, drivers, laws and enforcement, road design, teaching systems, the government. Few have escaped accusation of some sort.

A lot of people are suddenly experts. In the US and abroad, safety committees and advisory panels are springing up like crabgrass in a suburban lawn. Everyone who drives, or knows someone who does, has sounded off on auto safety.

Auto safety unquestionably deserves this concern. Our annual tally of traffic deaths is appalling. We are killing each other off as if we were at war. (During the Civil War, there were 215,000 battle deaths, or about 50,000 a year—practically the same as our traffic toll.)

Who really is to blame? The presumably inanimate car, or its more vocal (and trainable) driver? Or is it the government?

What difference does it make who is at fault? Placing the blame won't solve the problem, nor will it save any lives.

The truth is: there is no pat answer. The solution lies in many areas; *all* should have attention rather than just those with loud voices. Autos ought to be more foolproof. Drivers must be selected more carefully and trained more fully. Roads should include more safety engineering. Traffic control devices are important. Throughout the nation, laws need to be brought up-to-date and enforcement made more uniform. Even pedestrians, frequently slammed around in auto mishaps, are part of the auto-safety picture.

For more than 10 years, electronics companies have included auto safety in their research and development programs. Many devices and systems have been introduced, and we've written of them in RADIO-ELECTRONICS. Only a very few have been adopted. Besides systems worked out especially for auto safety, there are dozens from other industries (aircraft, marine) that can be adapted. There is one expert who is in the best position to help every other class of expert find solutions to auto-safety problems—the *electronics expert.*

Here is a brief list of electronic approaches to auto safety. Some are in use, some being refined, some still in the lab.

*For the auto:* Collision-avoidance systems like those for planes. Separation-assurance devices, that automatically order evasion maneuvers. Rate-of-approach warnings. Electronically controlled acceleration and braking. Warning systems that stimulate the driver to action, and those which initiate evasive action automatically. Pedestrian warnings. Hazard warnings (ice, tailgater, low tire pressure, impending brake failure). Electronic speed governors. And so on.

*For the driver:* Electronic driver-training simulators. Computerized knowledge testing and stored driving records. Simplified instruments for quickly checking reaction time, medical reactions to emergencies, and health conditions that might affect driving.

*For the road:* TV traffic monitors. Radar/computer traffic-flow controls. Devices that forcibly prevent exceeding speed limits. Impending-trouble warnings that force autos to slow down as they approach a danger spot (stalled car, slick road, and the like). Electronic freeways (or tollways) that carry automated-drive cars at high speed with complete safety.

Everyone has a stake in solving the auto-safety problem. Whoever has an idea, no matter how unimportant it may seem, should make it known. (We'll gladly collect any from our readers.)

Government and the auto industry are tackling auto safety. They should look into all the facets.

Most important, however: Every single committee and advisory panel should include an electronics expert. It is from the electronics industry that many of the automotive safety devices of the future will come.

—*Forest H. Belt*

# Radio-Electronics

AUGUST 1966 VOL. XXXVII No. 8
Over 55 Years of Electronic Publishing

## EDITORIAL

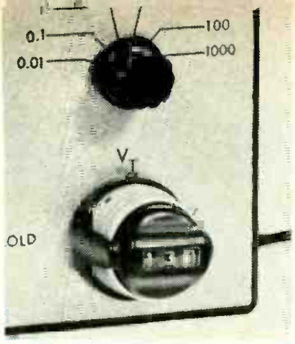
## TEST INSTRUMENTS

## TELEVISION

## ELECTRONICS

## GENERAL

## THE DEPARTMENTS



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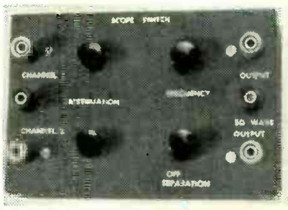

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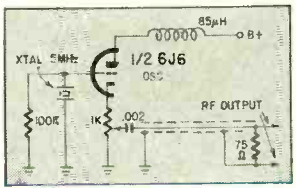

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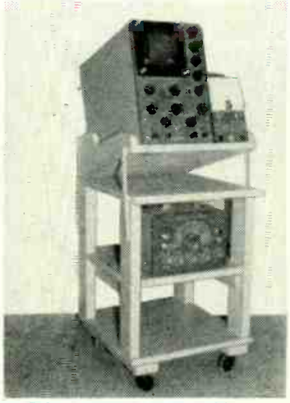

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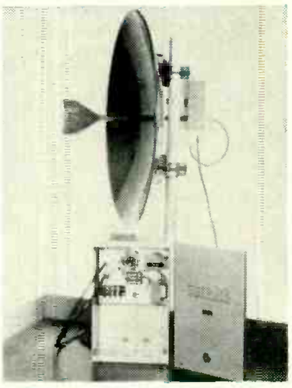

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***COVER FEATURE**

**p 26**–Electronic instrumentation and communications are rapidly gaining importance far below the surface of the world's oceans.

**LAB EQUIPMENT**

**p 41**–A home-brew pulse generator places this sophisticated instrument in reach of almost anyone's wallet.

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# NEWS BRIEFS

### GERNSBACK SCHOLARSHIP AWARD ACHIEVED BY EDWARD LANDAU

The 1966-67 Hugo Gernsback Scholarship awarded annually to a New York University student was won this year by Edward Landau of Bronx, N. Y. The $1,000 grant is presented to a student chosen by NYU's College of Engineering faculty.

Member of a Radio-Electronics-reading family and graduate of the Bronx High School of Science, Mr. Landau entered New York U in September, 1963, and has just completed his junior year. He is a member of Eta Kappa Nu, the electrical engineering honor society, and of Tau Beta Pi, the national engineering honor society. He is president of the local chapter of Eta Kappa Nu.

Not confining himself to engineering activities, he is also a member of the social fraternity Pi Lambda Phi, in which he has held the offices of secretary and treasurer. He is also active on the Orientation Committee at NYU and has twice run the program for transfer engineers. "I also enjoy playing handball and football" he says, "and when I have some free time I like to read a good science-fiction book."

### NEW FLOW-RATE METER IS A MAGNETOMETER

A meter using magnetometer principles has been developed by the National Bureau of Standards cryogenic metrology group in Boulder, Colo. It will measure the flow of liquid hydrogren in a pipe and was developed because of the dangers of measuring that touchy fluid by ordinary means. A dc magnetic field orients the nucleii of the liquid hydrogen. An rf pulse from the transmitter raises the nucleii to a higher energy state. The energy the nucleii emit as they fall back to the ground state is detected as they pass the receiver pickup coil. The time it takes the tagged nucleii to travel from the receiver loop to the transmitter loop indicates the velocity of liquid hydrogen in the pipe and therefore the flow rate.

### NEW VIDEO RECORDER USES NON-PHOTO CELL

The new vidio recording device developed by CBS Labs does not use recording discs as was rumored last March. Instead, according to *Television Digest,* it operates with a narrow "non-photographic film" in a cartridge.

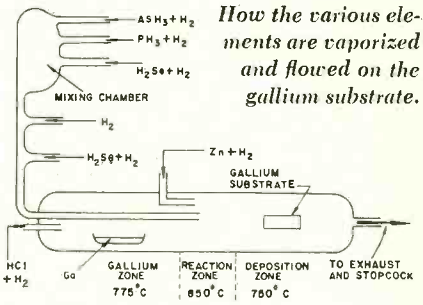
The March report by Jack Gould in the New York Times was denied by CBS spokesmen. They stated that CBS was doing no work whatever on a TV recording system. Now it appears that it was not developed for TV, but as a wideband storage device. CBS is still not commenting, but the band width is known to be wide enough to record TV and will presumably accommodate color.

The nature of the "non-photographic film" has not been made public. Engineers are speculating about the thermoplastic film demonstrated by General Electric in 1960, which could record TV at 5 inches per second on a video track only $\frac{1}{10}$th inch wide. Other engineers have mentioned the tape recording process described by Dr. Gy Almassy in a paper at the 6th International Instruments and Measurements Conference in Stockholm, (Radio-Electronics, January 1965, page 8). He described a technique of high-speed recording on a permanently polarized plastic tape—an actual tape electret.

### GALLIUM ARSENIDE CRYSTALS PRACTICAL WITH NEW TECHNIQUE

Dr. James Hillier, vice president of RCA Laboratories, has announced that for the first time a practical technology has been developed for the use of gallium arsenide alloys in semiconductor devices. This, he says, promises to be a third major technology complementing the earlier methods for making practical devices from germanium and silicon.

Methods that produce germanium and silicon crystals (such as alloying and diffusing) have given poor device results for gallium arsenide. As a result there has been little progress with that material. The work has been carried on for a number of years. The method is known as vapor phase growth and is carried in a vacuum. All the materials are prepared separately in gaseous form. They are then mixed and allowed to flow over a solid crystal of gallium or one of its alloys. The crystal is kept a little cooler than the gases so they condense on its surface. This forms a true extension of the crystal, differing from it only in that it contains the required impurities.



*How the various elements are vaporized and flowed on the gallium substrate.*

Experimental devices already produced by the new technology include:

The first semiconductor laser to generate physical light at room temperature.

A Gunn-effect microwave source that has operated at 40 GHz, the highest frequency yet achieved this way.

The brightest electroluminescent diodes yet developed.

An electro-optical modulator that can modulate a visible laser beam transversely at the rate of 100 million bits per second.

Experiental varactor diodes with the highest combination of cut-off frequency and voltage breakdown yet achieved.

### NEW ELECTRON-BEAM WELDER NOW WORKS IN OPEN AIR

Electron-beam welding, previously possible only in a vacuum chamber, can now be carried out in free space with a new portable, out-of-vacuum electron beam welder developed by Westinghouse. Besides working in open air, the device has been designed so that the welding head can be brought to the work, a new feature in electron-beam welders.

In the new welder, an extremely powerful beam of electrons is ejected into the air through a specially designed orifice system and then shielded

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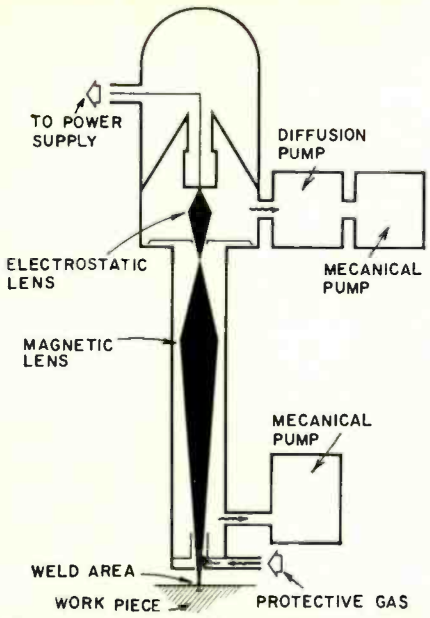

*Cross-section of the electron-beam welder.*

from air by a cloak of lightweight helium molecules. The equipment uses 13 kw at 150,000 volts. The tube is pumped continuously to maintain internal vacuum.

Electron-beam welding produces a joint with the minimum of heat, therefore welds made by the process weaken the metal less than any other type.

### PORTABLE SPEECH SCRAMBLER NOW ON MARKET

A low-cost speech-scrambling system has been announced by Litton Industries. It is intended for people who may have reasons to believe their telephones are being tapped, and especially for law-enforcement uses. It is particularly useful for investigations where detectives want to keep their communications off regular police channels. It could also be used in businesses, such as the oil industry, where certain bits of information could be very important.

To operate the device, known as Tel-Lips, the user simply drops the telephone handset into a special cradle in the case, and operates with a handset that forms part of the privacy unit. A similar device at the other end unscrambles the conversation.

The device is not considered a secure communications device in the military sense since security to such specifications would increase the cost many times. So a special feature was added. An alphabetic keyboard on the device makes it possible to send coded messages. The user simply states that an alphabetic word is to be sent, then depresses the proper buttons in the correct order. The corresponding button on the listener's Tel-Lips lights up as each button is pressed. The buttons on each pair of units may have the letters arranged in different sequences, to make deciphering extremely difficult. An unauthorized interceptor who does not know the correct keyboard configuration has about one chance in 100,000 for recognizing the entire sequence, according to Phineas J. Icenbice, director of the group that developed the unit.

### PHILCO ADDS TUNING EYE TO COLOR TV RECEIVERS

The new Philco color TV line includes a visual tuning indicator, resembling those used on stereo sound receivers. Converging green light bars indicate when the set is tuned exactly to the correct point for best color. The tuning indicator appears on the top model of the 23-inch line, all the 25-inch receivers and combinations and on the 21-inch color sets above $489.

### AUTO SALES HURT BY COLOR TV?

According to a New York consulting economist, the boom in color TV sales may be more responsible for any decline in auto sales than the belated discovery by prospective buyers that cars are not entirely safe. A typical color set, he says, costs about $500 or more. A car costs about $3,000 with an average $1,000 trade-in. Therefore a car requires about 4 times as much cash or credit as a color TV. This year about 3.2 million more color sets will be sold than in 1965. Thus, the TV industry could conceivably be responsible for affecting the sales of some 800,000 cars. END

#### CALENDAR OF EVENTS

**Automatic Controls Conference, August 17–19; University of Washington, Seattle, Wash.**

**NEA (National Electronic Associations, Inc.), August 18-21; Sheraton Motor Inn, Winston-Salem, N. C.**

**WESCON (Western Electronic Show and Convention), August 23–26; Sports Arena, Los Angeles, Calif.**

**NATESA (National Alliance of Television and Electronic Service Associations) Convention, August 25–28; Sherman House, Chicago, Ill.**

**IEEE 16th Broadcast Symposium, September 22–24; Mayflower Hotel, Washington, D. C.**

**New York Hi-Fi Music Show, September 22–October 2; New York Trade Show Building, New York, N. Y.**

### Radio-Electronics Adopts Hertz

RADIO-ELECTRONICS is now using the term *hertz* in place of cycles in all references to frequency. Hz, kHz and MHz, abbreviations for hertz, kilohertz and megahertz, are replacing cycles, kc and mc in all recently edited material.

# Radio-Electronics

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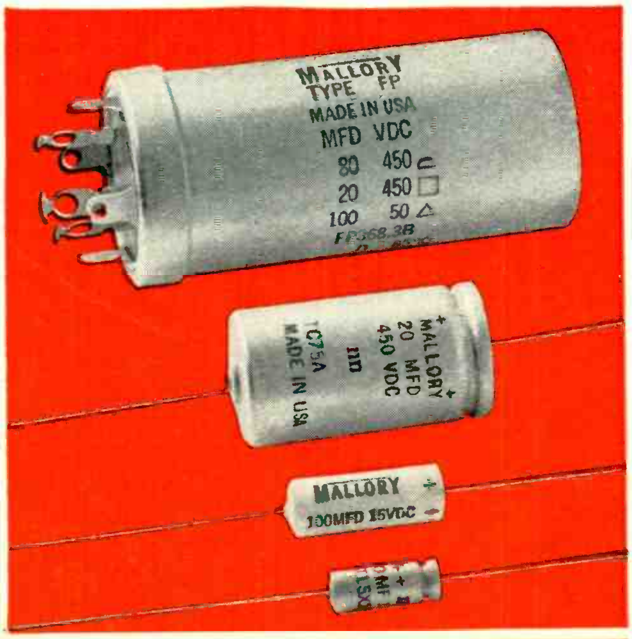
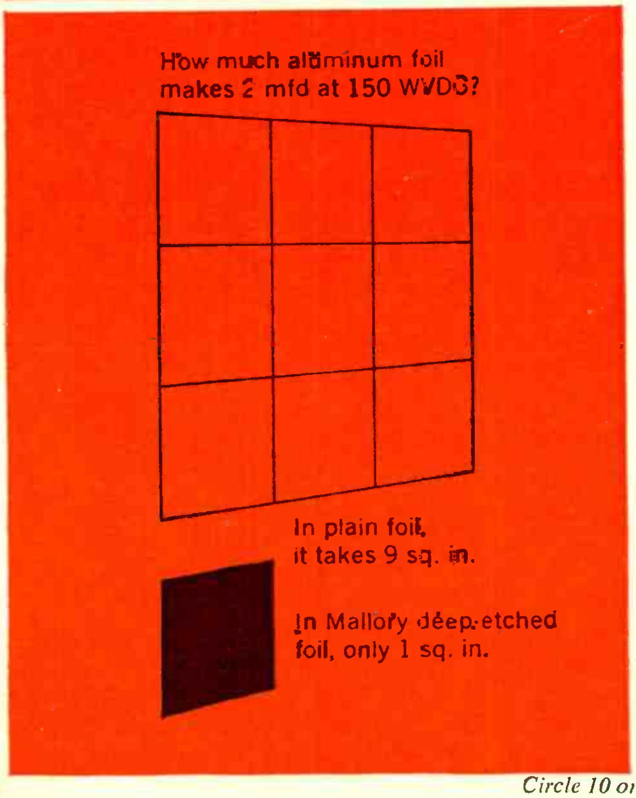
# MALLORY Tips for Technicians

# Tips on replacing electrolytic capacitors





Finding the right electrolytic capacitor for a replacement job often becomes a matter of juggling three factors: what the circuit originally called for, what you can get quickly from a distributor, and what you have on hand in your shop. Here are a few hints that may help to make your life easier.

The important parameters about an electrolytic are voltage rating, capacitance, temperature rating and size. You have a certain amount of leeway on all four of these . . . and knowing how far you can stretch safely may save you a lot of shoe leather looking for the exact replacement.

Let's take voltage first. You can *always* substitute a capacitor with *higher* voltage rating than that originally required, with absolutely no harmful effects (except maybe on your pocketbook, because you may pay for extra capability that you don't need). But you should *never* replace with a voltage rating *lower* than the original.

How about capacitance? Our advice—don't go too far from −10% +50% of the original value. You've probably heard that standard industry specs allow tolerances of 10% low and up to 150% high. Actual manufacturing practice at Mallory, is to make capacitors to considerably tighter tolerances . . . because most radio and TV manufacturers won't tolerate the wider variations. Too small capacitance is apt to raise hum levels. Too high capacitance may lead to surge damage to silicon rectifiers.

On the temperature score, you don't have to worry if you use a Mallory FP-WP, TC, TT, or MTA type, because they're all rated for 85°C (except for three odd-ball TC's), and that's plenty for home instruments or industrial electronics. Our wax-filled cardboard tubulars are rated 65°C. The few cents extra that you might spend for a Mallory capacitor, compared to the cheapest ones you could buy, will assure you of *several* times longer service life.

How about size? Don't be surprised when you find that in many instances the Mallory replacement is *smaller* than the original capacitor (naturally, it will still fit chassis cutouts). That's because of our new techniques for deep-etching aluminum to increase the effective area of the anode. So we can get about nine times more microfarad-volt rating inside a given container than with plain foil.

One final tip. Our new Capacitor Replacement Guide makes it a cinch to find the exact part number to specify, to replace just about any electrolytic you may encounter. Ask your Mallory Distributor for a copy, or write Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., P. O. Box 1558, Indianapolis, Indiana 46206.

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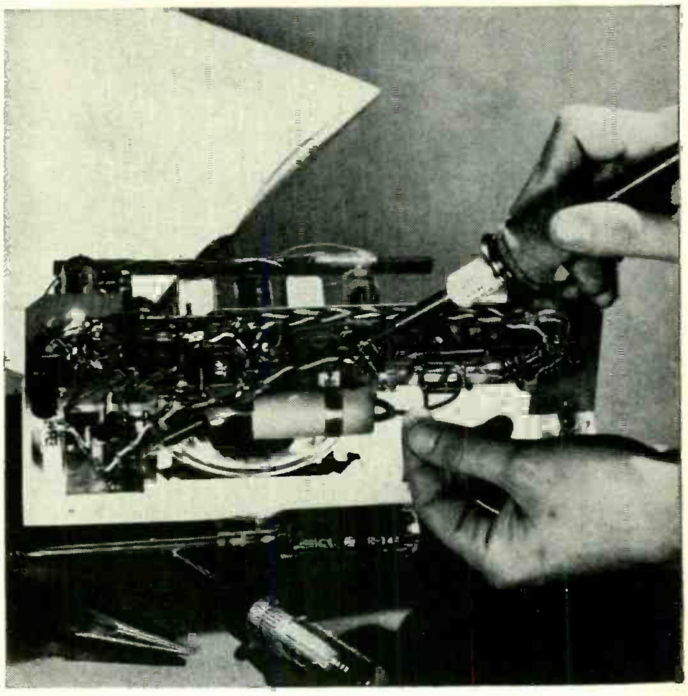

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# Correspondence

## SLIPS!

*Dear Editor:*

The May 1966 What's Your EQ? (page 48) wasn't fair. I disagree with your solution to the "Black-Box Equivalent" problem. The problem establishes a reference for current direction—i.e., the current arrow is shown pointing to the left, therefore current is going from "+" to "−" inside the battery. Fine. Next, the problem states: ". . . note the resultant current readings in the reference direction shown . . ." The solution given on page 89 would cause current to flow in the opposite direction from that shown in original problem. The problem would have been correct if it had read:

$E = 12V, I = 2A$
$E = 6V, I = 0$
$E = 0V, I = -2A,$

instead of:

$E = 12V, I = 2A$
$E = 6V, I = 0$
$E = 0V, I = 2A.$

My correction to the first problem may be too picky, but I get frustrated when I can't find an answer and it turns out the hangup is caused by an ambiguous problem.

S. STRAHM
*Los Gatos, Calif.*

[The solution we printed is indeed incorrect. It says the flow is "2 amps" for the given conditions. Since in one case, the flow is opposite to that of the other, one must be −2 amps and the other +2 amps. Your analysis is correct if you assume correctly that electron flow is out of the negative terminal of a battery. Wish we could blame the printer . . . !—*Editor*]

## "MORE ON . . ."

*Dear Editor:*

Re: your May 1966 editorial "Color TV Has a Problem," I heartily second the motion that something be done about the annoying hue changes.

I would like to air another gripe, although it is far less important than the hue changes. If black-and-white commercials must be shown during a color program, why doesn't the controlling facility switch off the color burst during those transmissions? The

In just a few short months the Electro-Voice Model 676 has gained quite a reputation as a problem solver — no matter what the odds. Now the 676 has a teammate. The Model 674 has the same unique backbone that rejects unwanted sound... an exclusive with Continuously Variable-D (CV-D)<sup>T.M.</sup> microphones from Electro-Voice. And the improvement in performance is dramatic.

Troubled with feedback or interfering noise pickup? Most cardioid microphones cancel best at only one frequency—but CV-D* insures a useful cardioid pattern over the entire response range. And its small size means the pickup is symmetrical on any axis.

Bothered by rumble, reverberation, or loss of presence? A recessed switch lets you attenuate bass (by 5 or 10 db at 100 Hz) to stop problems at their source. And there's no unwanted bass boost when performers work ultra-close. CV-D eliminates this "proximity effect" so common to other cardioids.

Wind and shock noise are almost completely shut out by the CV-D design. Efficient screening protects against damaging dust and magnetic particles, and guards against annoying "pops".

As for overall sound quality, only expensive professional models compare with the 676 and 674. The exclusive Acoustalloy® diaphragm gets the credit. It's indestructible—yet low in mass to give you smooth, peak-free, wide-range response with high output.

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Choose the 676 or 674 in satin chrome or non-reflecting gray finish for just $100.00. Gold finish can be ordered for $10.00 more (list prices less normal trade discounts). There is no better way to stand up to your toughest sound pickup problems. Proof is waiting at your nearby E-V sound specialist's. Or write for free catalog of Electro-Voice microphones today.

An important footnote: There is no time limit to our warranty! If an E-V microphone should fail, just send it to us. If there's even a hint that our workmanship or materials weren't up to par, the repair is no charge — even decades from now! Fair enough?

*Patent No. 3,115,207

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*Circle 12 on reader's service card*

### CORRESPONDENCE continued

b-w picture may have a sickening tint since the receiver's color circuits are activated. The commercials are bad enough without this. The situation seems worse now than a year ago. Have the engineers tired of flipping switches?

CHARLES W. BATTLE
*Plano, Tex.*

### FUTURE OF SERVICING

*Dear Editor:*

I have been buying Gernsback books and RADIO-ELECTRONICS for years and I wonder if you would answer some questions which are disturbing me.

Transistors are said to be 10 times as reliable as vacuum tubes. Since transistors are being used increasingly, won't this reduce servicing to something like one-tenth its present volume?

Also, the June issue tells about a chip in some black-and-white and color TV sets. This tiny chip replaces 26 components and RCA claims it is virtually indestructible. It seems to me this means the end of the service tech, especially if these chips can be replaced by a do-it-yourselfer.

How do you feel about the future of the radio-TV service technician? I am very pessimistic.

JAMES DONOVAN
*Whittier, Calif.*

[I'm optimistic about the future of radio and television technicians, Jim. It's true that individual sets need less than half as much servicing as they did 10 or 12 years ago. And transistors are cutting that even further—though not by 10 as you've been led to believe, because other components still are part of the circuits. What you're overlooking is that there are 3 times as many sets as there were 10 or 12 years ago.

Integrated circuit (IC) chips are another matter; their dependability is at least 10 times better than that of transistors. But, once again, they will be responsible for more TV sets (and radios and hi-fi sets).

A do-it-yourselfer can replace tubes, but have you seen a transistor checker in the drug store or grocery yet? A faulty IC is even more likely to require diagnosis by a trained technician with good test equipment. Transistors and IC's should be good news to service technicians.

But more important, Jim, is the far future—5 or 10 years from now. When horses and buggies went out of style, wise blacksmiths became mechanics. When tubes go out of style, wise technicians will become solid-state specialists. When radios and TV's go out of style, wise servicers will learn to repair the other equipment that will be in use. Now's a good time to start!—*Editor*]

END

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# Imagine.

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

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

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

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

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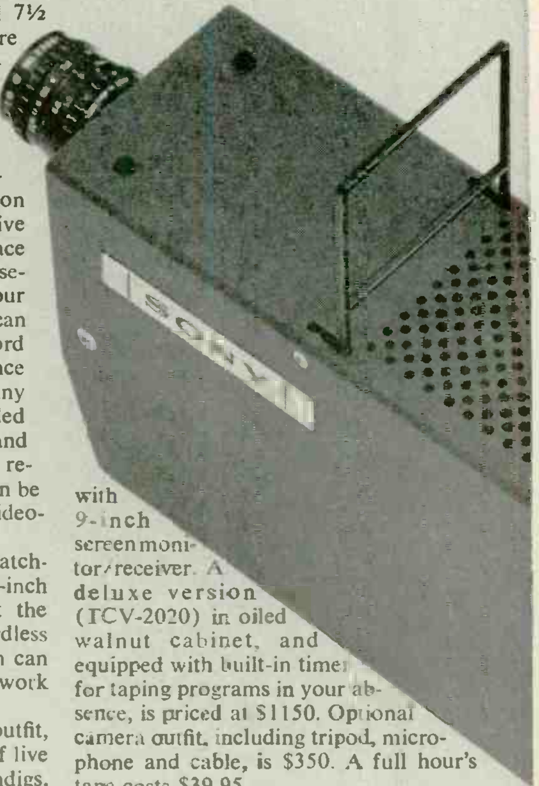
And with the optional camera outfit, you can record picture and sound of live events—family functions, social shindigs, community activities—you name it. You can also apply it to your business or profession or your hobby interests.



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

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*Circle 15 on reader's service card*

# SERVICE CLINIC

By **JACK DARR** Service Editor

## *USING TEST EQUIPMENT THE RIGHT WAY*

"I can repair any TV set with a soldering iron, long-nose pliers and a vom." (Hey, get him! Who does he think he is? Darned smart-Alec!) That's all right; it got your attention, didn't it? That's all I wanted.

Actually, anybody can do what I just said I could. All you have to do is replace all the parts until you hit the right one. Of course, it takes about a week for each set, and you won't make a heck of a lot of money. But you *can* do it.

This brings us to the point of this discussion. Why do we have so much test equipment, and what good is it? Well, for one thing, if everybody's as suggestible as I am, they can't resist it. I'll frankly admit to being test equipment happy, and most of you are just like me. However, there is one very good reason why we should have the right test equipment. It's called "food"—follows "money." With the right equipment, that steak can be a lot thicker!

Ohm's law is simple arithmetic; so's this. How much we make depends on how many TV sets we get out of the shop in one working day. This depends on how long it takes us to diagnose and repair each one. Now we're getting somewhere! The right test equipment can cut the diagnosis time in half or less. Diagnosis is what takes the time. The actual *repair* of any TV set is a matter of replacing a resistor, capacitor, tube, etc., and should take about 5 minutes at the most.

We've run several articles on test equipment selection, and it's still a matter of personal choice. This is the way it ought to be. I've got my way of working; you've got yours. For us, they're the ones that give us the best results. That's what customers pay off on—results. Put another way, test equipment gives us what we can't get in any other way: information. Information about what's going on in a given circuit, and *why* it is happening.

As long as we have equipment that will measure the *basic* quantities we work with—ac and dc volts, resistance, capacitance and waveforms—we can add whatever specialized equipment we happen to like. The basic criteria for picking any piece of test gear is this: Will it do a certain job faster and easier? Will it save money? If the equipment meets these standards, buy it!

There's one important factor that I didn't mention: interpretation. The most elaborate test gear in the world won't *fix* a TV set. All it can do is tell us what's wrong with it, and it won't even do that unless we interpret its readings properly. The day of the "automatic set tester" is far in the future.

Correct interpretation depends on only one thing: a full, solid knowledge of the circuits in that TV chassis, all the way from one end to the other. This isn't as hard as it sounds. They are all

**This column is for your service problems—TV, radio, audio or general and industrial electronics. We answer all questions individually by mail, free of charge, and the more interesting ones will be printed here.**

**If you're really stuck, write us. We'll do our best to help you. Don't forget to enclose a stamped, self-addressed envelope. Write: Service Editor, Radio-Electronics, 154 West 14th Street, New York 10011.**

# Why does one of these men earn so much more than the other?

More brains? More ambition?

## No, just more education in electronics.

You know that two men who are the same age can work side-by-side on the same project, yet one will earn much more than the other.

Why? In most cases, simply because one man has a better knowledge of electronics than the other. In electronics, as in any technical field, you must learn more to earn more. And, because electronics keeps changing, you can never stop learning if you want to be successful.

But your job and family obligations may make it almost impossible for you to go back to school and get the additional education you need. That's why CREI Home Study Programs are developed. These programs make it possible for you to study advanced electronics at home, at your own pace, on your own schedule. You study with the assurance that what you learn can be applied on the job to make you worth more money to your employer.

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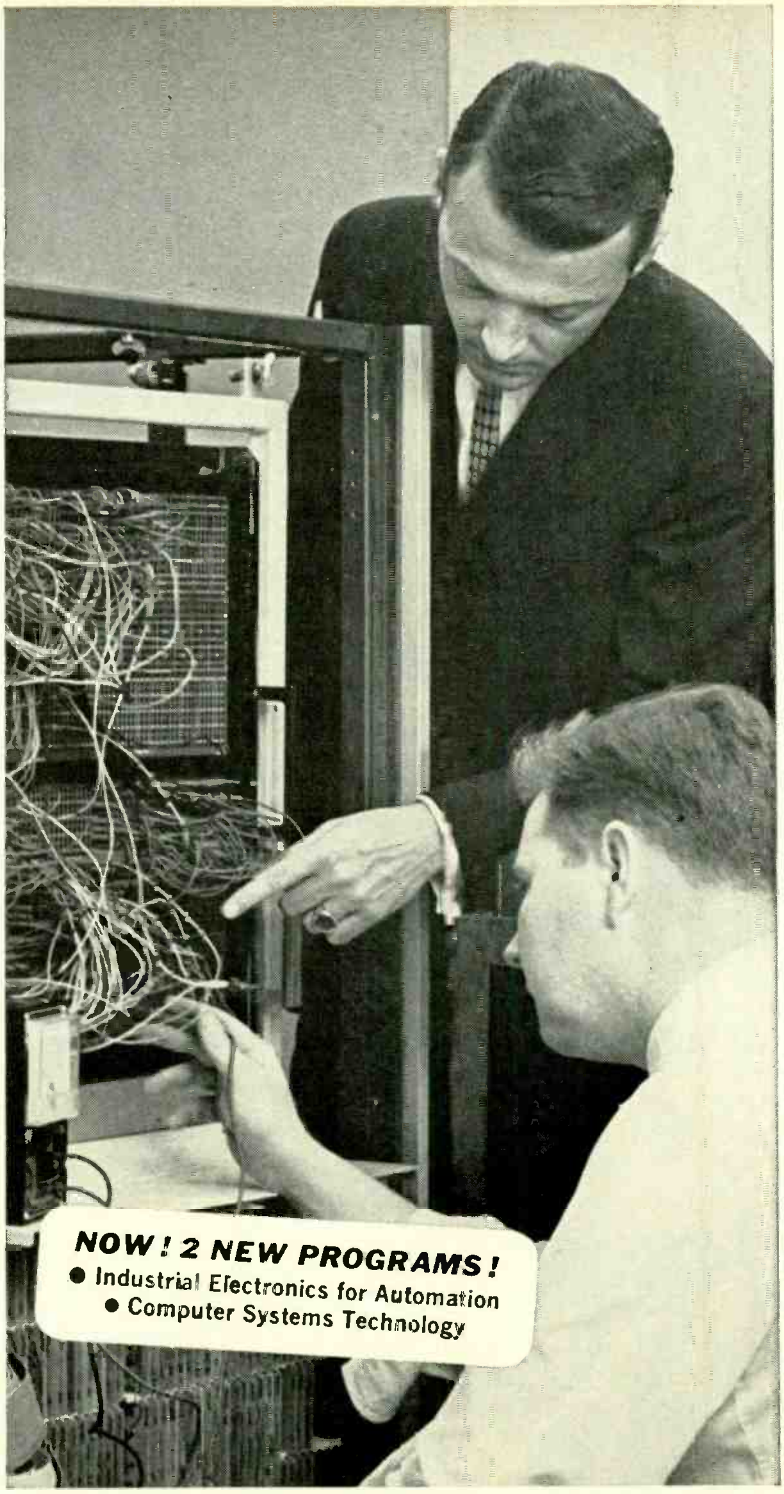

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alike. TV sets all have tuners, i.f.'s, low- and high-voltage power supplies, sync circuits and so on. Differ in details, yes, but the *basic* parts are there in all of 'em. Have to be or the thing wouldn't work! If you know the basic circuits, and how they work, you're OK. You can carry a schematic in your head and look at it any time!

Let's take a typical service job and see what equipment we need. Remember, you can always refer to the schematic you're carrying in your head. White horizontal streak across screen; no vertical sweep. Why? Well, we can eliminate several things right away. Low- and high-voltage power supplies, horizontal sweep, boost, etc. These are OK or we wouldn't have as much as we do. All we have left is a simple multivibrator circuit (in most TV sets. anyhow).

From circuit knowledge, we take a shortcut—break the circuit in half and make a test. Jump the heater of the vertical output tube to its control grid. **(Small screwdriver.)** We get about half a raster. Since the output stage does work with this small ac signal on its grid, we have eliminated half of the circuit right away. Look for trouble in the input half.

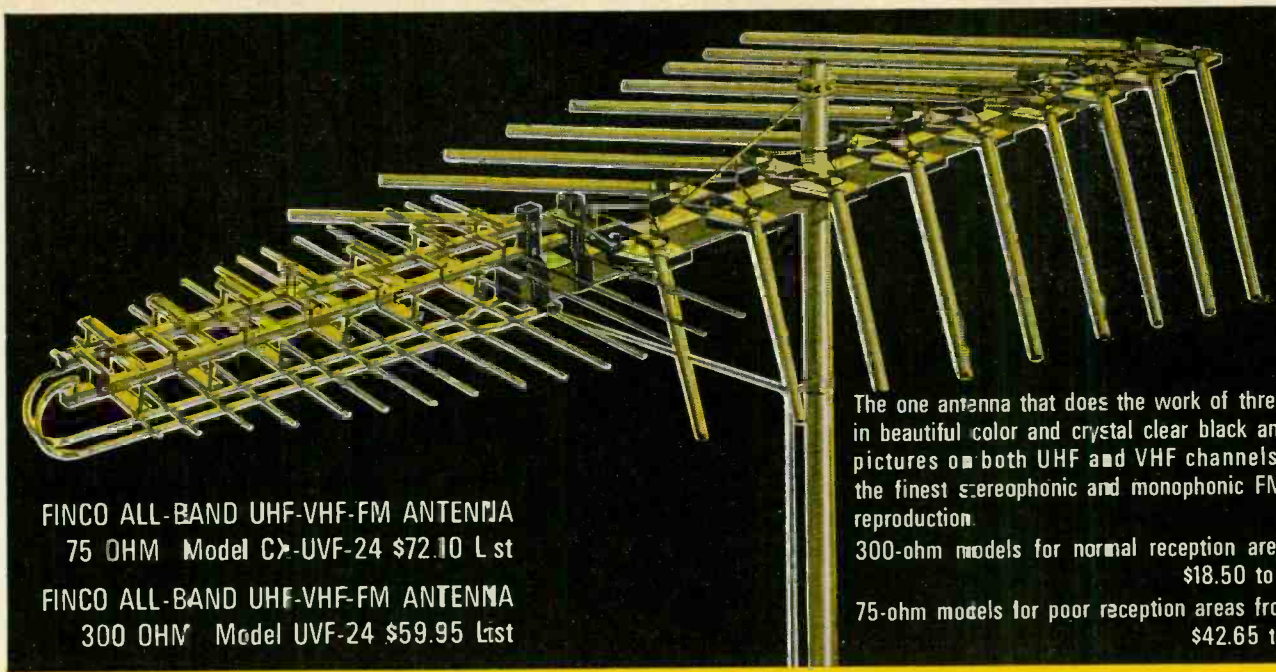
Next, we check the dc voltages on this stage. **(Dc voltmeter.)** No circuit will work properly without the correct voltages, but you would be surprised how many men forget this elementary fact. Also, anything that happens gives us a clue, by its effect on the operating voltages. It does here. The plate has a big fat 10 volts on it.

This must be a little low (joke!). Normal voltage here, through the big resistors we can see, should be from about 50 volts on up. So, we check for a short at the plate. **(Ohmmeter.)** Several megohms of resistance to ground tell us that this is not it, so we go on.

Hooking the voltmeter to the plate, we turn the set on again. The voltage comes up to about 350 volts, for this one has silicon rectifiers. The tube warms up, and down goes the plate voltage. Oh, oh! A meaningful symptom has just showed up. (Tube changed first, of course.) What makes a vacuum tube act like this? **(Circuit knowledge, vacuum-tube theory.)** A positive voltage on its grid. As the tube warms up, it draws too much current, and the voltage is dropped across those big resistors. Finding the leaky coupling capacitor **(capacitor tester)**, we replace it, and the thing works. Job done.

Here, we have used test equipment from a screwdriver to a capacitor tester, as required. Someone asks, "How about a scope?" What in thunder for? We *know* that the oscillator isn't working. All the scope could tell us in this case was what we could see with our uncalibrated eyeballs. So, it wasn't needed.

Now, with different symptoms, we



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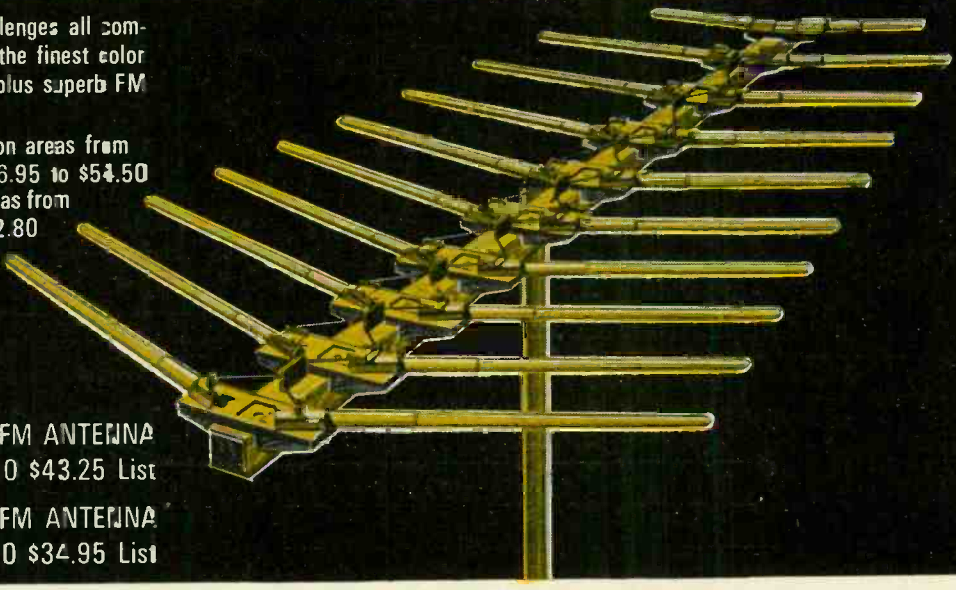

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*Circle 19 on reader's service card*

*must* use the scope. Suppose we do have raster and picture, but the picture floats calmly up and down without stopping. No sync. Our screwdriver or voltmeter isn't going to do us a bit of good here. We must find the point where the sync is getting lost. So we go to the point where it starts, in the video amplifier plate, and *follow it* **(Scope.)** through the various sync separator and sync amplifier stages till we get to where it must be on the sync input of the vertical oscillator. **(Circuit knowledge).**

We don't stop to take dc voltage or resistance measurements until we find a place where there is trouble. For example, if we have a good signal on the grid of a tube, but none on the plate, we put down the scope, and take dc voltage measurements to find out what's going on. There are times when the scope will point directly to a bad part. For another example, if we find a capacitor with plenty of sync on the input side, and none on the load side, we know the chances are very good that this capacitor is open.

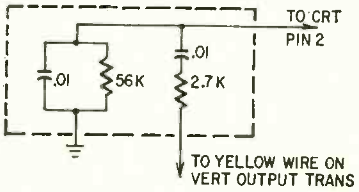
There's the usual alternative—a short on the load side—but from experience, the odds are in favor of an open capacitor, so we check that first. Incidentally, all these service techniques work just as well with transistorized circuits as with tubes.

So, after all this, I finally get to the point: See how the right use of the right test equipment can lead you directly to the trouble? In just a few logical steps, we can pin down a defect to a certain stage, then to a circuit, then to a part. To do this quickly and accurately, you're going to have to use the best test instrument of all—that little old brain of yours! Without it, no test equipment reading is any good at all!

### "Lines" in Admiral 17XP3 TV

*I've got a lot of slanting horizontal lines in an Admiral 17XP3 TV. I thought this set had retrace blanking? W. S., Norman, Okla.*

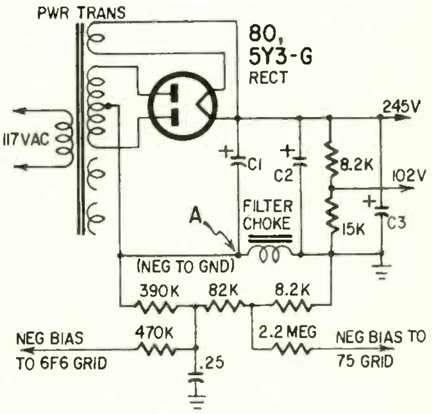
It does. The blanker is a printed-circuit plate, pretty hard to find, but it's there. If it's bad, and you can't get an exact duplicate, make up one from separate parts, as in the diagram.



### G-E 73 Radio Power Supply Circuit

*A friend(?) gave me an old GE-73 radio. The power supply has been very severely worked over—wires clipped, parts missing. I can't find a diagram of it. Can you help?—S. O., Fresno, Calif.*

Yes. Full service data on this chassis are in Rider's *Troubleshooter's Manual*, Vol. 12, page 37. This is a rather wild power supply circuit, by today's standards, but it worked. The diagram shows how it's hooked up.



They don't give the size of the electrolytics on the diagram, but I'd use something like a dual 10-$\mu$F and one separate 10-$\mu$F. The *negative* leads are separated. (See point A.) END

# Analyzing Failures in Solid-State CB Transceivers

Today, the Citizens-band transceiver is no longer a toy. It's a compact, 23-channel, solid-state unit with very sophisticated transmitter circuitry that may include electronic switching of the antenna from the transmitter to the receiver. Many units have crystal-controlled dual-conversion receivers using a frequency synthesizer. Since a typical transceiver may carry a price tag over $200, the CB user wants his unit to be repaired by an expert technician, and there is a growing need for such experts in the service industry. This article is just one of many from the *special section on CB and Communications in September* RADIO-ELECTRONICS. This feature goes on to describe some of the newer and possibly unfamiliar circuits and offers extra servicing know-how.

## SIX CB SERVICING TIPS

Experience is the best teacher and September RADIO-ELECTRONICS will bring you six unique case histories, each providing important servicing tips based on practical shop experience. A few of the problems covered include what to do when your receiver oscillator drifts and sometimes cuts off altogether; what's wrong when your equipment does not transmit, but receives OK, and clicks when the mike button is pushed; and what to do when receiver sound is intermittent and transmit audio is OK.

## COMMUNICATION PACK FOR THE FREE LANCER

Here's a unit that has everything in it except the kitchen sink. It's the Free-Lance's Communi-Pac—a complete portable communication center. The author of this exciting feature built the unit to handle specialized problems when out chasing a story. He demonstrates how you can assemble a unit to suit your individual needs. He devised the Communi-Pac as a single package to eliminate the need to lug several separate pieces of equipment. It contains a Citizens-band transceiver, a marine-band receiver, a tape recorder and an AM-FM radio. An aircraft-tower receiver that can be added as a modification is still in the planning stage. You'll find out how the unit is assembled and why particular instruments were selected—in September RADIO-ELECTRONICS.

## DO YOU UNDERSTAND SQUELCH?

Most receivers used in mobile communication have a squelch *circuit*. This applies to both auto and marine two-way radio systems. A squelch circuit does not eliminate interference noise (as does suppression, filtering, and shielding) or reduce its volume (as does a noise limiter). The squelch silences receiver hiss until a signal is received. There are only three basic ways they operate and they're all explained in clear detail in September RADIO-ELECTRONICS.

## AN ALL-PURPOSE SUB BOX

If you have ever built, wired, assembled, designed, serviced or experimented with a transistor circuit, you will have a special appreciation for this piece of test equipment. If not, file this story where you can find it the day you do your first work with transistors. It combines several test items in one compact case. Read all about it next month.

*These are just 5 of the 25 top-priority*
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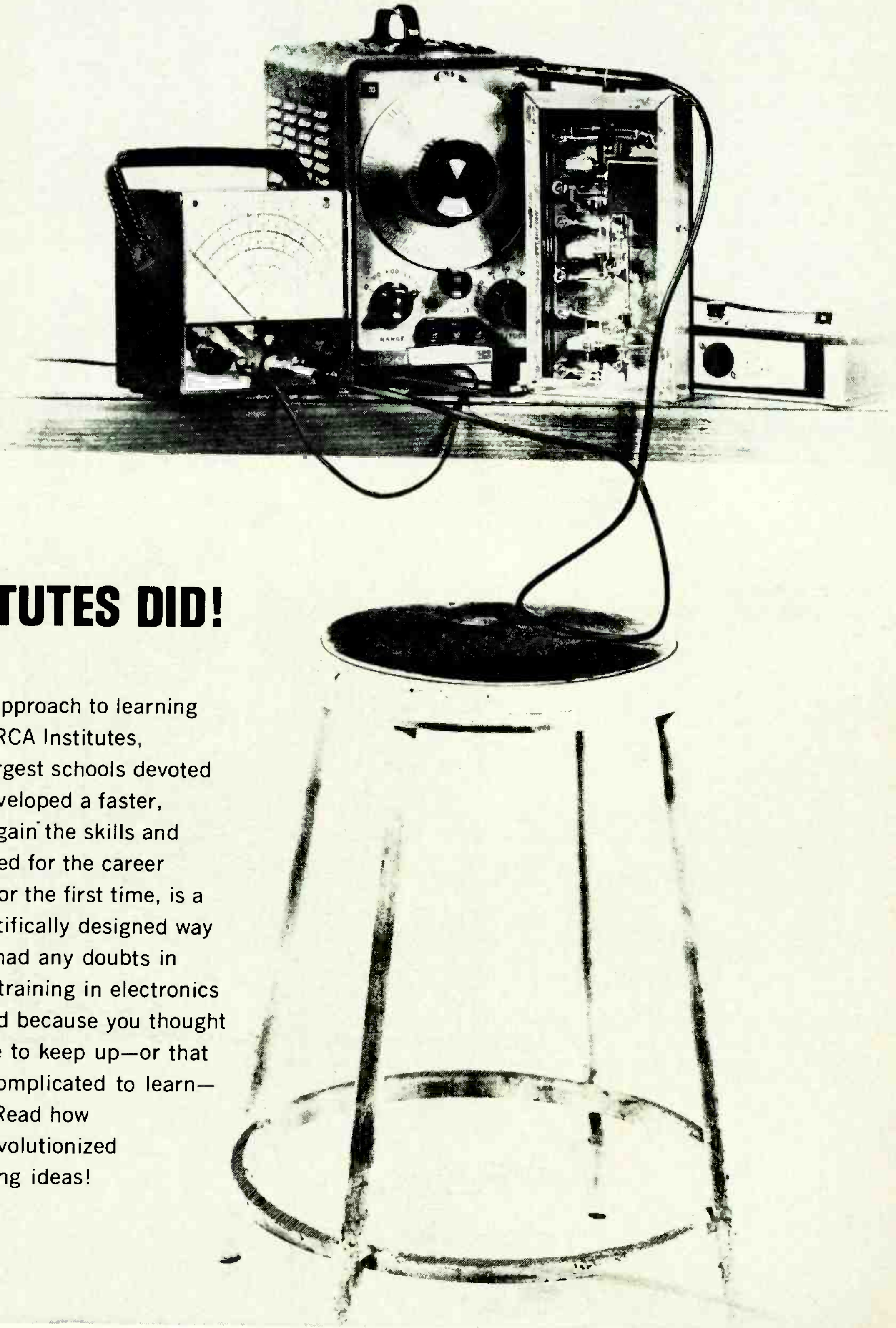

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**Radio-Electronics**
**Hugo Gernsback, Editor-in-Chief**

# Electronics Puts to Sea!

**Undersea discovery promises to be second only to space exploration in worldwide importance. Electronics is playing a significant part in opening up this new frontier. You'll want to follow this glamorous activity.**

**By CLEMENT S. PEPPER**

ON A SUNNY AFTERNOON IN EARLY MAY this year, at the Navy's Underwater Sound Laboratory at New London, Conn., two modern systems of undersea testing apparatus were officially launched: research submersible Star II and Star III were lowered into the Thames River just east of Long Island Sound.

Both vessels are slated for the fascinating field of oceanographic exploration. They carry extremely advanced undersea navigating and locating devices, sophisticated intercommunicating systems, and impressive panels of undersea testing instruments. Star III, the larger of the two, can carry up to 500 additional pounds of special testing apparatus for almost any imaginable underwater test.

For decades, scientists have been making measurements in the oceans. Only lately, however, have electronic systems really gone down into the seas as working tools. Oceanographers who venture beneath the ocean's surface have navigation and communication needs that still are not fully met by any existing system.

Topographical mapping, observing trends in currents, taking temperatures, testing salinity, and an enormous volume of other tasks were handled in years past from surface ships. This picture is changing dramatically. The ocean floor is not yet carpeted with instrumentation, but it is becoming so.

The transistor started the trend. An early application was in preamplifying hydrophone signals. Oscillator, amplifier, control and logic circuitry quickly followed. Low-cost silicon transistors—and now low-cost integrated circuits—are incorporated into buoy systems, deep-towed instrumentation vehicles, and sea-floor instrument packages. Solid-state systems have long operating lives, and require only small battery packs.

A good portion of ocean research is involved in one way or another with acoustics. Sound is so far the only means of communication and information transmission other than through cables.

But sea water isn't a very dependable carrier of sound waves. The sound waves just can't travel in nice straight lines as they do in the air.

Sound waves travel faster in denser material. Beneath the sea, sound velocity varies from about 4,700 to 5,100 feet per second, depending on water conditions. From surface to sea floor, ocean water varies in temperature, density, pressure, salinity and distribution of life. The resulting speedups and slowdowns in velocity produce almost unpredictable bends in the sound "rays." Imagine switching on the headlights of your car and seeing the beams bend away in a series of smooth curves. That is what can happen under the ocean when you aim an acoustic beam at a distant target. The beam might even split, and one part be ducted along an unseen "sound channel" for many miles.

The upper regions of the ocean consist of two temperature zones: (1) a *surface zone* subject to atmospheric influences, and (2) a *thermocline* of rapidly decreasing temperature. The surface zone is a region of thermal instability, and it is here that sound-path predictions are not only important but difficult to produce.

Underwater sound is also affected by reflection. Upward-traveling sound waves are reflected into the sea at the surface. Since the surface is in constant motion, the reflections occur in all directions. Some of the reflected sound gets back to the source as reverberation. From the sea floor, smooth sand reflects sound very effectively, whereas soft mud is especially poor. Not surprisingly, a smooth rock bottom is best.

Another problem in sonic communications underwater is background noise—any sound that interferes with the reception of the wanted signal. *Self-noise* originates in the testing equipment and its platform (ship, buoy, etc.). *Ambient noise* originates in the sea. In the deep ocean, the predominant source is the combined effect of waves, wind and rain at the surface. In coastal waters, snapping shrimp and certain fish can become so conversational at times as to drown out all other sounds.

*Newest submersible, the Star III, is scheduled for undersea retrieval operations, as well as for use in oceanographic research.*

**Chart I—Manned Research Submersibles**

| Name | Manufacturer | Crew | Depth (ft) |
|---|---|---|---|
| Aluminaut | Reynolds Alum. Co. | 3 | 15,000 |
| Alvin | Litton Industries | 3 | 6,000 |
| Asherah | Electric Boat Div., General Dynamics | 2 | 600 |
| Benthos | Corning | | 30,000 |
| Cubmarine | Perry Submarine | 2 | 600 |
| Deep Star | Westinghouse | 3 | 4,000 |
| Deep Quest | Lockheed Missiles & Space Co. | 4 | 6,000 |
| Pisces | International Hydrodynamics Co., Ltd. | 2 | 5,000 |
| Star I | Electric Boat Div., General Dynamics | 1 | 200 |
| Star II | Electric Boat Div., General Dynamics | 2 | 1,200 |
| Star III | Electric Boat Div., General Dynamics | 2 | 2,000 |

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**Automatic Controls.** Prepares you to be an Automatic Controls Electronics Technician; Industrial Laboratory Technician; Maintenance Technician; Field Engineer.

**Digital Techniques.** For a career as a Digital Techniques Electronics Technician; Industrial Electronics Technician; Industrial Laboratory Technician.

**Telecommunications.** For a job as TV Station Engineer, Mobile Communications Technician, Marine Radio Technician.

**Industrial Electronics.** For jobs as Industrial Electronics Technicians; Field Engineers; Maintenance Technicians; Industrial Laboratory Technicians.

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### Other research

Much ocean research is not related to acoustics. Electronic instruments abound.

Some oceanographers study water temperature, salinity, density and the movements of currents through electronic sensors and recorders.

A number of institutions are seeking fuller knowledge of the geology of the sea floor. In seismic experiments, sound waves passing through the ocean's underlying structure are carefully recorded. High-precision echo sounders make detailed graphic displays of rock and sediment layers.

Thermistor probes measure temperature differences at the sea/sea-floor interface and to a sediment depth of several feet, for heat-flow studies. Proton-precision magnetometer sensors towed behind ships detect variances in the magnetic field of the earth.

Acoustic pingers, attached to coring devices, heat-flow probes, and deep-sea cameras monitor the descent of the equipment and permit highly accurate measurement of their depth for intricate control, even in very deep water under adverse sea conditions.

### Government projects

The oceans have always been vital to defense. Antisubmarine warfare (ASW) is an important part of the Navy's job of protecting the oceans. To keep up and improve ASW weapons and systems, the Navy spends $2.5 billion a year. About $5 million of it is spent on research and development, much channeled into industrial and university laboratories all over the country, often in programs aimed only at pure scientific research.

At sea, the Navy gathers data by an extensive network of station ships, ships passing through, ocean buoys, and aircraft. All this material is transferred through communication centers to data-processing units for analysis. The centers provide detailed charts forecasting sea-surface temperature, layer depths, vertical gradients, detection ranges, sonar environmental factors.

Another important Navy project has been the development of a deep-ocean test range for submarines, their weapons, and ASW devices. The project, termed AUTEC, is located in the Tongue of the Ocean, a deep-water channel just east of Andros Island in the Bahamas. The Navy will be able to test several systems simultaneously over a vast area in water that varies from 4,200 to 6,000 feet in depth.

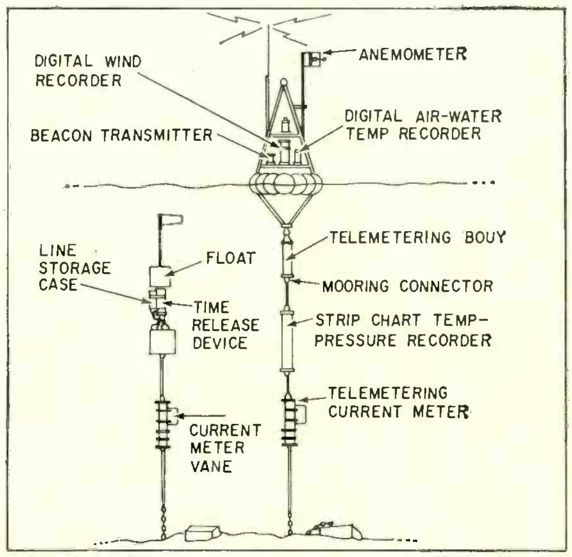
Consider the work that had to be done to develop this range. About 100 sediment cores were taken and analyzed. Bottom photographs were made, many of them stereo. Some 10,000 temperature and salinity observations were made, time-and-space related by simultaneous recordings using a number of ships. Subsurface moored buoys telemetered temperature, pressure and sound-velocity readings to shore stations. A thorough study was made of ocean currents from surface to floor. All this took thousands of dollars' worth of test instruments.

### Role of electronics

Oceanic work is also sponsored by other agencies of the Federal Government, and by state universities, scientific institutions, and commercial concerns. There is intense interest in sea-floor minerals, the oil that underlies the continental shelves, sea food, and water sports. About 25 bills related to undersea projects were placed before Congress last year. There has even been talk of a Federal agency comparable to NASA to coordinate and direct the underseas effort.

Nothing like the sums associated with the space effort has been spent on underseas exploration. But the tempo of activity is rising and this low-budget picture is changing.

*Rugged ocean buoys, carrying widely assorted instrumentation, are stationed in remote unattended spots.*



*Surface buoy (right) with weather-reporting devices, homing transmitter, air-water temperature indicator, telemetering system. Subsurface unit (left) carries fewer instruments, but is more protected.*

Instrumentation emphasis is on systems which collect diverse data automatically for long periods of time—frequently from moving ships, often on the sea floor itself. Analog data may be displayed graphically on chart recorders. Digital systems store data in more compact form, transmit it with fewer errors, and record for longer time intervals on less power.

Keep in mind, too, the unorthodox environment this equipment has to live in. Sea water is very corrosive. Metal containers must be protected by anodizing, epoxy coatings, or protective paints. It's cold—just above freezing everywhere below the surface zones. The waters are alive with tiny creatures possessed with peculiar appetites.

There are no electrical outlets on the sea floor. Circuits have to manage on microamperes for long-term operation from battery packs.

Pressure at depth is enormous: at 20,000 feet the pressure is 8,800 lb on every square inch of exposed surface. Total force on a typical instrument container may be millions of pounds. The majority of undersea electronic testing instruments are housed in pressure cases of stainless steel or aluminum. For use near the surface, some are packaged in epoxy. Where pressure is not too great, some devices may be in oil-filled containers vented to the sea.

Much research is being done to develop electronics parts which can themselves be subjected to great ocean pressures without harm. A number of semiconductor chips and thin-film devices are used in this way. Surprisingly, a number of ordinary commercial resistors, capacitors and other components can take considerable pressure. Electrical connectors and cables capable of withstanding 20,000 psi (lb per square inch) for long periods are made by several companies.

### Undersea test instruments

One basic measurement package is shown at right top in the photo. The instruments measure pressures, temperature and salinity. Pressure measurement provides depth information, since the other two must be measured at known depths. Such precise measurements are required for accurate predictions of sound velocity at specific locations and depths.

In the salinometer, true salinity is measured. Sensors built into the unit make direct compensation for temperature and pressure.

Each device in this package employs a Paraloc (a Bisset-Berman trade name) oscillator. The salinometer circuit is diagramed at right (center). A sea-water loop connects two toroids. The resistance of this sea-water loop will vary with salinity, temperature and pressure. The toroids are part of the Paraloc oscillator's frequency-determining circuit, and the loop's resistance variations result in corresponding frequency variations. The temperature- and pressure-compensating networks are also part of the frequency-determining circuit.

The top-mounted unit you see in the photo (right, top) is a frequency mixer and telemetering transmitter. The various sensor outputs are multiplexed and sent up a cable to receiving equipment on a ship. FM detectors develop proportional dc signals to drive recorder styli.

Wave-measuring systems are important in developing harbors and beaches, as well as in learning about the formation and distribution of ocean-wave patterns. Wave movements are sensed by differential-pressure transducers (right, bottom) with built-in hydraulic filters. The filter time constant can be adjusted to detect the type of wave it is to observe. For example, sea swells which produce rapid pressure changes can be recorded while slowly changing pressures, such as those produced by tides, have negligible effect. The pressure waves are converted to electrical signals by a resistance-type strain gage. A typical strain gage has a resistance of 350 ohms and an output of 25 mV full scale, and can measure waves 22 feet from trough to crest.

Instrumentation-buoy systems can record data on magnetic tape for computer input. In one, a subsurface buoy is attached to a short line so that the anchor holds it below the surface. This protects it from storms, collisions and curiosity seekers. A locating buoy rides on the surface.

One firm has developed a digital instrumentation system that can be adapted to record just about any parameter you might wish to measure. Data are recorded in digital form by light pulses on camera film or magnetically on tape. The film or tapes can be processed to provide the researcher with a graphic plot, decimal printout, or magnetic tape that fits his own data systems.

Ocean-current meters are important to the interpretation of other data being gathered. The one shown on the opposite page (center, left) is a common type. The current sensor is a Savonious rotor, used almost universally because of its simplicity, reliability and accuracy. The rotor is linear up to about 5 knots and accurate within 0.1 knot, depending on the electronics. Inside the case are follower units: The vane follower drives a binary encoding disc, which is interposed between a light source and fiber-optic light-pipes. The light-transmitting pipes pass light "bits" developed by the disc to the camera. The rotor-follower gear train drives a cylindrical light chopper, perforated so that a pulse is generated on each first and tenth revolution. Another set of light pipes carries this information to the camera.

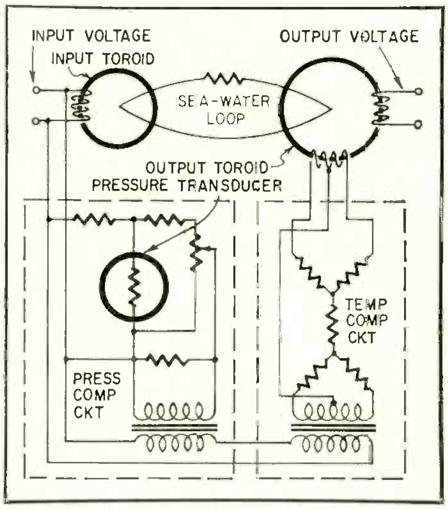
All data are recorded on standard 16-mm film. One hundred feet of film permits 5,000 minutes of recording rotor speed, plus vane and compass direction. The film advances 0.24 inch per minute, but only when directed to do so by the precision clock timer. Battery life is based on using the 100 feet of film over an interval of one year.

### In the really deep

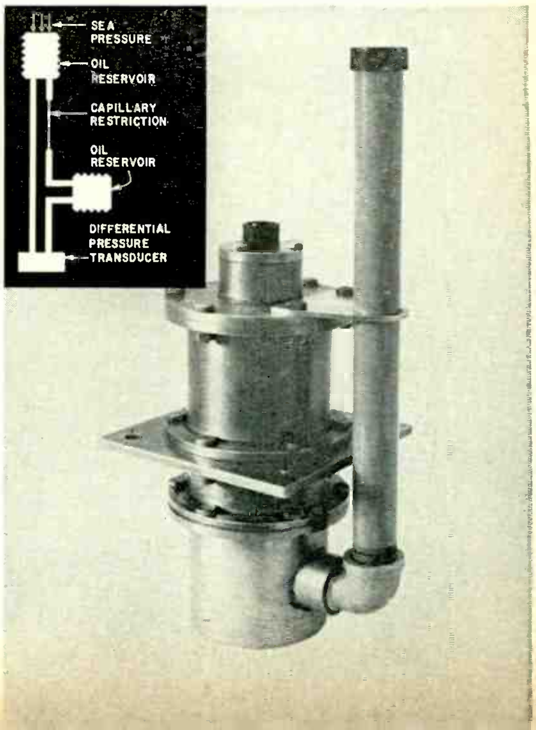
A number of government and university laboratories are developing deep-ocean test instruments. The Deep-Tow system (right, top) of the Scripps Institution of Oceanography is a general-purpose instrument vehicle operating close to the sea floor. Several sensors observe bottom and near-bottom conditions in fine detail. Instruments can measure magnetic field, pressure, temperature, vehicle pitch and roll, differential pressure, and water velocity. Some of these measurements are vehicle-position information; the remainder are scientific data. Instrumentation can be revised as specific data needs arise.

The vehicle may be towed to within 100 feet of the bottom in water many thousands of feet deep. This imposes positioning problems, since the two cables may be as much as 30,000 feet long. What's more, all power for the electronics, control signals and data signals must be carried in the tow cable. This cable is electrically equivalent to RG-58/U coax, with an added outer braid of tough stainless steel. The cable length causes great

*Instrument package used beneath the sea telemeters its measurements to surface by FM. Schematic (below) is transmitting circuit for measuring the salinity of the sea water.*



*Hydraulic filter in this pressure transducer is adjustable, selects period of wave measured.*



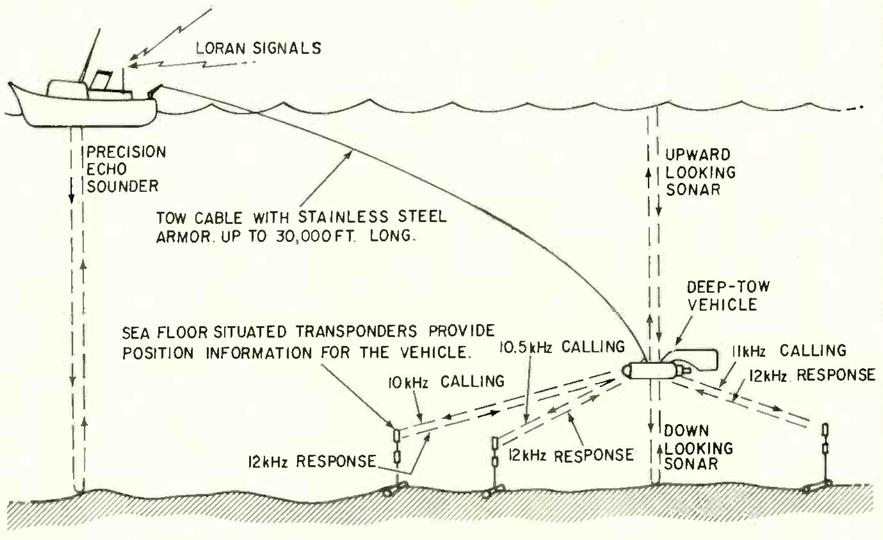
signal loss, overcome by boosting the input. High-level control signals go down simultaneously as weak data signals come up—a potentially serious crosstalk situation. Signals are carried on FM and SSB with a frequency span from 500 Hz to 235 kHz. Ingenious circuitry detects which way signals are traveling on the line and picks out the weak incoming signals even in the presence of high-intensity outgoing signals.

The accuracy of the data obtained depends, not only on the quality of the sensors, but equally on knowledge of how the vehicle is oriented and of its "swimming" patterns. Assume for example that the bottom is flat and 100 feet below. If the vehicle path follows a low-frequency oscillation of 10-foot peak-to-peak vertical amplitude, the uncorrected data for the sea floor will appear to have a rolling characteristic identical to the oscillation. Pitch and roll accelerometers and a highly sensitive differential-pressure gage keep the shipboard circuits informed of what is going on below. Timing corrections are made to the gating signals for the scanning sonar, and the graphic recorder is automatically corrected to reveal measurements for the flat bottom as they really are.

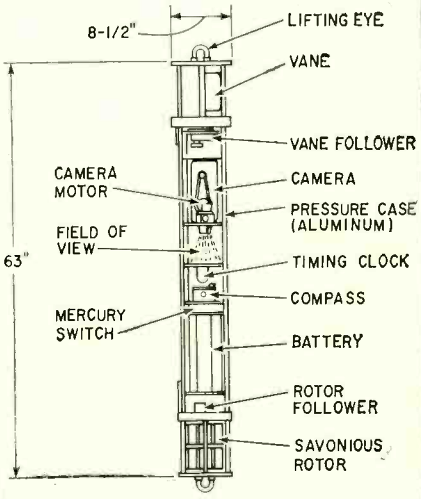
The data obtained from Deep-Tow or any other submersible are of little value unless the exact location of the submerged vehicle is accurately known. A transponder system provides vehicle-position information. The transponders are interrogated by the towship with a 3-msec pulse on separate calling frequencies, and answer on identical response frequencies. Relative vehicle position is determined by comparing round-trip times to each transponder. Reliable range is a good 5 miles. More sophisticated systems, such as used on the new Star II and Star III, tie into the surface-ship Loran system to give precise geographic locations.

A deep-sea *instruments capsule* (above, right) measures and records deep-sea tides and temperatures. The unit is designed to fall freely from a surface ship in depths up to 20,000 feet, remain on the bottom from several days to several months, then return to the surface upon command from the ship. Two 21-inch-diameter aluminum spheres (with 1-inch walls that can withstand the 9,000-psi pressure) house the instruments and provide buoyancy. Lead-acid automobile batteries, mounted on an angle-iron frame and connected to the spheres by 60 feet of cable, provide ballast and power. The capsule is recalled from the bottom by a coded acoustical signal from the ship, which activates an explosive disconnect from the battery ballast.

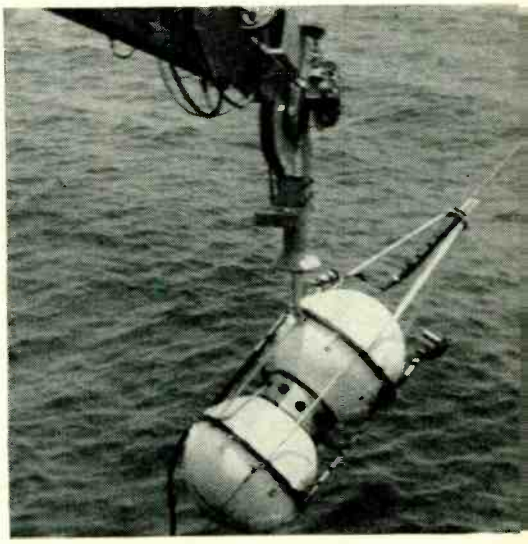
To recover a deep-sea capsule, the ship is navigated by Loran to within 5 miles of the capsule on the bottom.



*Deep-Tow project uses underwater "fish" on end of cable up to 6 miles long. Also diagramed here are sonar depth-finding devices and transponder position indicators.*



*System for measuring ocean currents and their directions and reporting them to surface ship. FM transmitter is used.*



*Instrument capsule for deep-sea measurements is held at depth by heavy battery pack (not shown). Marker buoy relocates.*

A pinger attached to the top sphere transmits short acoustical pulses to provide a homing signal received by directional hydrophones to guide the ship to a position directly above the capsule. The pinger's pulse rate is also programed by devices in the capsule to indicate whether or not the instruments are recording properly, leaks have developed, release commands have been received, and whether or not the ballast was released. Upon its return to the surface, the capsule is located by a directional range finder and flashing light.

## Undersea electronics' future

A number of well-known institutions and government agencies support research projects. About 6,000 companies provide and use the electronic items needed to probe the ocean deeps. Altogether, business in the oceans is worth some $3 billion each year, and going up.

Technicians and engineers design, build, test, use, repair and maintain thousands of dollars' worth of undersea test instruments. And many more thousands of dollars are spent for instruments to keep the undersea stuff operating—oscilloscopes, voltmeters and the like.

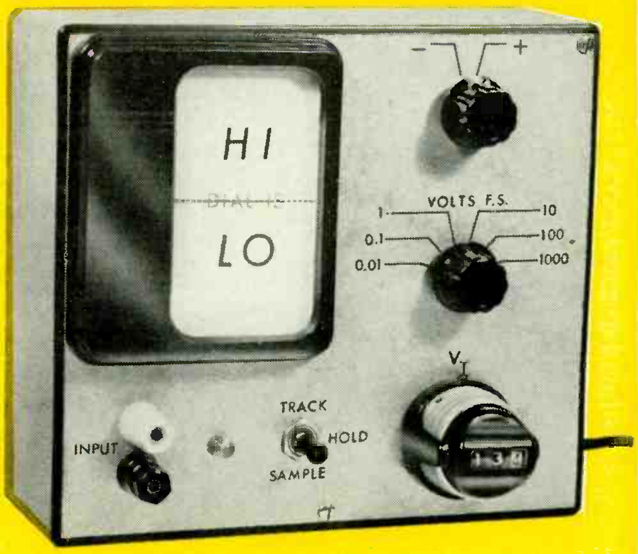
Manufacturers of deep-sea electronic instruments say their most valuable asset is know-how. That means people. Opportunities for topnotch technicians and engineers are excellent.

Only a few years have passed since the first Vanguard flew into orbit—and a giant industry was born. But nobody lives on the moon, nor will for a while. Meanwhile, the ocean covers 70.8% of our world. A source of food, of mineral wealth, of scientific knowledge just waiting to be developed . . . by electronics! END

# The Poor Man's Digital Voltmeter

**By CARL DAVID TODD**

**Many of the advantages of a lab digital-reading voltmeter can be yours with this unique instrument—at one-fifth to one-tenth the price!**



IF YOU'RE A SERIOUS EXPERIMENTER OR CIRCUIT DESIGNER, you've certainly had times when you wanted to measure voltages with a little better precision (or at least better resolution) than you could with the usual vom or vtvm. It would also be helpful if the meter had a built-in memory and could indicate even slight changes in the voltage under test.

These wishes can be granted with a digital voltmeter (dvm), but the price of even the cheapest is well beyond the means of most experimenters and small electronic laboratories.

The Poor Man's Digital Voltmeter, or pmdvm, meets both those demands at a price of less than $65 with all-new components. With a little shopping and some help from the junk box, the cost can be held to less than $20.

The Poor Man's Digital Voltmeter measures voltages to three digits with an overall accuracy of better than 0.5% if properly calibrated. The sensitivity is 1 megohm per volt and the range of about 1 mV to 1,000 V covers most requirements.

The instrument is rugged and will withstand very severe overloads without damage or shifting calibration for more than a few seconds. Full operating accuracy comes with only 10 to 30 seconds warmup. The instrument is small enough to be carried around. In addition to providing the increased accuracy and resolution, digital readout decreases fatigue, with its possible errors, from continual interpolation of meter readings. It also eliminates parallax (viewing-angle) error.

The pmdvm does not claim the accuracy possible with more sophisticated digital voltmeters, but it will serve the purpose in many applications and illustrates the basic principles used by its more expensive cousins.

## How a dvm works

Let's look inside the usual digital voltmeter and see just what happens when it is used to read a voltage.

There are three main sections in the dvm (Fig. 1): a precisely adjustable voltage, an indicator, and a comparator.

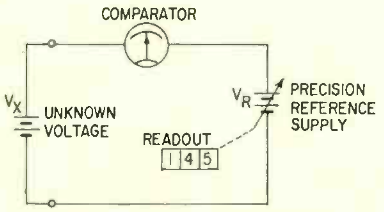


*Fig. 1—(Above) Basic operation of digital voltmeter.*

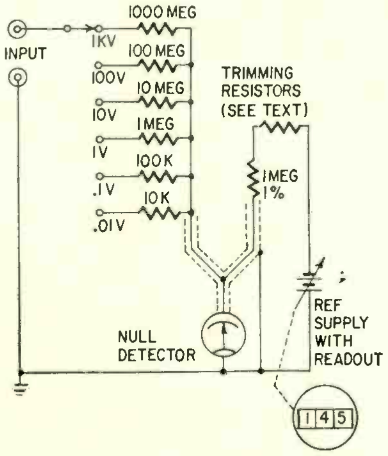


*Fig. 2—(Center) Basic circuit of "Poor Man's" version.*

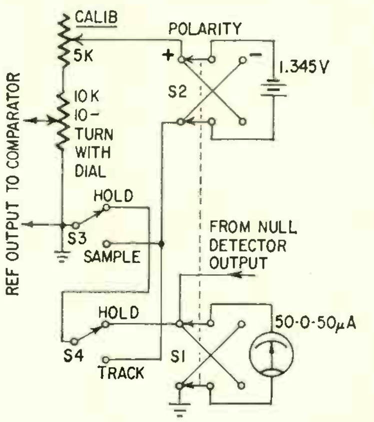


*Fig. 3—(Far right) The reference supply and polarity switching.*

The precision reference supply must be a very stable source of voltage adjustable to equal exactly the unknown input voltage, for the simplified case shown in Fig. 1. Attenuators and voltage dividers are normally added to expand the range of a single reference supply.

The indicator or readout section indicates the equivalent value of the output of the reference supply. This is usually done by lighting lamps to illuminate digits in a dial display.

The comparator must decide when the precision reference supply has been correctly adjusted to a value exactly equal to the unknown input voltage.

In operation, the precision reference supply is varied automatically until the comparator indicates equality of the reference and unknown voltages. When the two voltages are the same, the adjustment stops and the readout indicating the value of the reference supply voltage now indicates also the value of the unknown voltage.

The actual manner in which the reference supply is varied may fall into one of several general approaches such as a voltage ramp, binary to analog converter, etc. The comparator may also have one of several possible forms but the basic operations just described are accomplished in one way or another.

### The poor man's approach

We can greatly simplify the dvm by substituting a man for much of the automatic adjusting circuitry. The operator can adjust the reference supply voltage by hand until the comparator circuit indicates that the output voltage equals the input voltage.

All we really need, then, is a power supply that we can adjust with a knob, and that will indicate the output voltage accurately. The comparator must be sensitive enough to indicate small errors. It can drive a simple meter movement.

In the pmdvm, we have a variable voltage supply that can be adjusted with a 10-turn potentiometer. The pot has a dial that indicates the position of the wiper in digits, and thus the output voltage. A very sensitive null detector drives a center-scale meter movement. Other features are added to make the instrument more useful.

The schematic (Fig. 2) looks much different from the block diagram in Fig. 1. Actually, it is the same except for the use of a shunt or summing method for the comparator. We could use the direct or series comparison method, but the differential null detector required would be more complex and expensive than the single-sided circuit used in the pmdvm.

**AN R-E EDITOR REPORTS ON THE PMDVM**

"The digital voltmeter was tried on voltages varying from 1.5 to several hundred, and found through these ranges to compare favorably with an ordinary vtvm.

"One effect not seen in vtvm's was noted: the meter was affected by any ac component of the voltage measured; thus, with points where there was considerable ac in addition to the dc voltage, the meter might read higher than normal (or with prods reversed, lower). The author suggests that this might be eliminated by using the isolating probe he describes in his article, and points out that this effect is due to the 60-Hz chopper and is presumably much more noticeable on 60-Hz ripple than on ac of other frequencies."

To see how it works, assume that we have an input voltage of +1.45 we wish to measure. This will produce a positive current in the null detector of 145 nA, if we can assume that the null detector input voltage will be kept very low in comparison with the voltage under test. If we adjust the reference supply until a negative current, also 145 nA, is injected into the null detector, the net sum of the currents is zero and the meter will indicate a null or zero. The dial on the reference-supply pot would indicate the digits 1, 4 and 5, and the reference supply would actually be delivering 0.145 V into the 1-megohm resistor.

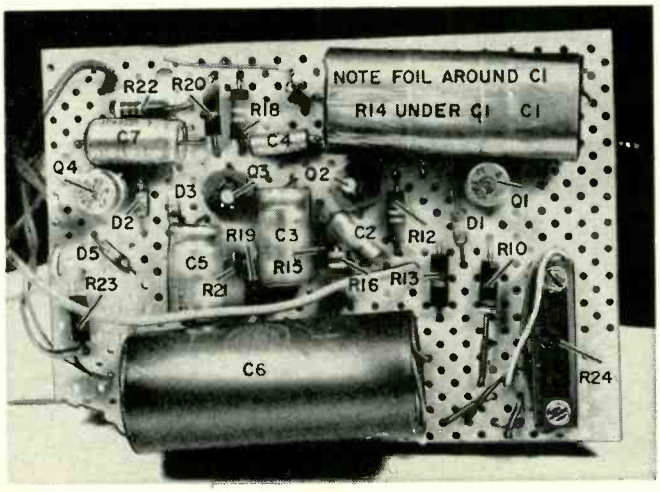
Let's take a close look at the detailed circuit diagram for the reference power supply (Fig. 3). The power source is a single mercury cell, a very economical way to get a fairly accurate and quite stable reference voltage.

A calibrate potentiometer in series with the mercury cell and the adjustment potentiometer divider drops the excess battery voltage beyond the 1 volt desired across the pot. It also compensates for slight errors in resistor tolerances and other factors.

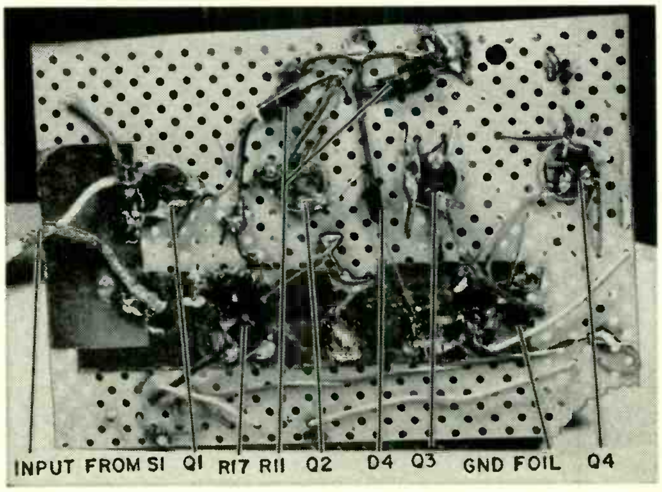
A reversing switch, S2, is included so that we can change the polarity of the reference supply and meter current and hence the polarity of the input signal that may be measured.

Switches S3 and S4 are shown in their normal (HOLD) position, from which they are changed only when we wish to read an input voltage. S3 is a spring-return switch and samples the input voltage by completing the reference-supply ground-return path and removing the shunt path from the null detector meter. This saves the battery when it is not actually needed to supply a reference. It also prevents continual overdrive of the meter movement when the input and reference voltages are unequal and producing a net current into the null detector.

*Circuit board has most chopper and amplifier components on top.*



*Foil under circuit board provides shielding and ground points.*



S4 does exactly the same thing as sampling switch S3, but allows the instrument to be actively measuring the input voltage for a time without requiring that we hold S3 down. This mode is referred to as *tracking*.

These two switches are combined into a single READ switch with a toggle action on one side of center and momentary action on the other.

The potentiometer is a 10-turn type with a tolerance of 5% in end-to-end resistance. This error is compensated for in the calibration adjustment. More important is its linearity, usually 0.25%, but available better than .05%. The indicating dial can be one of the simpler designs made for 10-turn potentiometers, or one of the more elaborate units with in-line digital readout as shown in the photograph of the complete unit.

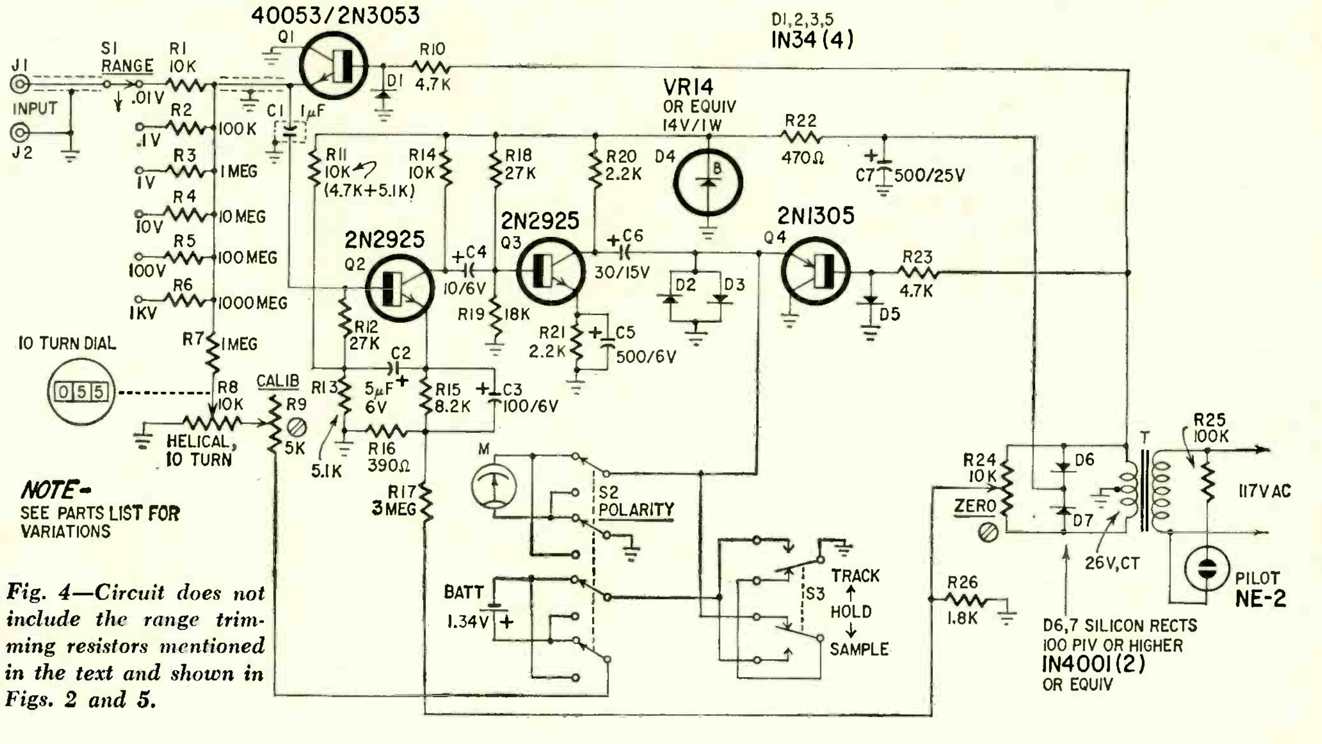
The schematic diagram of the null detector circuit used for the comparator is shown in Fig. 4, the complete schematic. Basically, this is a two-stage transistor amplifier (Q2, Q3) with a shunt chopper–modulator (Q1) before it and a shunt synchronous detector (Q4) following it.

Q1, used as a chopper, is connected in an *inverted* mode —that is, its emitter and collector terminals are transposed. As the base of Q1 is driven alternately positive and negative, it will be turned off and on accordingly. When Q1 is conducting or on, the net input current applied to the null detector is shunted to ground. The current is applied to the amplifier during the half-cycle that Q1 is turned off.

The result is a pulsating dc voltage between the emitter and collector terminals of the chopper transistor. It is coupled to the transistor amplifier through C1.

The amplifier, Q2 and Q3, is a conventional R-C-coupled circuit, except that in the first stage the base bias voltage is applied through R12, which has one end bootstrapped up by signal voltage obtained from the emitter of Q1. The signal at the emitter is in phase with the input voltage and about equal in amplitude. This technique decreases the loading effect base-biasing resistor R12 has on the input resistance of the amplifier.

An error signal from the ac power supply is applied to the emitter of Q2 via R24 and R17. This allows us to adjust

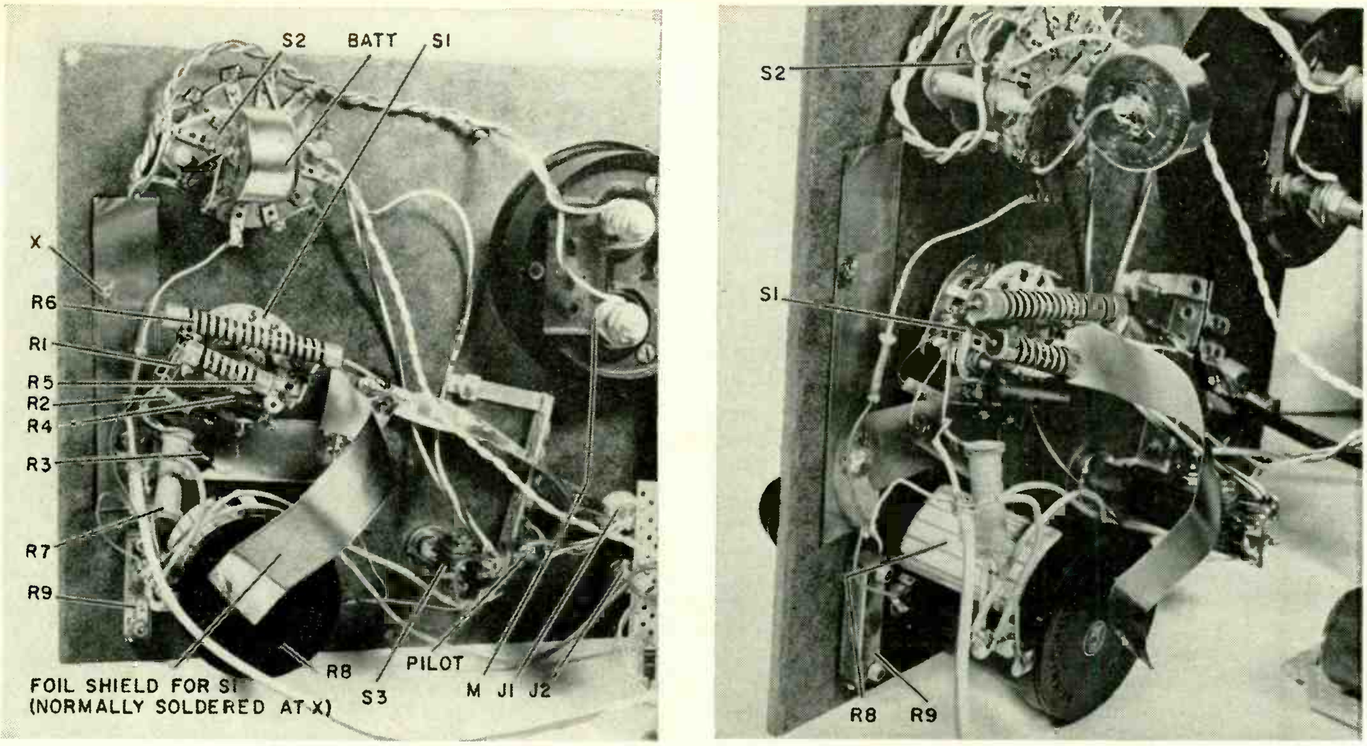


**NOTE-**
SEE PARTS LIST FOR VARIATIONS

*Fig. 4—Circuit does not include the range trimming resistors mentioned in the text and shown in Figs. 2 and 5.*

BATT—1.345-volt mercury cell (Mallory RM-4R)
C1—1 µF, 100 volts (Sprague "Vitamin Q" low-leakage paper type 96P10591S2 or equivalent)
C2—5 µF, 6 volts
C3—100 µF, 6 volts
C4—10 µF, 6 volts
C5—500 µF, 6 volts
C6—25 µF, 16 volts
C7—500 µF, 25 volts
**Capacitors C2 through C7 are electrolytic.**
D1, D2, D3, D5—germanium diode: 1N270, 1N34
D4—Zener diode, 14 volts, 1 watt (Sarkes Tarzian VR14 or similar)
D6, D7—silicon rectifiers, 100 piv or higher, any current rating (1N4001, 1N1692, 1N3754, etc.)
J1, J2—jack-top (5-way) binding posts
M—zero-center microammeter, 75–0–75 µA or higher sensitivity (Simpson 27, Triplett 321T, etc.) 100–0–100-µA meter can be used with very slight loss of sensitivity.
Q1—2N3053 (RCA) (Not all similar n-p-n silicon transistors behave well as choppers. Be careful with substitute types.)
Q2, Q3—2N2925 (G-E)
Q4—2N1305 (RCA, TI, Motorola) (Almost any medium-to high-gain p-n-p germanium will work)
R1—10,000 ohms, 1%, 1 watt (Texas Instruments CD1MR)
R2—100,000 ohms, 1% (Texas Instruments CD½MR)
R3, R7—1 megohm, 1% (Texas Instruments CD½MR)
R4—10 megohms, 1% (Texas Instruments CD1R)
R5—100 megohms, 2% (Aerovox CPX-2) (Newark)
R6—1,000 megohms, 3% (Victoreen HVAW)
R8—10-turn helical potentiometer, 10,000 ohms, with digital turns-counting dial. Author used Bourns 3500S, 3% tolerance wirewound, with Borg (Amphenol) 1310 dial. Spectrol 30-1-11 dial is cheaper
R9—pot, 5,000 ohms (author used Bourns Trimpot type 3607-S but cheaper Trimpots or ordinary pots should do as well)
R10, R23—4,700 ohms, 10%
R11, R14—10,000 ohms
R12, R18—27,000 ohms
R13—5,100 ohms
R15—8,200 ohms
R16—390 ohms
R17—3 megohms
R19—18,000 ohms
R20, R21—2,200 ohms
R22—470 ohms, 10%
R24—pot, 10,000 ohms (see Information with R9)
R25—100,000 ohms, 10%
R26—1,800 ohms, 10%
**All resistors ½ watt, 5% except as indicated**
S1—2-pole, 6-position rotary non-shorting, ceramic (Centralab 2003 or equivalent). Single-pole switch can be used if trimming resistors (see text) are not needed
S2—4-pole, 2-position (Centralab 1450 or equivalent)
S3—dpdt center-off, one side positive (locking), other side spring-return (2 sets of form C contacts, one set normally open, the other normally closed. Switchcraft 29306 or equivalent)
T—power or filament transformer, approximate 26 vct, any current rating (Triad F40X or similar)
Miscellaneous hardware, cabinet, line cord

**Circuit boards for the pmdvm are available from the author, C. D. Todd, 2270 Meyer Place, Costa Mesa, Calif. 92627 for $5.90 postpaid. Ask for board PMDVM-1.**



*Panel wiring views. Foil shield was partly removed to show range switch. Corona dope or other high-dielectric-strength varnish may help in humid climates to reduce leakage across switch and 1,000-meg resistor. Shafts of R8 and S1 must be grounded.*

the output voltage to zero even though the chopper stage is somewhat imperfect and generates a very small ac voltage even when there is no input. The zero adjustment will also compensate for small amounts of hum pickup at the input which would otherwise look like an input signal.

The output of the amplifier is capacitively coupled to a shunt demodulator which acts like a rectifier but whose conduction is controlled by the drive current applied to the base of Q4, rather than the polarity of the ac voltage across it. This arrangement produces an average output current that is of one polarity if the base drive is in phase with the ac collector voltage of Q3, and of the opposite polarity if the amplifier output voltage is out of phase with the drive signal. This is done to retain a sense of polarity of the dc input current.

Note that no attempt is made to control carefully the voltage gain of the amplifier. We want the gain to be as high as possible since we are interested merely in determining whether an input current is present and, if so, of what polarity.

Germanium diodes D2 and D3 are placed across the meter to limit the maximum current through it to about three times the full-scale value and thus prevent damage during a substantial unbalance.

The simple power supply produces power for the null detector as well as the two-phase ac signal needed for the zero-adjustment circuit. Zener diode D4 is used not so much for dc regulation as to remove ripple. It can be replaced by a 2,000-$\mu$F capacitor if desired.

Since the null detector cares only how much net input current it is receiving, the summing resistor for the input voltage can be made variable for range switching. Since the voltage from the reference power supply is variable up to 1 volt, the full-scale current is 1 $\mu$A. Thus we have an input sensitivity of 1 megohm per volt. Six ranges (R1–R6) are calculated on this basis.

R1 through R6 are specified as precision units. However, their exact values are not as important as the fact that they must have a very close decade relation to each other for high accuracy on each range.

The range-switching scheme in Fig. 5 permits you to use multiplier resistors (R1 through R6) that are not exact multiples of 10 by switching in small "trimmer" resistors in series with R7 and R8. This allows for individual compensation of the voltage ranges. The values are selected for correct full-scale calibration on all ranges with just one setting of the calibrate control. The trimmer resistors will normally be only a few percent of the value of R7 so ordinary carbon-composition units can be used.

Physical layout is not critical, but the low-level input of the null detector should be isolated from the ac line or other possible sources of external pickup. The input leads and as much of the input stage as practical should be shielded. Coupling capacitor C1 should be shielded with grounded copper foil as shown in the photo of the circuit board.

Also, since the input to the null detector consists of very small currents, any leakage paths must be avoided. Otherwise, sensitivity will drop. If printed circuits are to be used in high humidity, appropriate guard rings must be included. Ceramic switches were used in the original for lower leakage.

If an insulating material is to be used for the front panel, ground the shaft of the reference-supply potentiometer and the range switch to avoid coupling hum into the circuit from your hand.

My pmdvm was built in a 7½ x 8½ x 3-inch Bakelite case with a tempered hardboard panel. I put the power supply in one corner and the null detector at the opposite end.

Before calibrating the instrument, we must set the zero adjustment. This is done by placing a short across the input terminals, setting the range switch to the .01V position and adjusting the zero potentiometer to give a meter reading of zero (center).

Calibration requires a known voltage. A not-too-old mercury cell can be assumed to have a terminal voltage of 1.345 V. If you have a really accurate dc meter, use it to set up your calibrating reference. The known voltage is applied to the input terminals of the pmdvm with the range switch set to the appropriate position.

The trimming resistors may be omitted if the range resistors are sufficiently accurate. If you intend to use them, they should be chosen during calibration. First, insert a trimming resistor for the 1V range with a value equal to a percentage of the 1-megohm resistor which represents the greatest tolerance of any of the range resistors to be used. (For

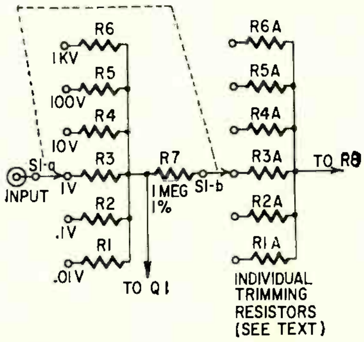


*Fig. 5—(Left) Details of range switch and the trimming resistors.*

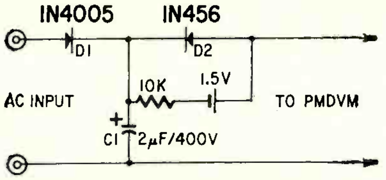


*Fig. 6—(Above) Ac-measuring adapter, which reads in terms of peak volts. See text for rms conversion.*

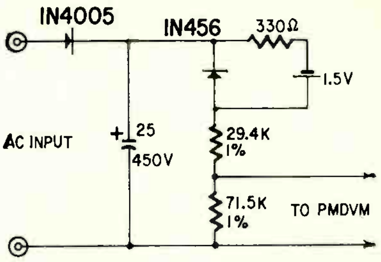


*Fig. 7—Another ac-measuring adapter for power-line rms readings.*

example, if the greatest tolerance is 5%, the trimming resistor would be about 50,000 ohms.) A known input voltage of 1V or less is applied to the pmdvm. (If a mercury cell is to be used for calibration, it will be necessary to use a voltage divider consisting of two equal precision resistors.) Next, adjust the calibration potentiometer to give a zero reading on the null detector meter with the read switch in the TRACK position and the dial indicating a value equal to the input voltage. This calibrates the 1V range.

The five other ranges are then calibrated in a similar manner except that you select trimming resistors to give a null rather than adjusting the calibration potentiometer. A decade box is convenient for this. Each range is independent and must be calibrated individually. When you have calibrated one range, it can be used to measure a voltage for calibration of an adjacent range.

As with any other voltage measurement, the range switch must first be set to the proper position. If you don't know even the rough order of magnitude of the unknown voltage, then set the range switch high. A rather large overload will not damage the instrument; up to 100 volts may be applied to the .01V range without any problem.

With the read switch placed in either the SAMPLE or TRACK position, adjust the reference-voltage dial to give a zero reading on the meter. Read the value of the voltage from the dial. If the reading is less than one-tenth of full scale, change the range switch to the next lower range and readjust the dial to give a more accurate reading.

The null meter can be marked to indicate that the dial and range combination setting is too high or too low. This aids immensely in balancing. If you can't get a balance and the null meter indicates that the dial setting is too high even when at zero, then the polarity switch is in the wrong position.

Normally you will want to use the SAMPLE position of the read switch since this automatically disconnects the reference cell and shunts the null detector whenever you are not actually adjusting the dial. To monitor a voltage continuously, place the READ switch in the TRACK position.

Note that a reading is held on the dial until a new adjustment is made. This "remembers" the input voltage.

To compare two voltages to determine which is the larger, first connect one of them to the pmdvm and balance for a null. Switch the pmdvm to the second voltage, and the null detector meter will indicate whether the dial setting, which now represents the value of the first voltage, is higher or lower than the second. While the exact sensitivity will depend on the gain of the amplifier, a difference of only 5 mV out of 10 V produces a noticeable deflection in the meter. This represents a difference of only .05%.

The pmdvm can be used as a sensitive null detector for Wheatstone bridges and such. Set the voltage dial to zero and the range switch in the .01V position (for maximum sensitivity). In this range, a voltage as low as about 30 μV produces a noticeable deflection on the meter.

Several attachments will extend the pmdvm's usefulness even further. The first is a circuit to allow the pmdvm to measure ac voltages.

The simplest arrangement (Fig. 6) is merely a half-wave rectifier consisting of diode D1 and filter capacitor C1. Another diode, D2, and a current source made of a 1.5-volt battery and a 10K resistor have been added to compensate for the small forward voltage drop across the rectifier diode. This would otherwise cause an appreciable error in measuring voltages even as high as 100 V. By adding the compensating circuit, we can use the circuit shown in Fig. 6 down to several volts with fair accuracy.

Since the output voltage will be in terms of the peak input voltage, the pmdvm will read the equivalent peak value of the ac input voltage. If the input voltage is a sine wave, then we must divide the peak voltage by 1.414 (or multiply it by 0.707) to get the rms value.

A second possible ac converter circuit is shown in Fig. 7. This approach is especially useful when it is necessary to measure ac line voltages accurately. A voltage divider in the attachment performs the necessary peak-to-rms calculation so that the dial on the pmdvm will indicate the ac voltage directly in terms of ac rms volts. The voltage divider and the larger filter capacitor will cause substantial loading on many circuits but do not present any problem when measuring line voltages, etc. Be very careful to connect the ground lead of the pmdvm to the *ground* side of the line to avoid possible shock (which could be lethal) since the knob is connected to the instrument ground.

Neither circuit should be used for more than about 200 volts input. A higher-voltage converter can be made with a higher-voltage diode and filter capacitor. The voltage-divider resistors in Fig. 7 can be increased for the high-voltage converter since the loading of the pmdvm input (which is 1 meg/V) will be less. Also, the compensating diode may be eliminated since the error contributed by the forward voltage drop of the rectifier will be small in comparison with the larger input voltage.

Another attachment, which you may wish to design into the instrument rather than use as an accessory, is a probe with an isolating resistor in it. A resistance of 100K can be inserted in the probe and then the .01V range eliminated with the 0.1V range resistor (R2) made equal to zero. A 1-μF capacitor should then be connected from the meter side of the 100K isolating resistor to ground to act as a filter. An isolating resistor probe may be used with the basic instrument if you adjust the reading to compensate for the error it causes. For example, a 100K isolating resistor causes a 100% error in the 0.1V range, a 9% error in the 1V range, but only a 1% error in the 10V range.

If we add a series resistor equal to the range resistor, then we must multiply the dial reading by 2 to get the actual voltage. This technique can be used to compensate for loading effects on high source resistances by letting the source resistance be a portion of this external resistor. END

# Is That Distortion in Your Scope?

**If a wave seems to increase in frequency at the right of the screen—or if all traces have flat tops—it sure is!**

**By WILLIAM DARRAGH**

IF YOUR SCOPE PATTERNS START LOOKing funny—especially on all jobs—then it's time for a checkup. It's hard to find distortion in an amplifier if there's more in your own scope!

Amplifier circuits in the scope are exactly the same as those you'll find in a TV, so they suffer from the same kinds of troubles. Vertical amplifiers in a broad-band scope are nothing but video amplifier circuits. Fortunately, they're easy to check. All you need is a reasonably pure audio signal. Feed it into the scope and check the patterns. A sine-square audio signal generator, or a sine-wave generator plus the Monterey "Squaremaker" (reviewed in a test equipment report, April 1965) will do the job.

There are two kinds of distortion: vertical and horizontal. From my experience with scopes over the years, I'd say vertical trouble seems to be the more common. However, you can easily have horizontal trouble, or both vertical and horizontal at the same time. (In other words, scopes are just like any other electronic equipment!) Many scopes use push-pull amplifiers in both circuits; unbalance in them can cause some odd-looking distortions, like one-sided waveforms.

First, of course, change the tubes and check the supply voltages. This often cures a lot of trouble. The other troubles will be plate or screen resistors changed in value, or leaky coupling or bypass capacitors. These can often cause the same kind of distortion. Fig. 1 shows a pattern caused by a change in the plate resistor of one vertical amplifier tube in a push-pull stage. I've seen the same pattern caused by slight coupling-capacitor leakage. Notice the excessive slope only on the tops of the square waves.

Fig. 2-a shows a similar one-sided pattern on a sine wave. This was caused by a plate resistor that had gone far above normal value. Fig. 2-b shows exactly the same effect, but much worse. Half of the wave is actually turned up instead of just being flattened. Both the same thing, but in different degrees.

Fig. 3 shows a high-frequency square wave, about 16 kHz. The thickening of the horizontal parts of the pattern is due to 60-Hz hum. At the sweep frequency used here, it won't show up as the familiar rippling in the waveform. To check, just turn the sweep frequency back down to 30 Hz and you'll see the characteristic waving, or ripple in the pattern.

This one happened to be the fault of a tube with some leakage, but anything that lets 60-Hz hum into the vertical amplifier signal path will cause the same pattern. The waveform will have a slight jitter, vertically—that's your clue. The jitter is the cause of the blurtal lines, although there will be some riness in the photo. A normal square wave should have sharp, clean horizonrounding on square waves above 10 or 15 kHz if your scope's response falls off at about 200 kHz.

Trouble in the horizontal circuits will show up as a nonlinearity of the sweep. If the normal linear sawtooth is distorted, the beam can't travel at the same speed all the way across the screen (Fig. 4). Note how the pattern crowds at the right. The beam is traveling more slowly on that side, so we get more cycles crammed into the same space.

The horizontal amplifier has the same kind of trouble that the vertical does: leaky capacitors, drifting resistors, bad tubes, etc. Use a sine-wave test signal, and set the sweep rate to display about 8 or 10 cycles, as in Fig. 4. You can use a square wave for this, but I think the sine wave shows it a little plainer.

This particular pattern was caused by a bad plate resistor and leaking coupling capacitors. The patterns will be practically the same for either kind of defect.

Finally, let's say that the scope is OK and the amplifier is OK (the generator is OK, too!), but you still have distortion! You get a pattern like Fig. 5. What's going on here? The answer is simple; you're not doing it right. This is a typical pattern caused by feeding in too much signal and *overloading the vertical amplifier* of the scope! Notice that both tops and bottoms of the sine waves are flattened.

To check, turn down the output of the signal generator. If the pattern goes back to a good sine wave, then that was it. This same thing can also happen in audio amplifiers: I've done it on numerous occasions!

Therefore, for a quick check, feed the signal generator directly into the scope and make sure that they're both OK. Then you can get on with your rat-killin' with confidence that your equipment is all right. END

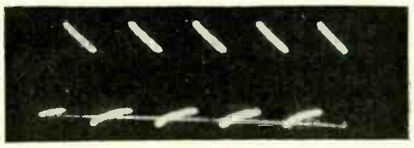


*Fig. 1—One-sided sloping of square wave shows up leaky or open coupling capacitor or a bad plate-load resistor.*

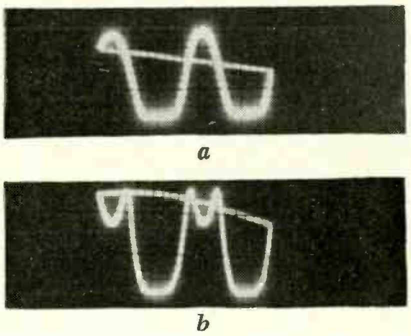


*Fig. 2—Two versions of what happens if one side of push-pull vertical deflection amplifier goes out of whack: a—slight flat-bottoming; b—serious clipping at bottom and flattening at top. In scope with retrace blanking, strong retrace line like this would usually indicate open blanking-pulse coupling capacitor or bad blanking amplifier, if any.*

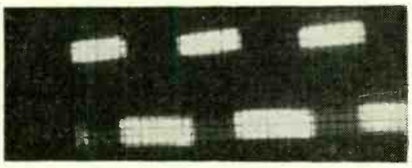


*Fig. 3—Broad, blurred trace as in this square wave usually means hum in vertical amplifier. A 30-Hz sweep shows blur for what it is: 60-Hz jitter on trace.*

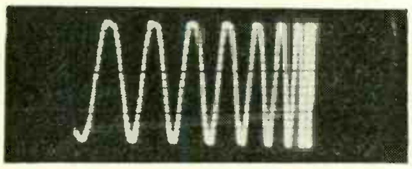


*Fig. 4—This is horizontal nonlinearity, which shows up as crowding of the trace toward right of screen. Trouble could be in oscillator or horizontal amplifier.*

*Fig. 5—Two-sided distortion can be caused by overloaded vertical deflection amplifiers, but can also mean much lower than normal B-plus or weak push-pull deflection amplifier (often a twin triode). The return trace is not blanked.*

# VIBRATION AND SHOCK—NATURE'S

**By WILLIAM F. KERNIN**[*]

IN CONTROLLED USAGE, VIBRATION AND shock are powerful and beneficial tools of nature. If they are uncontrolled—all havoc breaks loose. The random shock forces encountered by a ballistic missile, for example, exert tremendous loads on the electronic circuitry packed inside the "bird." Combined with ever-present vibration fields due to specific-impulse and frictional factors, these spurious effects do plenty to shake up—sometimes even destroy—the "black boxes."

To investigate these forces and design electronic equipment to survive them, the intensity and specific characteristics of the vibration and/or shock must be defined. That is where the vibration pickup and its associated electronic instrumentation play their roles. Let's examine typical equipment used to analyze these two very similar effects and determine how we can use it to define and catalog our twin topics.

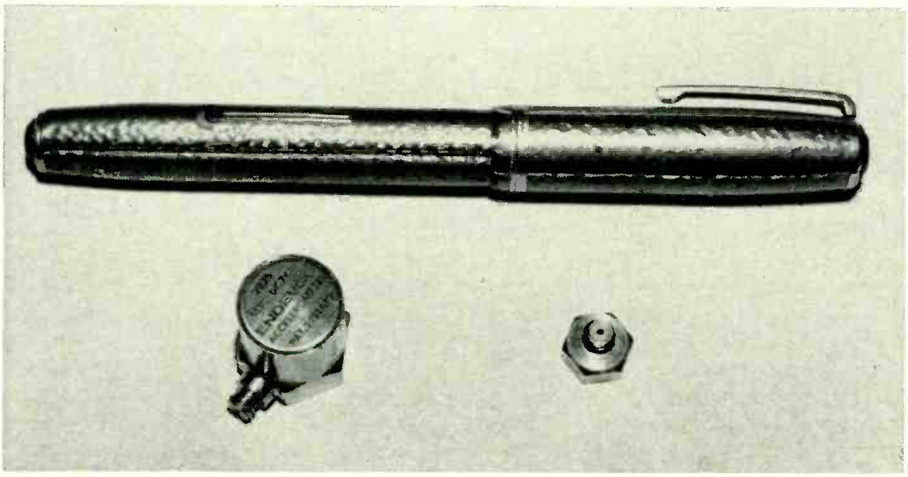


*Fig. 1—Two typical piezoelectric accelerometers. Most units mount with studs or cement.*

The most common device used to transform mechanical motion into an equivalent electrical signal is the piezoelectric crystal accelerometer. Fig. 1 shows two general-purpose devices suitable for many applications. Basically, a pickup of this type consists of a piezoelectric crystal which is mechanically preloaded, using a spring-and-mass arrangement. Any movement in the sensitive axis of the pickup causes a variation in its electrical output. The signal obtained from the pickup is fed to a companion amplifier by means of a low-noise, single-conductor shielded cable.

Various amplifiers with very high input impedance are available commercially for use with crystal accelerometers. One type uses a modified cathode-follower input stage to produce an input impedance variable from 100 to 1,000 megohms, depending on the circuit design and the user's selection of resistor values.

Fig. 2 shows a typical input stage and its associated amplifier circuitry. Because input grid resistor $R_G$ is returned to ground through the cathode-load resistor $R_L$, the output-signal voltage is common to both input and output; thus a large degree of feedback is obtained. The feedback level is great enough to raise the input impedance from an expected value of 20 megohms, suggested by $R_G$, to a value of 200 megohms or higher. The actual impedance depends on the value of grid resistor $R_G$ and the overall gain of the cathode follower—a value always less than 1. As gain approaches 1, the input impedance rises to a very high value. Very high input impedances are necessary because the crystal accelerometer is a high-impedance voltage-producing device. It must be lightly loaded to maintain its sensitivity and response to low frequencies.

A gain control and voltage amplifier follow the input stage, allowing low-level signals to be boosted to a usable value. The output of this circuit then feeds indicating instruments of somewhat lower impedances: an audio frequency vtvm, scope, or tape recorder,

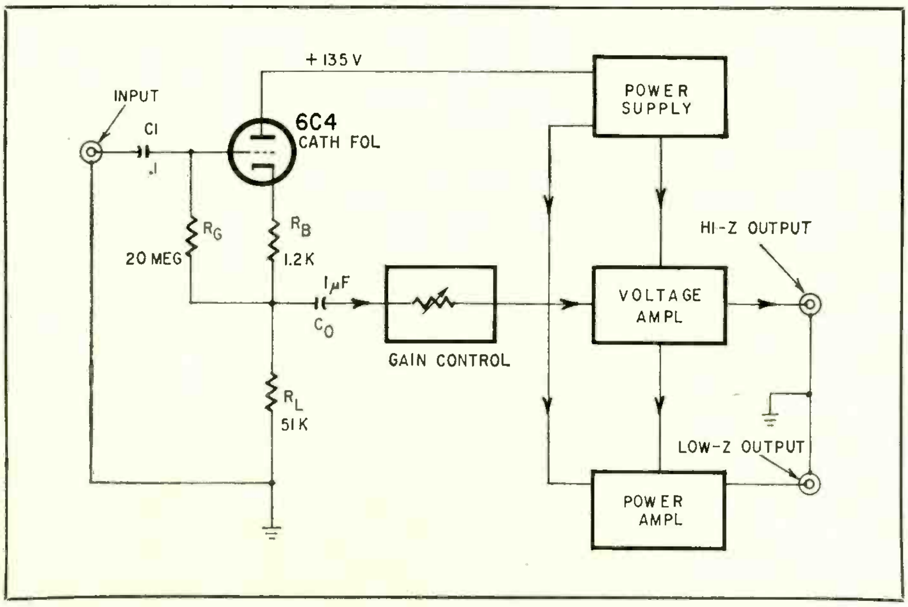


*Fig. 2—Cathode follower provides very high input impedance for accelerometer amplifier.*

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[*] *Instrumentation technician. Engineering Labs, Bell Aerosystems Co., Division of Bell Aerospace Corp., Buffalo, N.Y.*

# WRECKING CREW

for example. Also, this output can drive an additional power amplifier that in turn drives a low-impedance recording galvanometer or other type of direct-writing recording device.

To determine the frequency response of a cathode-follower/amplifier and its crystal accelerometer—particularly at frequencies as low as 1 Hz or so—the setup shown in Fig. 3 can be used. In this circuit, a 10Ω resistor is connected in series with the pickup case. The combination feeds the input of the cathode-follower and amplifier, feeding a nominal load. A low-frequency oscillator is connected across the 10Ω resistor as shown, using a 510Ω series resistor. The dc scope is used first to set the input level across the 10Ω load, then to measure the relative output level for each frequency. Gain at 1 kHz is found first and used as a reference level. Other frequencies can then be checked as desired to obtain a complete response curve.

In a typical test setup used to measure environmental vibration levels, three accelerometers are used—one for each plane (horizontal, vertical and lateral). The pickups can be stud-mounted or cemented directly to the component under test. In most cases, cement offers the best solution. Caulk Grip Cement—a dental product—is a good, general-purpose adhesive that sets sufficiently strong for vibration work in 30 minutes or so. For high-temperature work, as encountered on some points of a rocket engine, Armstrong type A-1 adhesive may be used. Fig. 4 shows a typical "black box" on which three accelerometers have been cemented prior to testing.

After mounting, each pickup is connected to its accelerometer amplifier through low-loss cable. A small rubber washer on the connector helps prevent shaking loose the cable. For high-humidity or altitude-chamber work, the connector is coated with a liquid silicone rubber (General Electric RTV-20) that cures at room temperature. When the test is over, the pliable rubber coating can be peeled off easily. As a final precaution, the miniature cable from the pickup is taped down close to the pickup and elsewhere along its length to prevent it from whipping around during testing.

Depending on what use is to be made of the test signal, the output of each amplifier can feed a scope, meter, tape-recorder channel, or recording oscillograph. Fig. 5 shows some equipment that may be used, singly or in combination.

Before a setup can provide meaningful data, the equipment must be calibrated, beginning by finding the pickup sensitivity. For most purposes, vibration and shock are measured in *G*'s, one *G* being equivalent to normal gravitational force. The pickup to be checked is mounted on a small shake table which will provide known variable *G* forces. Its output is checked against that of a standard pickup—also mounted on the table—at different frequencies. The sensitivity of the test pickup is then expressed in millivolts rms per *G* peak.

Pickup sensitivity is affected by the characteristics of the cable connecting it to its amplifier, by the amplifier's input capacitance, and by the pickup's internal capacitance. Thus, complete cali-

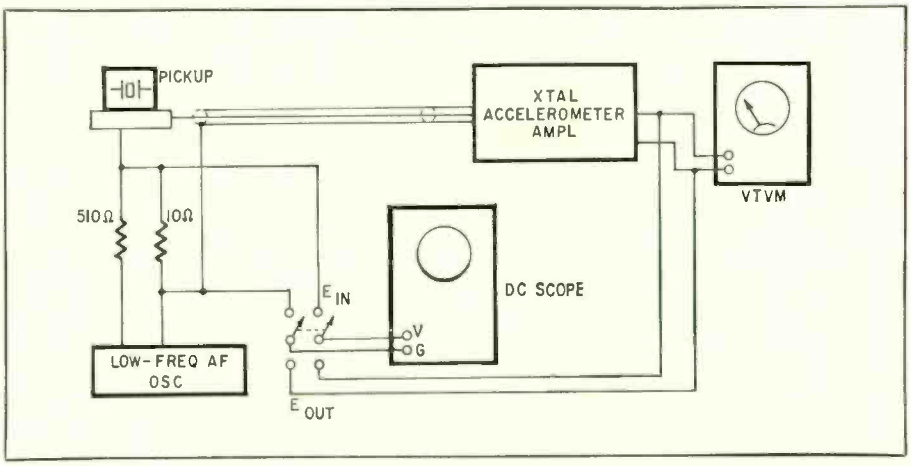


*Fig. 3—Setup for checking overall response. Scope or vtvm can be used for measurements.*

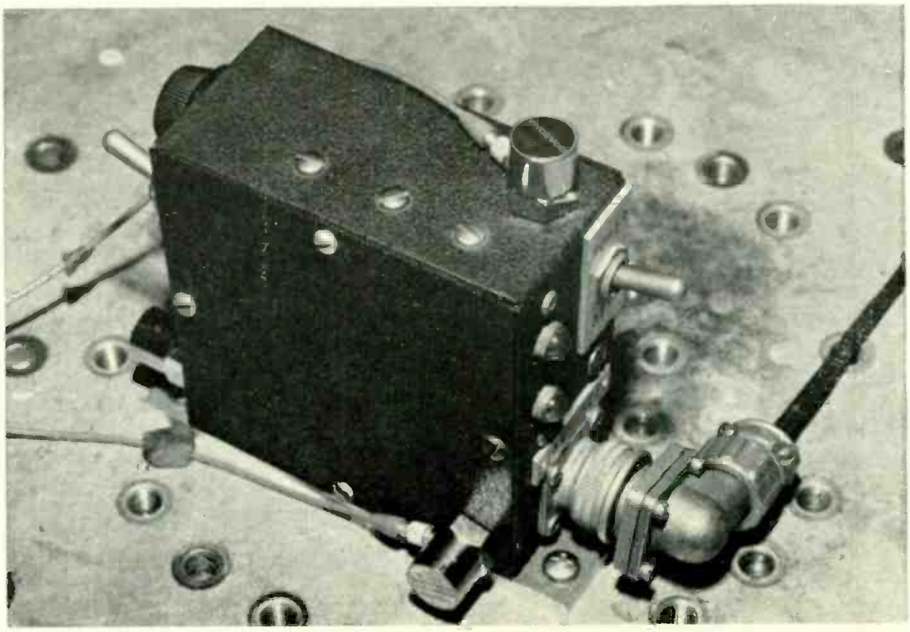


*Fig. 4—Vibration is checked in three planes by pickups on top, side and rear of equipment.*

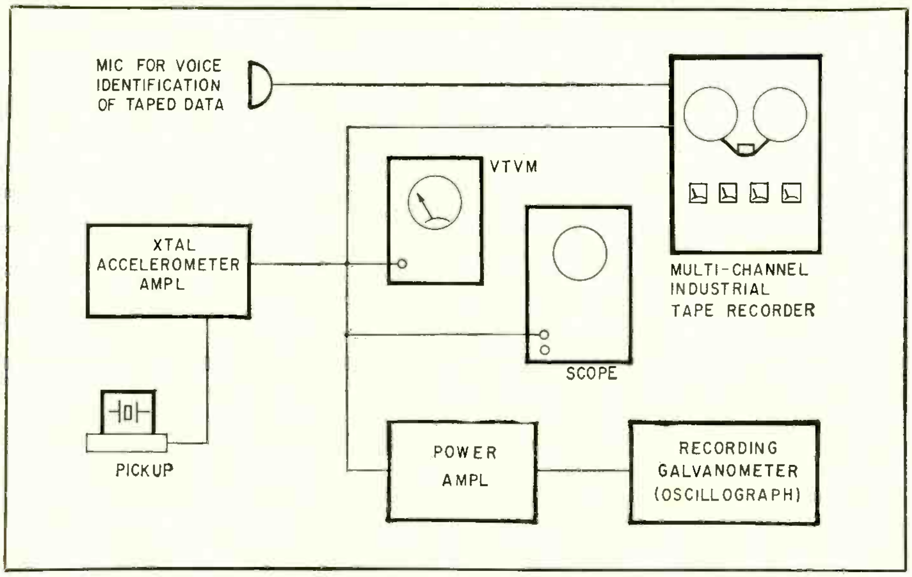


*Fig. 5—A typical instrumentation setup. Recorders preserve records for later analysis.*

bration information may read like this for a typical unit:

E (sensitivity) = 20 mV rms/G pk
C (pickup) = 900 pF
C (cable) = 87 pF (3 ft of cable)
C (amp input) = 23 pF

If, when setting up a test, a different length of cable is used, the pickup sensitivity must be corrected using the following equation:

$$E_{\text{run}} = E_{\text{calib}} \frac{C_{\text{pickup}} + C_{\text{calib cable}} + C_{\text{amp}}}{C_{\text{pickup}} + C_{\text{run cable}} + C_{\text{amp}}}$$

Thus, any convenient length of cable may be used and the calibration sensitivity corrected correspondingly, as long as the cable capacitance and amplifier input capacitance are known. The low-noise cables supplied with most pickups are normally tagged with their total capacitance values.

Continuing our hypothetical calibration: If for a particular test the expected level may reach ±10 G's, this suggests maximum possible signal of 10 × $E_{\text{run}}$ (200 mV rms, using the sample calibration data). Using an audio oscillator, a signal of approximately 1 kHz is fed into the input of the accelerometer amplifier at the expected 10-G level (200 mV rms). The amplifier gain control is then adjusted for some convenient output value—1 volt on a vtvm, 10 scale divisions on a scope, the maximum acceptable input for a tape recorder, or 2-in. deflection on the recording oscillograph. The system has then been calibrated so that a level of ±10 G's peak seen by the pickup will produce an easily read, known output. All pickup channels are calibrated this way, and the system is ready to go.

There are any number of applications for an accelerometer system in the measurement of vibration and shock levels. For example, the system can be used to obtain vibration informbation from apparatus under actual operating conditions, as in the recording of vibration levels on a rocket engin during hot-test firing. In actual tests of this type, multichannel tape recorders record highly varied vibration data ranging from dc signals to high-frequency vibrations. A permanent record of the rocket test run is obtained on tape, and it can be reduced, analyzed or transformed into any form desired.

### Vibration-inducing devices

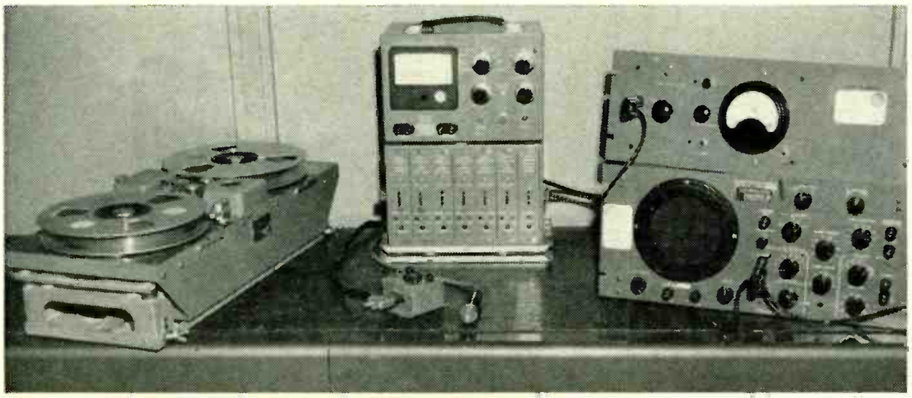
After actual operating or environmental levels are determined, much vibration testing is concerned with applying G forces to components, black boxes, and systems at known levels to reveal any defects, or to quality the equipment.

A common instrument used for such testing is an electrodynamic vibration exciter. This type of shaker consists of a massive driver—a voice-coil-driven table–field-coil arrangement. It is powered by high-energy amplifiers or a controllable, variable-speed motor-generator set. Equipment to be tested is mounted on the shaker head. Standard pickups are then mounted on the device under test so that forces applied can be recorded and used later for reference or evaluation.

A more elaborate type of shaker is the random-vibration machine. Instead of steady frequencies, this instrument employs a band of frequencies with no definite repeatability characteristics—random noise—to drive a specially designed shaker head through powerful amplifiers. Failures often show up during random-noise tests that might never be discovered in steady frequency tests. (See "Big Noise", RADIO-ELECTRONICS, Aug. 1963.)

Maintenance on vibration test equipment is basically a matter of common sense. The pickup should be kept clean to afford good mechanical contact; the connector must also be clean as possible. The miniature cables are tough, but no undue strains or sharp bends should be allowed, especially at the connector ends. Avoid excessive temperatures near the pickup. To shield a pickup from a nearby radiating heat source, several layers of shiny aluminum foil have proved quite helpful as a rough reflective cover. The cathode-follower/amplifier circuitry is not complex and can be serviced with standard signal-tracing techniques when trouble develops. To insure optimum operation and accuracy, the pickups and associated circuitry should be calibrated as often as possible: once a month is considered adquate.

While the typical industrial electronics technician may seldom see much vibration testing equipment, he should be aware of the basic principles and circuitry involved. Not only may this information come in handy when he does encounter such devices, but it may lead to further study and open new areas of new business through direct contact with those actively engaged in vibration testing. END



*Some of the equipment used to monitor and record vibration data. Industrial recorder is on the left, seven-channel FM recording amplifier and meter are in center. On the right is a dc oscilloscope and power supply. Pickup transducer is at front of table.*

# SIMPLE SCOPE SWITCH

**This inexpensive, easy-to-build electronic switch converts your oscilloscope to dual-beam model**

**By RANDALL K. KIRSCHMAN**

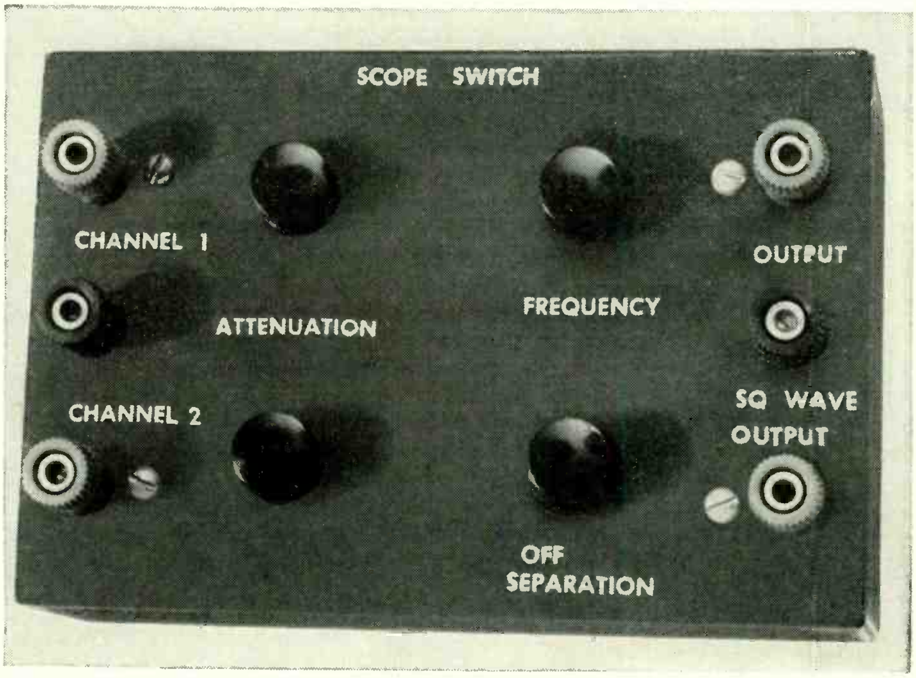
AN OSCILLOSCOPE SWITCH, SOMETIMES called simply an electronic switch, allows simultaneous viewing of two separate signals on an oscilloscope. It can be a very useful accessory in many situations. Unfortunately, most scope switches are fairly complex and costly. The average experimenter would not use one often enough to warrant the expense. Here is a solution: a scope switch that uses only a few parts and takes very little time to assemble.

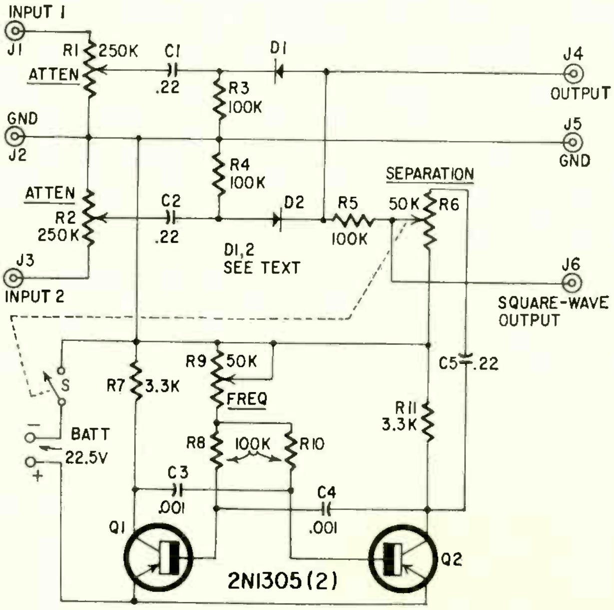
The diagram shows the circuit. None of the part values is critical, but the two channels should be matched, especially R1 and R2, R3 and R4, C1 and C2, D1 and D2. Also the two sections of the multivibrator should be matched (R7 and R11, R8 and R10, C3 and C4). The diodes can be inexpensive ones, such as 1N34A's.

All component leads should be kept short. Other than that, there is nothing special about the construction of this unit.

The switch operates very simply. The two transistors, Q1 and Q2, and associated parts form a common-emitter multivibrator that produces square waves at about 5 kHz. R9 controls the frequency of the switching square wave by affecting bias on the transistor bases.

The two diodes, D1 and D2, are switched on and off alternately by the square wave. When the square wave goes positive, D1 is forward-biased and conducts; signal 1 is connected to the output. At the same time, D2 is reverse-biased and open. When the square wave becomes negative, D1 conducts and signal 2 is connected to the output. This switching is very rapid—at the square-wave frequency—and the two input signals look as if they are simultaneous





*Schematic of the simple electronic switch. Square-wave generator can be substituted for the transistor multivibrator.*

PARTS LIST

C1, C2, C5—0.22-μF, 600-volt paper
C3, C4—.001-μF, 600-volt disc
R1, R2—250,000 ohms, linear-taper pot
R3, R4, R5, R8, R10—100,000-ohm
R6—pot 50,000 ohms, linear-taper (with switch)
R7, R11—3,300-ohm
R9—50,000-ohm linear taper pot
All resistors ½ watt, 10% except as noted
D1, D2—general purpose germanium or silicon diode (see text)
Q1, Q2—2N1305 transistor
J1, J2, J3, J4, J5, J6—5-way binding post
S—spst switch (part of R6)
BATT—22½-volt battery
Misc.—cabinet (2 x 4 x 6-inch aluminum chassis), knobs, battery holder, wire, etc.

on the scope screen. Potentiometer R6 adjusts the amplitude of the square wave going to the diodes, and thus places the input signals farther apart on the scope screen.

Once the unit is built, check out its operation. Connect the two signals to be observed to the inputs of the switch. Use a shielded test cable between the OUTPUT of the switch and the VERTICAL INPUT of the scope.

Synchronize the oscilloscope sweep with one of the input signals and not with the switching signal. This may be done by connecting one of the input signals to the scope's EXTERNAL SYNC post.

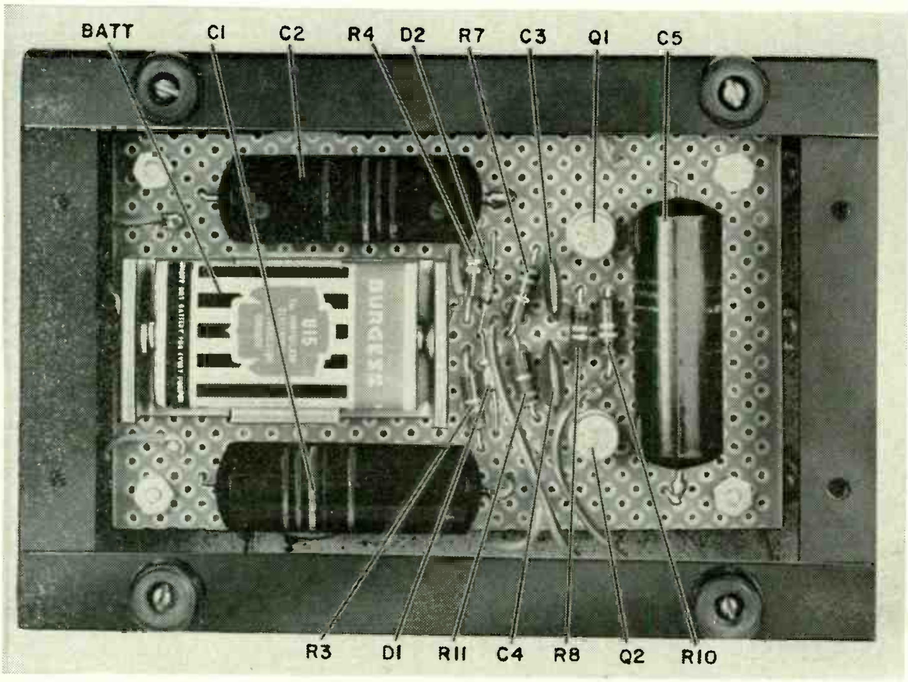
The oscilloscope should have good frequency response or else the switching signal will be distorted and the traces will not be clean.

The test signal connected to input 1 will be the upper trace on the scope screen. Potentiometers R1 and R2 vary the amplitudes of the test signals applied to the diodes. Adjust potentiometer R9 so that the traces look continuous on the scope screen and the switching square waves are hardly noticeable.

As might be expected of such a simple device, this switch has a few limitations. One is that the two traces cannot be superimposed or overlapped without crossmodulation and distortion. Also the input attenuators, not being frequency-compensated, are useful only to about 100 kHz.

The terminal labeled SQUARE-WAVE OUTPUT was added so that the switch could also be used as a square-wave source.

The multivibrator can be eliminated by using an external square-wave source to operate the switch. If the switch is used this way, the external square wave can be fed in at the SQUARE-WAVE OUTPUT terminal. END



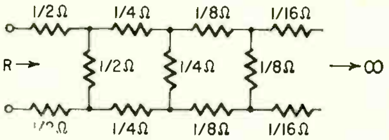
*The simplicity of the scope switch is indicated in this underchassis view.*

# WHAT'S YOUR EQ?

**Conducted by E. D. CLARK**

## Tapered Network

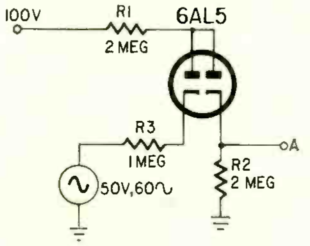
The diagram shows an example of a *tapered* ladder network that extends



to infinity. What is the input resistance?
*—Paul J. Nahin*

## ? ? ? Circuit

Under the conditions shown in the diagram, can you determine the waveform and range of the output voltage developed between terminal A and ground? The internal resistances of both



input voltage sources are assumed to be negligible. Also, the resistance and self-potential of the diodes are negligible.—*Kendall Collins*

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Write EQ Editor, Radio-Electronics, 154 West 14th Street, New York, N. Y. 10011.

**Answers to this month's puzzles are on page 91.**

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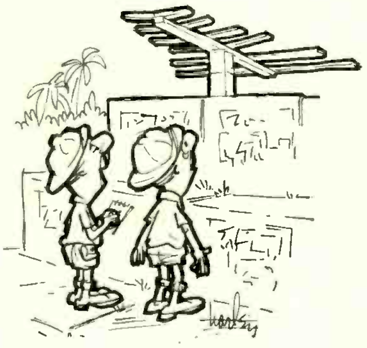
### 50 Years Ago

**In Gernsback Publications**
**In August 1916**
**Electrical Experimenter**

The Vacuum Detector and How It Works

A 100-KW Radio Frequency Alternator

Sending on Short Wave (150 meters)



*The Incas weren't so far advanced after all—that's only a black and white antenna.*

# Build Your Own Pulse Generator

**Build it for under $50—far less than a comparable manufactured instrument. What will you do with it? Read on!**

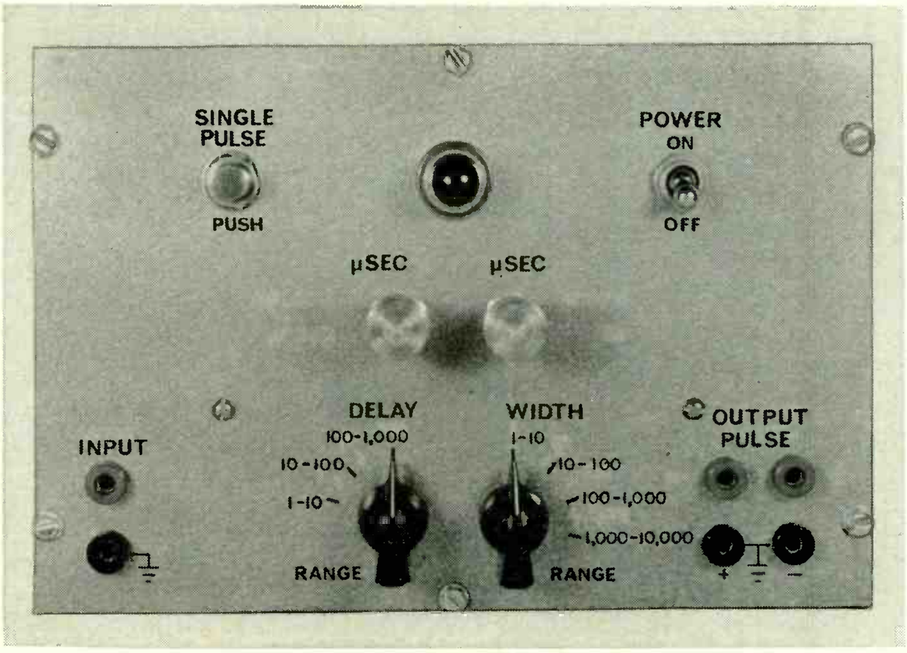
**David H. Sandrock**

IN DESIGNING, DEVELOPING, TESTING AND operating radars, televisions, computers, telemetric devices and hundreds of other kinds of equipment, a pulse generator is often required. This instrument, which can be used for most pulse-testing, costs only a fraction of what you'd pay for a commercial generator. It provides pulses from 1 μsec to 10 msec wide over a frequency range of 10 Hz to 100 kHz when triggered by an external audio oscillator having an output level of approximately 10 volts rms. A single-pulse switch also is provided, and a variable-delay circuit allows the pulse to start after the scope-trigger pulse. This useful feature allows the leading edge of the output pulse to be observed easily on the scope screen. Delay is variable from 1 μsec to 1 msec. Pulse amplitude is 25 volts, and rise time is 0.1 μsec; positive and negative pulses are available simultaneously.

The pulse-forming circuit for the generator (V1 in the schematic) is a modified cathode-coupled multivibrator, or *Schmitt trigger*. Circuit operation depends on dc-level changes, and the multivibrator has no built-in time constants. R4 establishes the static condition, with V1-a saturated and V1-b at cutoff.

The input signal, a sine wave fed from the external oscillator at any frequency within the specified range, reduces the plate current of V1-a during its negative half-cycle, and the plate voltage rises. (The initial positive half-cycle, of course, has no effect, because V1-a is already saturated.) This voltage rise is coupled through R6 to the grid of V1-b and drives the stage out of cutoff. As V1-b begins to conduct, increasing the voltage dropped across common cathode resistor R8, the plate current of V1-a drops still lower. The action is regenerative and increases rapidly until V1-a is cut off and V1-b is conducting fully. When V1-b saturates, its plate voltage rests at a low value. This negative step provides the scope-trigger pulse and also triggers the delay multivibrator. V1-b remains saturated until the input signal swings toward its positive half-cycle and allows V1-a to conduct, at which time the circuit switches back rapidly to its original condition. The next negative half-cycle starts the trigger action once again.

With no input signal and with the single-pulse switch open, C3 charges to about half the B+ voltage through R2. When the switch is closed to generate a single pulse, C3 is shorted to ground. This initiates a negative-going waveform that triggers the circuit through C2 in the same manner as for an external trigger signal. One pulse is generated each time the switch is closed.



*Panel of pulse generator shows its "black-box" nature—no clutter of controls.*

**PULSE-GENERATOR SPECIFICATIONS**

**Pulse rate:** 10 Hz to 100 kHz input using external sine-wave af generator; single pulse also available.
**Pulse width:** 1 μsec to 10 msec in four ranges; 1–10 μsec, 10–100 μsec, 100–1,000 μsec, 1,000–10,000 μsec.
**Pulse amplitude:** positive or negative 25-volt pulses across 470 ohms. Outputs separate and simultaneous.
**Pulse delay:** 1 μsec to 1 msec in three ranges; 1–10 μsec, 10–100 μsec, 100–1,000 μsec.
**Input trigger level:** input sine wave of 10 volts rms.
**Scope-trigger output:** negative step of about 10 volts peak.
**Power requirement:** 117 volts, 60 Hz, 40 watts.

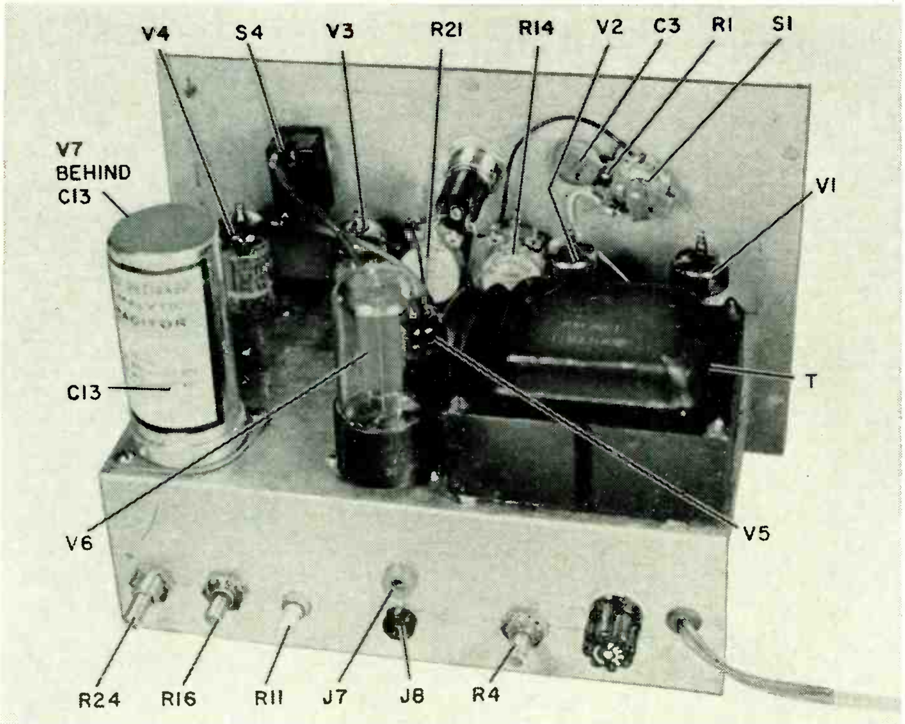
V5 is a cathode follower for the scope trigger used to prevent the capacitance of the scope and connecting leads from loading the trigger circuit and increasing its rise time.

The negative-going signal from the plate of V1-b is coupled to the plate of V2-a through disconnect diode D1 and through timing capacitor C6 = a, = b, or = c to the grid of V2-b. Under static conditions—no input signal—V2-a is normally cut off, and V2-b is conducting heavily. The negative pulse applied to the grid of V2-b reduces the plate-current flow in that stage and causes a decrease in the voltage dropped across common cathode resistor R12. The grid of V2-a then becomes positive to its cathode, driving the stage to saturation. The plate voltage of V2-a drops sharply, and the resulting negative pulse is coupled through C6 to the grid of V2-b, holding that half of the MVB (multivibrator) cut off for a time determined by the time constant $TC = C6 \times (R13 + R14)$. As the negative voltage at the grid of V2-b decays, the stage begins to conduct again, and the MVB switches back to its original state.

(D3 is a clamp diode that prevents the grid of V2-b from going positive, a circumstance which might keep the circuit from being triggered.)

The plate load for V2-b is an inductor (L) shunted by a diode. The rapid current alternations caused by the MVB action shock-excite the inductor into oscillation. When V2-b is first cut off the plate voltage rises, the first half-cycle of oscillation is positive and is shorted out by D2. When V2-b saturates, and its plate voltage drops after the time determined by the time constant selected, the first half-cycle of oscillation is in the negative direction. It is this pulse that is passed through disconnect diode D4 as a trigger pulse for width multivibrator V3.

This section of the generator oper-

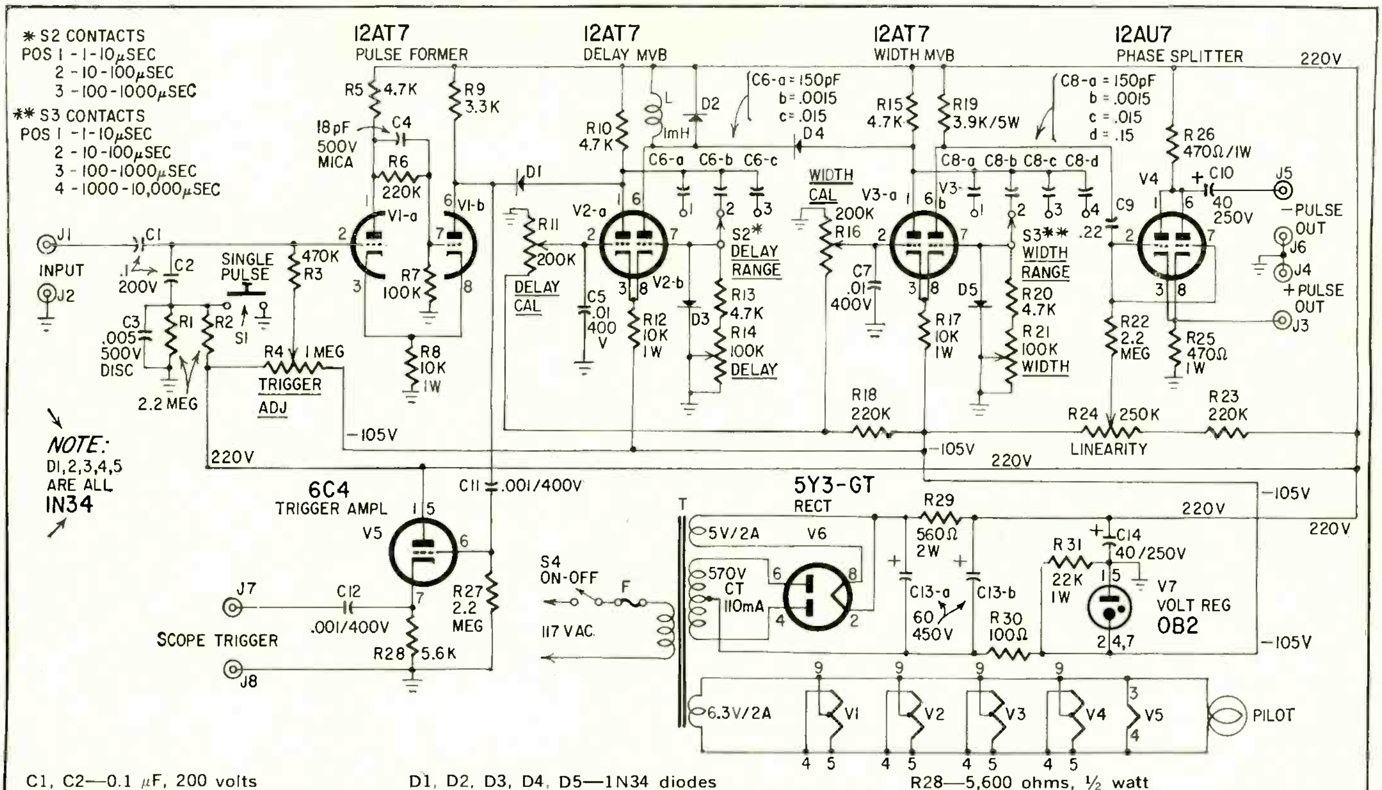


*Major chassis components are called out here. Controls on rear are setup adjustments.*

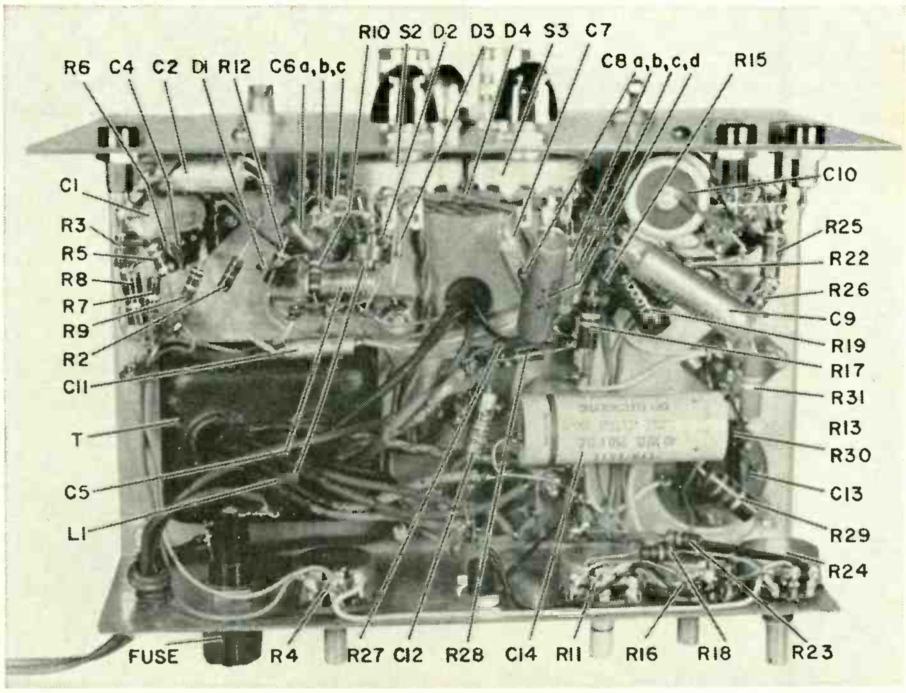
ates essentially like the delay multivibrator, except that its output plate load is a wire-wound resistor. The rapidly changing current surging through this resistor develops a rapidly changing voltage that drives the output stage. The inductance of the wirewound resistance element acts as a peaking coil in series with the plate load, sharpening the leading and trailing edges of the pulse.

Output amplifier V4 consists of both halves of a 12AU7 connected in parallel as a phase splitter. The cathode and plate resistors are equal, and equal voltages of opposite polarity are developed. Grid resistor R22 is returned to the arm of R24, which determines the correct bias for best linearity. The positive-pulse output terminal goes directly to the cathode of V4. C10 isolates the negative output pulse from B+.

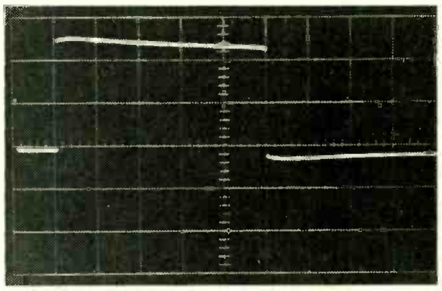
The power supply is a full-wave rectifier with the transformer center tap returned to the −105-volt line rather than to ground. Voltage-regulator tube V7, paralleled with R31, is connected between the −105-volt line and ground. Total current required by the Schmitt



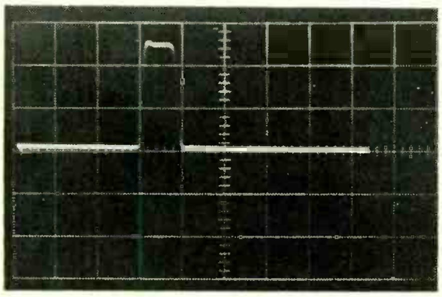
C1, C2—0.1 μF, 200 volts
C3—.005 μF, 500-volt disc ceramic
C4—18 pF, 500-volt mica
C5, C7—.01 μF, 400 volts
C6—delay-timing capacitors
  C6-a—150 pF, 500-volt mica
  C6-b—.0015 μF, 400 volts
  C6-c—.015 μF, 400 volts
C8—width-timing capacitors
  C8-a—150 pF, 500-volt mica
  C8-b—.0015 μF, 400 volts
  C8-c—.015 μF, 400 volts
  C8-d—0.15 μF, 400 volts
C9—0.22 μF, 300 volts
C10, C14—40 μF, 250 volts
C11, C12—.001 μF, 400 volts
C13—60 x 60 μF, 450 volts
D1, D2, D3, D4, D5—1N34 diodes
L—RFC, 1.0 mH
J1, J2, J3, J4, J5, J6, J7, J8—insulated banana jack
R1, R2, R22, R27—2.2 megohms, ½ watt
R3—470,000 ohms, ½ watt
R4—pot, 1 megohm
R5, R10, R13, R15, R20—4,700 ohms, ½ watt
R6, R18, R23—220,000 ohms, ½ watt
R7—100,000 ohms, ½ watt
R8, R12, R17—10,000 ohms, 1 watt
R9—3,300 ohms, ½ watt
R11, R16—pot, 200,000 ohms
R14, R21—pot, 100,000 ohms
R19—3,900 ohms, 5 watts, wirewound
R24—pot, 250,000 ohms
R25, R26—470 ohms, 1 watt
R28—5,600 ohms, ½ watt
R29—560 ohms, 2 watts
R30—100 ohms, ½ watt
R31—22,000 ohms, 1 watt
S1—pushbutton switch, normally open
S2—rotary switch, single pole, 3 pos.
S3—rotary switch, single pole, 4 pos.
S4—spst toggle switch
T—power trans.; 6.3 volts at 2 amps, 5 volts at 2 amps, 285-0-285 volts at 50 mA (see text)
V1, V2, V3—12AT7
V4—12AU7
V5—6C4
V6—5Y3-GT
V7—0B2
Misc.—cabinet, sockets, hardware, etc.



*Under-chassis components. Following this arrangement is the safest way.*



*Maximum tilt on long pulse is about 10%. Scope was set at 0.2 msec/cm sweep rate, 10V/cm vertical sensitivity. Input to pulse generator was set at approximately 100 Hz.*



*Minimum pulse width from this generator. Scope here was set for sweep rate of 1 μsec/cm, with vertical sensitivity at 10 V/cm as before. Generator input–10 kHz.*

trigger, output amplifier and voltage dividers flows through this regulator circuit. R30 is connected between the –105-volt line and the cathode of V7 to prevent the VR tube from acting as a relaxation oscillator. Capacitor C14 is a filter for the 220-volt supply.

Construction is not difficult. Any reasonable layout can be used, and lead dress is not especially critical. The only exception is to keep the leads short between the timing-switch capacitor assemblies and their respective tubes.

When soldering the disconnect and clamp diodes, be sure to provide some form of heat sink to avoid damage. (Pliers or an alligator clip on the lead being soldered will do.) You *must* use a cardboard sleeve or tape wrapping to cover main filter capacitor C13 because the can is 105 volts negative to chassis. C13 also must have an insulated mounting plate.

Maximum plate current drawn by the pulse generator is about 42 ma, and a transformer capable of delivering that current at 325 volts is required. Any transformer with a center-tapped plate winding supplying 590–650 volts at 50 ma will work well. It also must provide the 5-volt and 6.3-volt filament windings as noted on the schematic.

I used a 9 x 6 x 5-inch utility cabinet, and the chassis, formed of galvanized steel, was bolted to the front panel. Panel lettering was done with a lettering pen and India ink, and a protective plastic coating was sprayed over it. The back of the cabinet was left off for ventilation.

Final checkout requires only an oscilloscope and the af generator which normally will be used as an input trigger. Turn the generator on, allow it to warm up for about 5 minutes, then set output-level potentiometer R24 for maximum negative voltage. Apply to the input terminals a 10-kHz sine-wave signal of 10 volts rms. Trigger the scope with the same input signal, place the scope probe at pin 6 of V1, and adjust R4 for a symmetrical square wave.

Next, clip the probe to pin 6 of V2 and trigger the scope from the pulse generator's scope-trigger output. Set delay switch S2 at the minimum-delay position (150 pF) and R14 for minimum delay (minimum resistance). Adjust R11 for a stable trigger-pulse output. Run R14 from minimum to maximum to see if the pulse is stable over the entire range. If not, adjust R11 until it is.

To adjust the width MVB, connect the probe to pin 6 of V3. Set the width controls—S3 and R21—to minimum and adjust R16 for minimum pulse width. Check for pulse stability over the range of R21, and readjust R16 if necessary. Check to see that the pulse can be delayed through the complete low range (1 to 10 μsec). It may be necessary to readjust R16 slightly at the minimum-delay position, as delay-trigger amplitude decreases at the minimum-delay position of R14. Minimum pulse width should be slightly less than 1 μsec.

To check for correct amplifier operation, adjust S3 and R21 for minimum pulse width. With the scope connected to the "+" pulse output jack, adjust R24 for the highest pulse amplitude obtainable without clipping the waveform. Using appropriate input frequencies, check the delay and width controls through all ranges. Touch up calibration if necessary, back-tracking as required to obtain stable operation.

Remove the input signal and set the scope at a slow sweep speed before adjusting for single-pulse operation. Set the generator for maximum delay and width and press the single-pulse switch. It may be necessary to readjust R4 and R11 to provide reliable triggering. Dirty switch contacts may cause erratic or double pulsing at some width settings. If everything is operating normally, the setting for reliable single pulsing should give reliable triggering with input frequencies from 10 Hz to 100 kHz. It may be necessary to adjust R4 slightly to give reliable triggering at some frequencies, especially at the extremes of each range. For this reason, mounting trigger-level potentiometer R4 on the front panel might be a good idea.

*Note*: When adjusting the pulse width, use a duty cycle no greater than 20%. The duty cycle can be determined from this formula:

$$\text{Duty cycle} = \frac{\text{pulse width} \times 100,}{\text{pulse-repetition rate}}$$

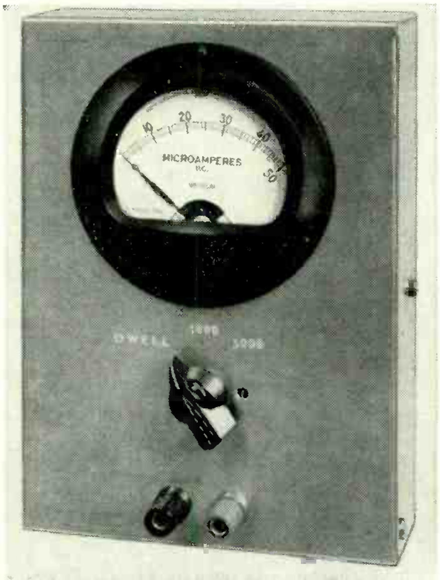
where the pulse repetition rate is the reciprocal of the frequency (1/f).

While the generator described here has few of the accurately calibrated controls of commercial equipment, it does provide an acceptably stable pulse for many test purposes. Construction will take just a few evenings, and the instrument should find many uses around the shop. END

# Simplest Tachometer/Dwellmeter

*Working without tubes or transistors, this dependable unit is insensitive to temperature or battery variations*

**By DUANE H. SWEET**



*For steering column or under-dash installation, this box configuration can be modified.*

THIS PROJECT STARTED WHEN A FRIEND asked for a tach circuit for his boat. I had a couple of circuits around, and knew of units in autos, so I thought I could get one working.

I started with a simple one-transistor model. It turned out very temperature-sensitive, and could not be used on my friend's eight after the parts had been selected for my six. Before starting to build one of the more complicated and larger monostable multivibrator circuits, I decided to give the project a little more thought.

Studying the circuits made it obvious that the object was to generate a square wave, and then let the meter measure its average current (in the case of the dwell meter), or the average current per unit time from a changing number of constant-height pulses in the tach circuit. (Remember that if the current through a d'Arsonval meter varies so rapidly that the pointer cannot follow, it will assume a position determined by the average current.[1])

It occurred to me that there might be a very simple method of doing this. The points, in making and breaking the ground (Fig. 1), should be generating a square wave, although the height would be questionable because of varying battery condition and points resistance, etc. Adding a Zener diode, however, should clamp the square wave to a constant amplitude. Then a simplified count-rate meter could serve as the tach. The advantage of the diode circuit is that only one lead is required from the points. The other connection, a ground, can be made anywhere on the car. Since battery voltage is not needed to activate transistors or tubes, and the diode voltage is our working voltage, battery condition has been eliminated as a parameter.

The remaining problem was to make a respectable square wave from the waveform across the points.

The circuit is shown in Fig. 2, along with the wave shapes at various points. The 6-volt Zener is arranged so that, with a 12-volt negative-ground system (where the voltage goes positive when the points open), the diode gives a 6-volt positive-going square wave. The resistor sets the current through the diode. The inductor is a 100-mH low-resistance toroid, which keeps the current from changing too rapidly and filters out the spikes.

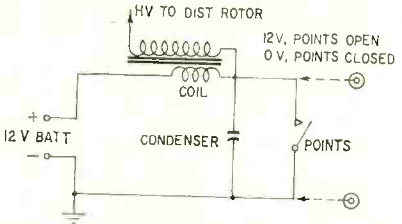


*Fig. 1—Simplified diagram of a conventional automobile ignition system.*

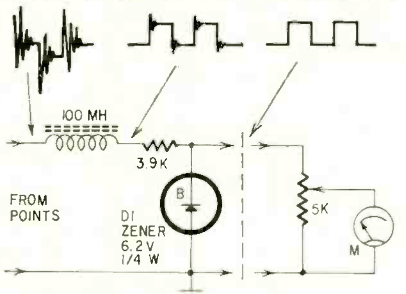


*Fig. 2—The Zener diode delivers a 6-volt square wave to dwell indicator.*

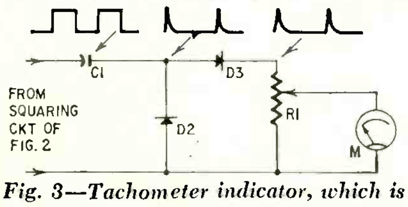


*Fig. 3—Tachometer indicator, which is used with squaring circuit of Fig. 2.*

Originally, I planned to use an L-C filter with a capacitor to ground between the inductor and resistor. However, the waveform was better without the capacitor, because the combination caused ringing on the negative half when the points closed. An R-C filter will not do the job properly either.

After obtaining a reasonable square wave, the rest is easy.

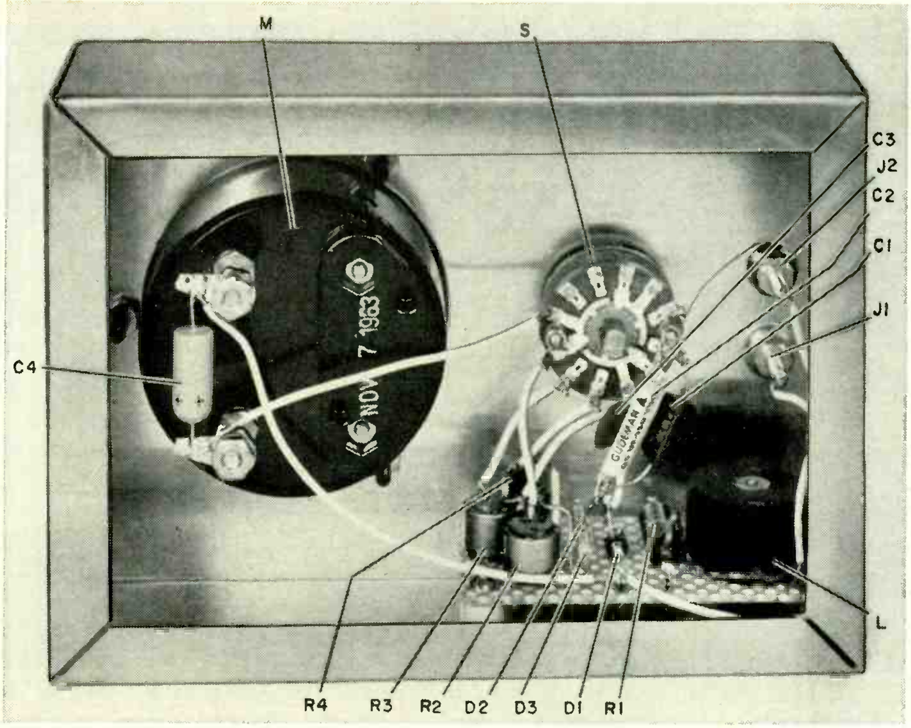
The dwell angle is defined as the time that the points are closed during each plug firing, and is specified by the manufacturer. (It is what you set when you gap your points.) The points must open and close once to fire each cylinder; this corresponds to one cycle of our square wave. During one revolution of the distributor (360°), the points must open and close once for each cylinder. The number of degrees allotted to each cylinder, then, is

$$\text{Degrees per cylinder} = \frac{360^\circ}{\text{No. of cylinders}}$$

This will be the number of degrees for a full-scale reading on the dwell meter for a given motor. The meter pointer will be at full scale for minimum dwell (points always open) regardless of the number of cylinders. But the scale *markings* must be changed to suit 4-, 6- or 8-cylinder engines. As an example, if the points never opened (maximum dwell), there would be no voltage across the Zener, and the average current would be zero. If the points never closed (minimum dwell), there would always be 6 volts across the Zener and maximum current through the meter. If the points closed for half the time, the average current would be half the maximum, etc.

The tach circuit is a little different. It is a simplified count-rate meter.[2] The circuit in Fig. 3. Here, we take the square wave and differentiate it into spikes of constant height and width with C1 and R1. Each spike is short compared to the total time of the shortest square-wave cycle at highest rpm. Now, as the time per cycle changes with rpm, the size and shape of the pulse do not change and, therefore, the average current is proportional to frequency or rpm. Diode D2 aids in discharging C1. The values of C1 and R1 are the critical ones here. If the product C1R1 is too large, the spike will become an appreciable part of the one cycle, and the readings at high rpm will "flatten out," because average current will no longer be proportional to rpm. If C1R1 is too small, the spikes may be too small, and a full-scale meter reading will not be obtainable. The values shown allow operation to 5,000 rpm, with four-, six-, or eight-cylinder autos, without changing anything except the overall calibration.

Recalibration is a necessary evil with all electronic tachs when changing to an auto with a different number of cylinders. For all the cylinders to fire, the crankshaft must do two revolutions, no matter what the number of cylinders (four-cycle engines only). The distributor, however, does only one revolution in this time, or a revolution per revolution of the crankshaft. This means you get two spikes from a four-cylinder engine, three spikes from a six- and four spikes from an eight for every revolution of the crankshaft. So, the average current is different in each case. Here, we have the opposite problem from that of the dwell meter. With the dwell meter, the current stayed the same and the scale changed. With the tach, the scale remains the same and the current through the meter must be changed. This could make matters difficult, but it turns out to be a simple task.



*Wiring and layout are not at all critical.*

One advantage of this circuit is that it's easy to calibrate. Since we have a squaring circuit built in, any positive-going waveform, larger than 6 volts, from a source that can supply about 15 ma. and has an accurately known frequency in the proper range, will do nicely. Offhand, I can think of nothing more common than the 60-cycle power line! By adding a 15,00-ohm resistance in series with the input, as in Fig. 4, to compensate for the increased voltage, we have a source of 3,600 cycles per minute. Since we get more than one pulse per revolution from our engine, we must calculate what this is equivalent to.

$$\text{Calibrating rpm} = \frac{3{,}600}{\tfrac{1}{2}\ \text{No. of cylinders}}$$

The meter is set at 1,800 rpm for use with a four-cylinder engine, at 1,200 for use with a 6- and at 900 for use with an eight. (In some units, three calibrating controls are used. A switch selects the proper one.) Because of capacitance tolerances, some units may not reach 1,800 rpm for calibration on a four-cycle engine. C1 should be increased until the unit can be calibrated.

I have built two units: one with a 50-$\mu$A meter, and one that plugs into my multimeter, which has a 100-$\mu$A movement. The 50-$\mu$A movement has a convenient scale for 0–5,000 rpm, but the scale divisions are not convenient for the dwell meter. The multimeter, on the other hand, has convenient scales of 3, 6, 12 on a large 4½-inch scale. I use the 6-scale, even though I have to read it in reverse, for 60° dwell, with one division per degree. For the tach I use the 6 and 12 scales for 6,000 rpm and 1,200 rpm. The lower range is good for setting idling and other low-rpm adjustments. You get it by increasing the value of C1.

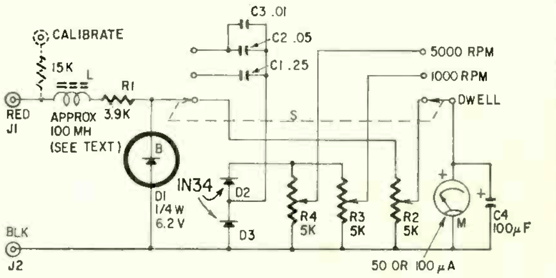
I have checked the accuracy of the unit with the 50-$\mu$A meter on the 0-5000 scale and found it to be within 2% of full scale. This was done with a power audio oscillator, which could furnish the current. I have not checked the accuracy of the low-rpm scale on the multimeter unit yet. The dwell meter has been checked by several people who have carefully gapped their points, and then taken a reading: the reading has been within the manufacturer's specifications every time.

As far as temperature stability is concerned, the unit was taken to 120°F by placing it 9 inches in front of an electric heater, and then to 22°F by placing it in the freezer. At no time did the reading change more than 1% or 50 rpm.

Construction is noncritical. The meter will probably be the most expensive item in the unit. A bit of digging may turn up a surplus meter, or a new one can be bought from Lafayette Radio Electronics Corp. or other mail order firm, for about $6. If you use your multimeter, you can eliminate this expense. The choke may be the hardest thing to find—here, you may have to experiment. The choke does not have to be a toroid. Almost any low-resistance one of more than 50 mH, and less than 500 will probably do. A single-pie rf choke of about 100 mH worked well. Since it has rather high resistance, its resistance was subtracted from the value of R1 to keep the total value about 3,900 ohms. Miller No. 960, 961 or 860 will do nicely. I know of one unit built with all new parts for less than $10. END

C1—0.25 $\mu$F, paper or Mylar
C2—.05 $\mu$F, paper or Mylar
C3—.01 $\mu$F, paper or Mylar
C4—100 $\mu$F, 12 volts (electrolytic)
D1—6.2-volt ¼-watt Zener diode
D2, D3—1N34 or 1N34-A diodes
J1, J2—binding posts
L—100-mH (approx.) choke—see text
M—50- or 100-$\mu$A dc meter—see text
R1—3,900 ohms, ½ watt
R2, R3, R4—pots, 5,000 ohms
S—2-pole, 3-position rotary switch
Case and hardware to suit mounting preference

*Fig. 4—Complete unit, with two tachometer ranges and one dwell range. For positive-ground electrical systems, no change is necessary; just connect metering circuit to car so that the red binding post is positive.*



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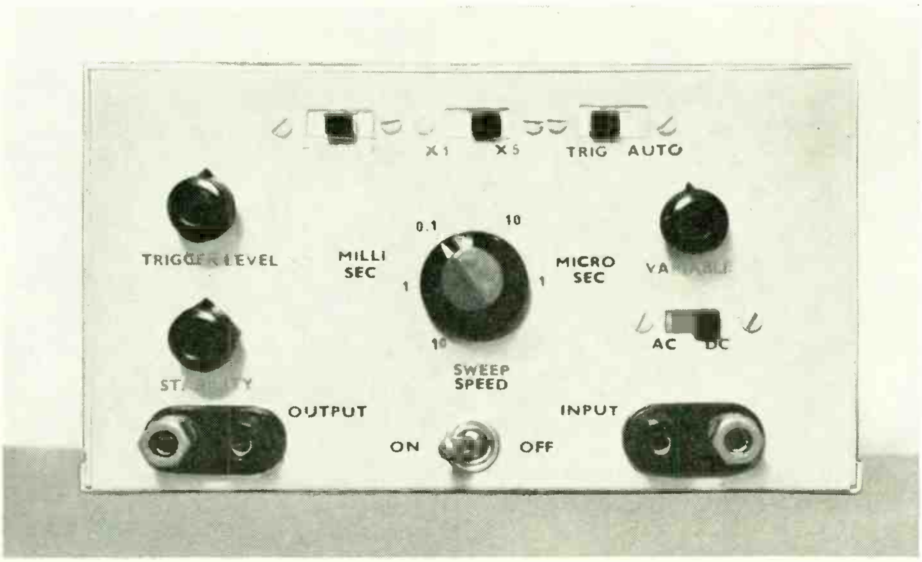
1. Skilling, H. H., *Electrical Engineering Circuits*; John Wiley and Sons, Inc., 1957.
2. Elmore and Sands, *Electronics*; McGraw-Hill, 1949.

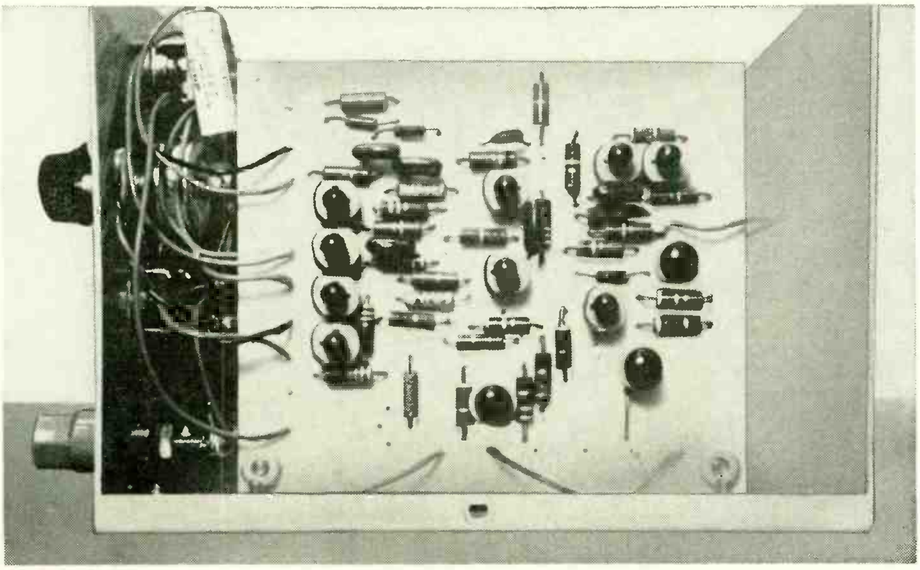
# Trigsweep Upgrades Inexpensive Scopes

**Easy-to-build solid-state triggered-sweep unit works with any scope, gives sweep rates to 1 microsecond per inch**

**By THOMAS B. MILLS and WILLIAM O. HAMLIN**

MOST MODERATE AND LOW-PRICED OScilloscopes have free-running sweeps. The trace is held still by setting the sweep speed to a submultiple of the input frequency. Laboratory instruments, on the other hand, have a *triggered sweep*—the sweep speed is constant rather than variable. The sweep is started by the input signal so there is no synchronizing problem, and usually the trace is blanked out until the sweep starts. When sweep time is a simple, constant number such as 1 or 10 μsec per division, it is easy to measure pulse shape, width, rise and fall times, and even frequency, without Lissajous patterns.





*Trigsweep is constructed on two perforated boards. The one seen here carries all the circuitry except the blanking amplifier and power supply, which are on the other board. Power transformer is on the floor of the cabinet. Printed circuit boards are available.*

You can easily add triggered sweep to your scope. This Trigsweep* unit plugs into the horizontal input jacks, blanking goes to the Z jack, and away you go. Any scope that has wide bandwidth is ideal for this modification. In the EICO 460, all necessary connections can be made at the front panel. Other scopes for easy Trigsweep conversion are the Knight-Kit KG-635 and the Heathkit IO-12.

## The circuit

Fig. 1 is the Trigsweep's schematic diagram. The input amplifier lets you control the level of input at which triggering begins, whether it is on a positive or negative excursion of the input, 180° phase shift, and selection of plus or minus dc levels. Input levels from 100 mV to 50 volts rms can be handled. Larger voltages require an attenuator.

Switch S3 controls operating mode. On TRIG the screen is blank until an input signal is present; on AUTO, free-running sweep allows adjustment of intensity and focus. The AUTO oscillation immediately syncs to input signals.

Trigger multivibrator Q3–Q4 has a square-wave output which is differentiated and clipped by D1 to give a sharp positive spike. This drives the sweep start–stop multivibrator, Q5–Q6.

Q6's collector is normally *low*, holding Q7 *on*, and there is no sweep output. The stability control is set so

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**Semiconductor Kit and Etched Boards**

Drilled etched circuit boards for the Trigsweep are available for $4.95 each. A kit of all semiconductors except the power supply diodes (D4, D5, D6 and D7) are available for $12.95. Fairchild semiconductors are supplied. Order boards or semiconductor kits from Solid-State Services, 1720 Kimberly Drive, Sunnyvale, Calif. 94087.

the voltage on Q5 is just below cutoff. A trigger spike will turn Q5 on, turn Q6 and Q7 off, and the sweep starts. Sweep capacitor $C_A$ charges linearly through R25 and R26 due to the gain of Q8 and Q9 (called a Miller sweep). Switching of $C_A$ is shown in Fig. 2.

The current through Q10 falls as the charge across $C_A$ increases, thus developing the sweep voltage. Both positive and negative sweep outputs are available to take care of the horizontal input phase requirements of any scope. Sweep for the scope should be taken from either the plus or minus output, not both, for a left-to-right sweep.

Q11 and Q12 stop the sweep when Q10's emitter voltage nears −20 and *holds off* or prevents triggering until sweep flyback (retrace) is complete. This circuit is called a "one-shot" multivibrator because Q12's collector stays low at the end of the sweep until C2 discharges. The holdoff voltage is applied through a feedback loop to the base of Q5. Holdoff should be about 10% of sweep time, so $C_B$ is made a

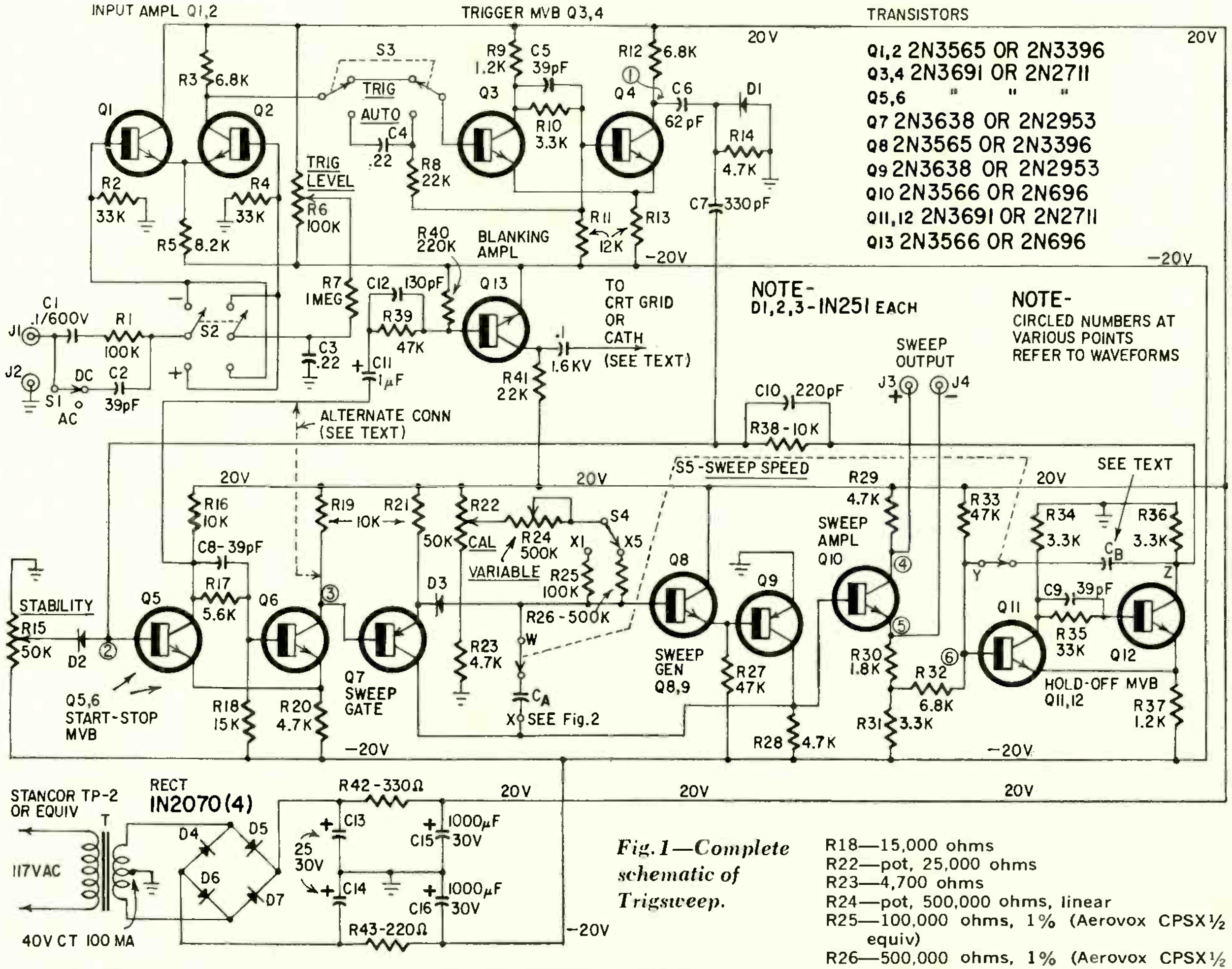


*Fig. 1—Complete schematic of Trigsweep.*

C1—0.1 µF, 600 volts
C2, C5, C8, C9—39 pF
C3, C4—0.22 µF
C6—62 pF
C7—330 pF
C10—220 pF
C11—1 µF
C12—130 pF
C13, C14—25 µF 30 volts, electrolytic
C15, C16—1,000 µF 30 volts electrolytic
C17—0.1 µF, 1,600 V
D1, D2, D3—1N251
D4, D5, D6, D7—1N2070
J1, J2, J3, J4—jack-top (5-way) binding posts
Q1, Q2, Q8—2N3565 or 2N3396
Q3, Q4, Q5, Q6, Q11, Q12—2N3691 or 2N2711
Q7, Q9—2N3638 or 2N2953
Q10, Q13, 2N3566 or 2N696
R1—100,000 ohms
R2, R4, R35—33,000 ohms
R3, R12, R32—6,800 ohms
R5—8,200 ohms
R6—pot, 100,000 ohms, linear
R7—1 megohm
R8, R41—22,000 ohms
R9, R37—1,200 ohms
R10, R31, R34, R36—3,300 ohms
R11, R13,—12,000 ohms
R14, R20, R28, R29—4,700 ohms
R15—pot, 50,000 ohms, linear
R16, R19, R21, R38—10,000 ohms
R17—5,600 ohms
R18—15,000 ohms
R22—pot, 25,000 ohms
R23—4,700 ohms
R24—pot, 500,000 ohms, linear
R25—100,000 ohms, 1% (Aerovox CPSX½ or equiv)
R26—500,000 ohms, 1% (Aerovox CPSX½ or equiv)
R27, R33, R39—47,000 ohms
R30—1,800 ohms
R40—220,000 ohms
R42—330 ohms
R43—220 ohms
**All resistors ½ watt, 10% except as marked**
S1, S4—spdt slide or toggle switch
S2, S3—dpdt slide or toggle switch
S5—2-pole 5-position rotary switch
T—transistor power transformer, 40 volts ct, 100 mA (Stancor TP-2, Triad F-94X or equivalent)
Metal case (8 x 6 x 4½ in. used here), perforated phenolic circuit board, hardware, transistor sockets if desired

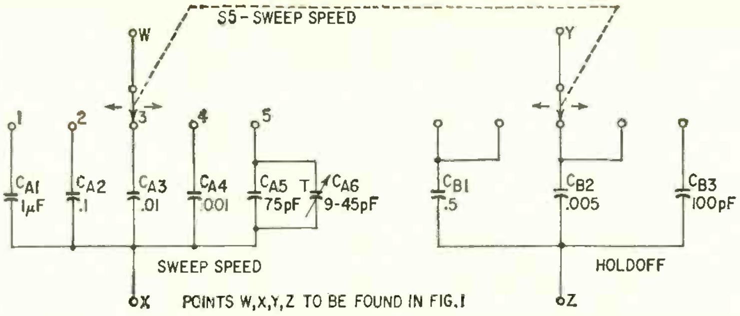


*Fig. 2—Timing-capacitor and hold-off-capacitor networks for Trigsweep. Timing capacitors $C_{A1}$ through $C_{A4}$ should be high-stability, close tolerance types. $C_{A5}$ is trimmed with $C_{A6}$ for highest range to compensate for stray capacitance, so tolerance is not critical there. The switch should be of the low-capacitance type.*

$C_{A1}$—1 $\mu$F Mylar or metalized paper, 5%
$C_{A2}$—0.1 $\mu$F Mylar or metalized paper, 5%
$C_{A3}$—.01 $\mu$F Mylar or dipped silvered mica, 5%
$C_{A4}$—.001 $\mu$F dipped silvered mica, 5%
$C_{A5}$—75 pF dipped silvered mica, 5%
$C_{A6}$—mica trimmer, 9–45 pF
$C_{B1}$—0.5 $\mu$F
$C_{B2}$—.005 $\mu$F
$C_{B3}$—100 pF

**All these capacitors can have voltage ratings of 50 or higher. For $C_A$ capacitors, tolerance of 2% or better will do no harm, for the sake of timing accuracy. Tolerance of $C_B$ capacitors is not critical.**

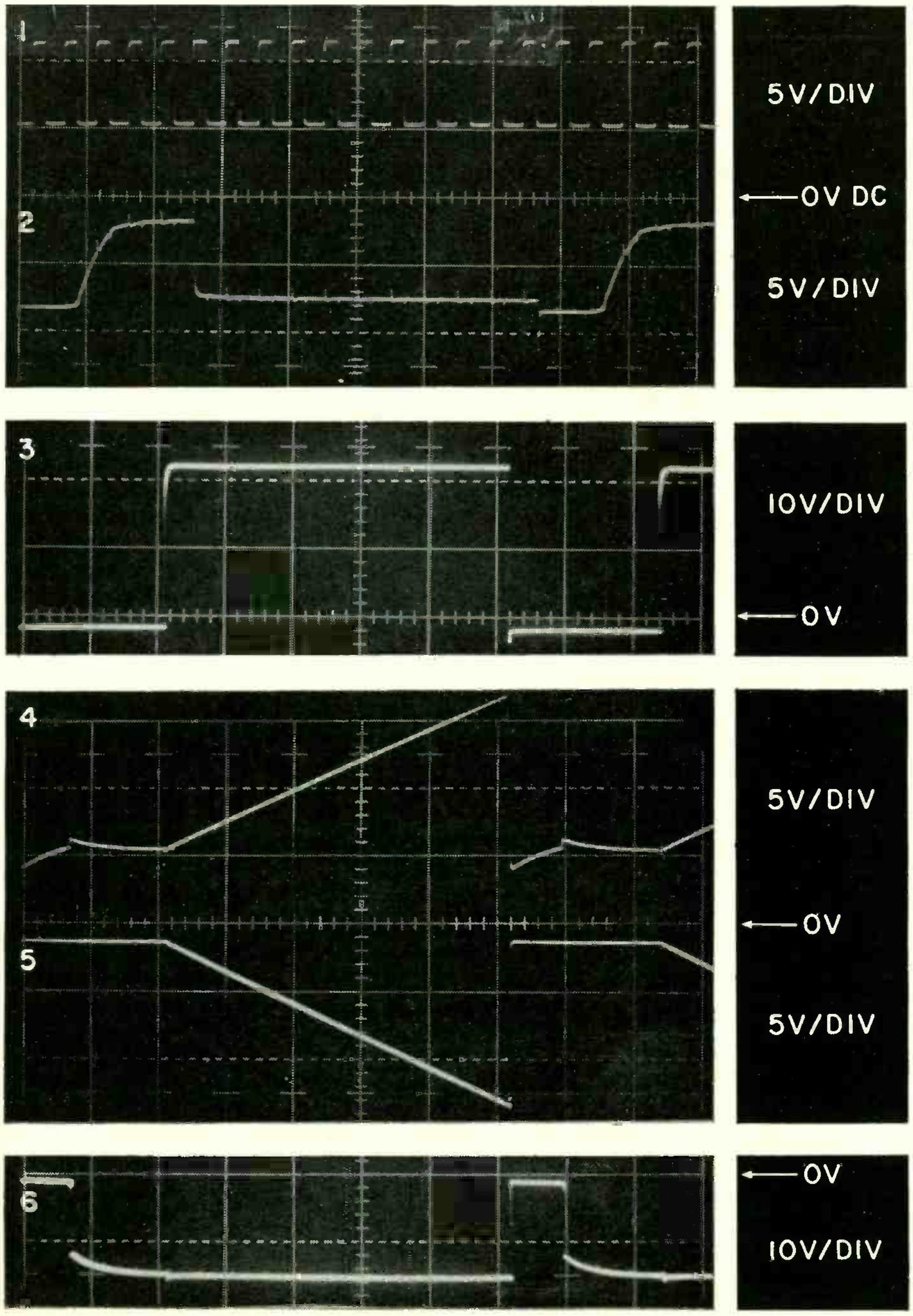


*Fig. 3—These waveforms are at correspondingly numbered points on Fig. 1 schematic.*

different size for each speed (Fig. 2).

Blanking transistor Q13 is driven from the collector of either Q6 or Q7. Drive from Q7 provides a negative unblanking signal for CRT cathode control, and from Q6 the opposite phase for CRT grid control. The Eico 460 has the CRT cathode connected to the Z-axis jack. You can disconnect the scope's internal blanking with a switch when the built-in free-running sweep is not to be used.

The Trigsweep input will load high-impedance circuits under observation. Because of that you'll find it better to take the trigger signal from the scope's vertical amplifier at some low-impedance point. The existing tapoff for internal sync is fine. The signal can be taken conveniently from the internal/external sync switch on the scope through a 0.1-$\mu$F capacitor. Just add a banana jack on the scope's front panel.

All transistors are silicon planar (11 n-p-n's and 2 p-n-p's). The diodes are also silicon. Transistor characteristics are not critical except for voltage ratings, which must be over 40-volt breakdown (30 volts for the p-n-p's). Current gains over 100 are recommended. Q10 should be a medium-power type (1 watt). The waveforms of Fig. 3 will help in troubleshooting—if you have trouble.

A right-side view is shown in the photo. The box for the sweep unit is larger than necessary (8 × 6 × 4½-inch LMB box) to give plenty of panel space for controls. The power supply and unblanking-amplifier circuit board is on the left side.

## Calibration

Calibration sets sweep length vs time to give you an exact time base. To calibrate, set the variable sweep speed and calibration controls to zero (zero resistance) and set multiplier switch S4 to × 1. Apply an accurate signal source with known frequency to the sweep trigger input and scope input—for instance, 1 kHz or 10 kHz. Adjust horizontal gain so the sweep covers the screen from the left to the right limit lines on the graticule. Set the sweep switch to an appropriate position: position 1 for 60 Hz, position 2 for 1 kHz, position 3 for 10 kHz, etc. Adjust R2 for exactly 8 cycles or 10 cycles between the 4-inch or 10-centimeter marks respectively. (Most service scope graticules are marked in inches but laboratory scopes are in centimeters.) The time base can now be read (switch position 2 and 1-kHz signal) as 2 msec (.002 sec) per inch or 1 msec per centimeter.

Next calibrate the highest sweep speed with $C_{A6}$ (Fig. 3). Use a 1-MHz accurate signal source and set $C_{A6}$ for 8 or 10 cycles from left to right (inches or centimeters, respectively). Each time the scope is used, set horizontal gain to cover the 4-inch or 10-cm sweep length for correct time vs distance.

Available sweep times are listed in Table I for the calibration setup above. Table II shows the relationship between time and frequency.

If you are accustomed to thinking in frequency rather than time, you will be surprised how easy it is to invert your reference, especially when you no longer have to diddle a frequency control to sync the picture. Time of 1 cycle equals 1 divided by frequency ($T = 1/f$), or vice versa ($F = 1/T$). Therefore, switch position 1 at .02 sec per inch equals $F = 1/.02 = 50$ Hz. That is, 1 cycle per inch at 50 Hz or 2 cycles per inch at 100 Hz. Position 5 at 2 µsec/in. gives $F = 1/(2 \times 10^{-6}) = 0.5$ MHz for 1 cycle per inch and 1 MHz gives 2 cycles per inch.

To measure frequency, set the sweep speed for a convenient number of cycles on the screen. To read, total the time and divide by the number of cycles and invert the number. For instance (see table), if at position 4 with the expansion switch at × 5, your unknown signal results in 10 cycles across 3 inches, the total time is 3 inches $\times 100 \times 10^{-6}$ sec per cycle. Frequency is $F = 1/30 \times 10^{-6} = .033$ MHz, or 33 kHz.

TV vertical scan can be observed on switch position 1 with four pulses per sweep, while position 2 and × 5 will show two pulses per sweep.

A TV horizontal scan line will best be observed on position 4, which will stretch the 63-µsec TV horizontal line over the whole 80 µsec (20 µsec × 4 in. = 80 µsec).

It is important to remember that the Trigsweep unit takes the trigger signal from TV vertical, TV horizontal or signal generator circuits. Trigsweep has the advantage of giving you the time relationship between the point of triggering and point of observation. Thus you can measure delay through stages and networks. Better yet, you easily keep track of what you are looking at. After a little experimentation and practice, triggering will be like duck soup.

When you are looking at single-pulse phenomena, the time between the start of sweep and the pulse of interest is important. The sweep may begin its excursion too late for the leading edge to be seen. Lab scopes take care of this by including built-in delay lines in the vertical circuit. With the Trigsweep, just select the trigger source carefully. For instance, the 9-µsec horizontal sync pulse of a TV signal can be stretched over almost an inch on position 5, × 1, by using the horizontal flyback pulse for triggering. The plus or minus input selection and trigger level control give you flexibility on where the triggering will start.

The ability to see fast rise times on the scope without jitter makes measurement of amplifier bandwidth easy. Drive the amplifier under test with a good square-wave source from which you can also trigger the Trigsweep. Observe the waveform at the input to see if it is really square or limited by the scope's bandwidth. Now observe the waveform at the output and measure its rise or fall time (see Fig. 4). Approximate bandwidth is 0.35 divided by this time ($\Delta f = 0.35/t$). For instance, a 35-kHz bandwidth audio amplifier will have a rise time of 10 µsec (½ inch on position 4, × 1). For tuned amplifier systems, a square-wave-modulated signal at the passband frequency is required. The modulated output is fed to the scope's vertical input. END

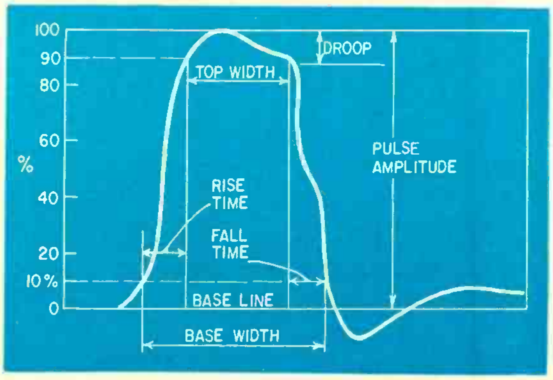
TABLE I

| Sweep speed switch pos | ×1 per inch/per cm | ×5 per inch/per cm | Freq for 2 cycles/inch |
|---|---|---|---|
| 1 | .02 sec/.01 sec | 0.1 sec/.05 sec | 100 Hz |
| 2 | 2 msec/1 msec | 10 msec/5 msec | 1000 Hz |
| 3 | 200 µsec/100 µsec | 1 msec/0.5 msec | 10 kHz |
| 4 | 20 µsec/10 µsec | 100 µsec/50 µsec | 100 kc |
| 5 | 2 µsec/1 µsec | 10 µsec/5 µsec | 1 MHz |

TABLE II

| Time | Frequency | Time | Frequency |
|---|---|---|---|
| .1 µsec | 10.000 MHz | 60.0 µsec | 16.7 kHz |
| .2 | 5.000 | 70.0 | 14.3 |
| .3 | 3.333 | 80.0 | 12.5 |
| .4 | 2.500 | 90.0 | 11.1 |
| .5 | 2.000 | 100.0 | 10.00 |
| .6 | 1.667 | 200.0 | 5.00 |
| .7 | 1.429 | 300.0 | 3.33 |
| .8 | 1.250 | 400.0 | 2.50 |
| .9 | 1.111 | 500.0 | 2.00 |
| 1.0 | 1.000 | 600.0 | 1.67 |
| 2.0 | 500. kHz | 700.0 | 1.43 |
| 3.0 | 333. | 800.0 | 1.25 |
| 4.0 | 250. | 900.0 | 1.11 |
| 5.0 | 200. | 1. msec | 1.00 kHz |
| 6.0 | 167. | 2. | 500 Hz |
| 7.0 | 143. | 3. | 333 |
| 8.0 | 125 | 4. | 250 |
| 9.0 | 111. | 5. | 200 |
| 10.0 | 100. | 6. | 167 |
| 20.0 | 50.0 | 7. | 143 |
| 30.0 | 33.3 | 8. | 125 |
| 40.0 | 25.0 | 9. | 111 |
| 50.0 | 20.0 kHz | 10. msec | 100 Hz |

*Fig. 4—Definition of terms used in measuring a pulse—easy to do with "one-shot" display from the Trigsweep.*



# 2.5-GHz Microwave ETV Systems

**Another blossoming application of microwaves is calling out for qualified installers, operators and techs**

**By GEORGE SITTS**

IF YOU'RE AN ANTENNA WATCHER, YOU might notice a new species sprouting on your neighborhood school. A growing number of school systems are using the new Instructional Television Fixed Service established by the FCC in the 2.5-GHz (2,500 MHz) band. All types of formal educational systems, from the smallest public and private grade schools to the largest university centers, are taking advantage of this new service.

Educators use low-power transmission in the microwave bands to connect a central ETV center with designated schools within a region.

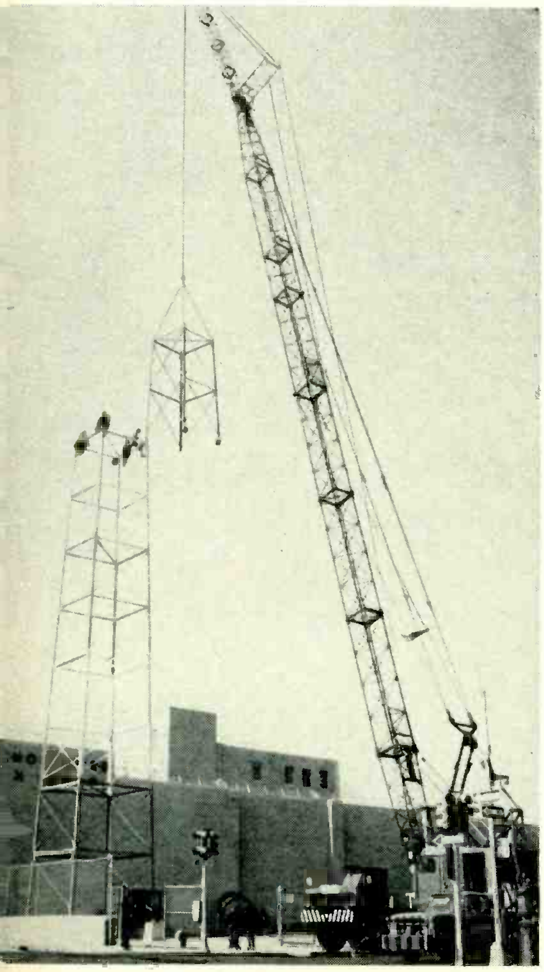
The FCC first proposed the new instructional television service in mid-1962 for the transmission of instructional programs. Many education administrators who wanted to use TV thought that the cost of cables between schools was making it impractical for them. However, the proposal received general approval and was tested in the Plainedge, N.Y. school district using a 2,000-MHz transmission system produced by Adler Electronics Inc.

The test sparked much comment, in and out of the educational field. Commercial television broadcasters, whose TV auxiliary service band was being used for the test, liked the idea; however, they suggested it be instituted in the 2.5-GHz band. They pointed out that 31 channels could be allocated there, whereas only 20 channels were available in the 2-GHz band, and many of these were already being used by commercial TV broadcasters.

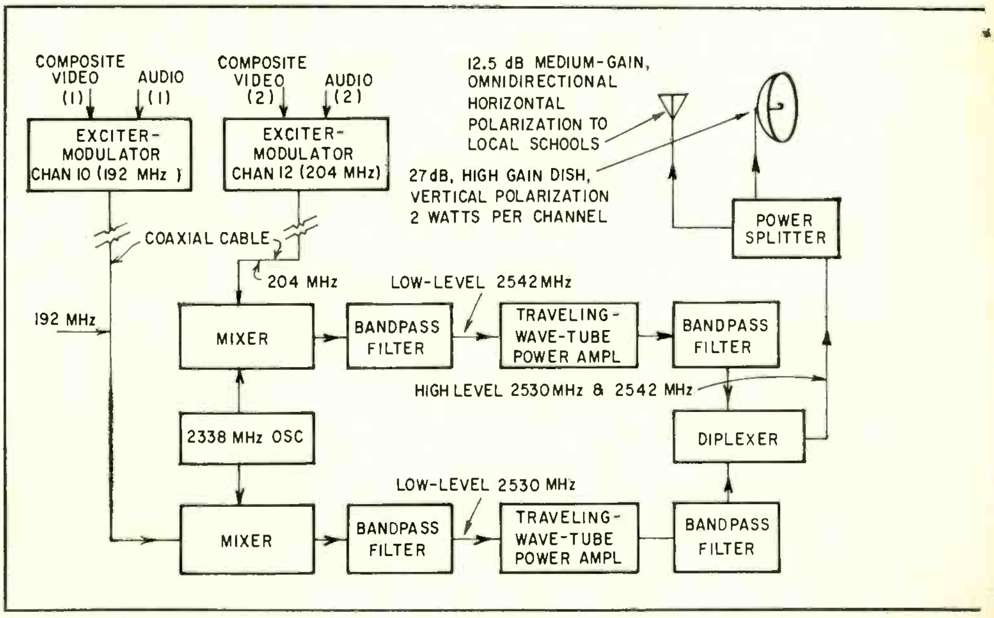
On September 9, 1963, the Commission decided on the 2.5-GHz frequencies. It specified a maximum power of 10 watts per channel, with additional power to be authorized only on proof of need. After further experiments in the field, Adler Electronics suggested that multiple frequency assignments (a school system may request up to four channels) be spaced so that the output signal, when heterodyned with a single local oscillator, would fall exactly on vhf TV channel frequencies. Adler also recommended that the output signals be close enough to each other in frequency to allow them to be received by a single broadband preamp. The FCC, which up to that time had been assigning only every sixth channel, evaluated the suggestions and began assigning alternate channels to multiple-frequency educators in May, 1964.

The first school system to use the new service was Plainview-Old Bethpage school district in Long Island. They applied for a license in early January, 1964, and were in single-channel operation by October, 1964. By the time the Plainview system was on the air, over a dozen other public and private school systems had formally applied for construction permits. By February 1966 there had been so many applications for the 31 channels that the Commission proposed new rules to limit the number of channels for a single licensee to four.

The FCC does not distinguish between licenses for an originating station



*Bishop Ford High School in Brooklyn gets a new tower to support its 2.5-GHz microwave television antenna system*



and for a repeater station. A separate license good for up to the four-channel maximum is granted for each repeater. Some school systems now hold as many as seven 4-channel licenses, presumably for one originating station of four channels and six 4-channel repeating stations.

This much activity, particularly in heavily populated areas, could cause serious intersystem interference. The FCC has recognized the problem. It suggests directional receiving antennas and locating transmitters where receiving antennas will not be aimed toward other similar transmitters.

The FCC expects new applicants to use as many state-of-the-art refinements as possible to eliminate potential interference from their own or neighboring systems. Cross-polarization, counter-rotating circular polarization, patterned transmitting antennas, careful selection of operating frequencies and transmitter location are all part of careful engineering in this microwave service.

To protect future space communications, the FCC does not allow "periscope" type transmitting antenna systems—ones that use a high-gain antenna aimed vertically up a tower at a tilted reflective screen.

In school systems with only a few schools, or schools conveniently located, a directional transmitting antenna system is used. It may be a series of microwave dishes, each aimed at a particular school or string of schools, or it may be a specially constructed antenna covering 90° or more. In larger school systems, a separate antenna for each school is impractical, and a high-gain omnidirectional antenna is used. Typical horizontal power gains of an omni antenna are 12 or 13, giving adequate signal to directional receiving antennas located beyond 12 miles, as long as they are line-of-sight from the transmitting antenna.

In fact, line-of-sight seems to be the secret of 2.5-GHz TV transmission. If the transmitter antenna does not have line-of-sight to schools even a few blocks away, it is not likely the signal will be received there unless a receiving antenna tower is erected.

Often, to cover nearby schools as well as distant schools, about 1 dB of the transmitter output is spent in *null-fill* transmission. Designed into the transmitter antenna, null-fill is a low-power, low-gain circular pattern aimed downward from the transmitting antenna to cover schools that would otherwise be underneath the almost horizontal plane of the main power beam.

In places where coverage to all schools in a district is practically impossible from a single transmission point, the FCC has provided for repeater stations.

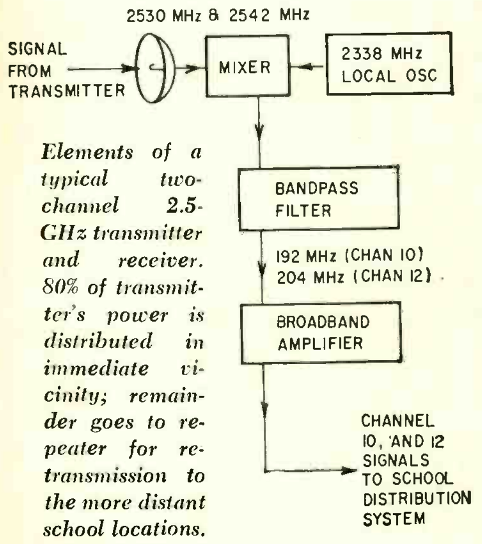
A typical repeater will receive the signal or signals of the originating station on a high-gain, tower-mounted microwave dish antenna. The signal is then fed down the tower to the repeater transmitter where a crystal-controlled oscillator heterodynes the signal or signals to a new frequency. Still in the 2.5-GHz band, the new frequency is then amplified and reradiated from a transmitting antenna system.

## How the equipment works

Transmitters for the new service consist of two major parts, the modulator and the 2.5-GHz transmitter. The modulator is much like in closed-circuit television. It accepts a composite video signal and an audio signal and converts them to a crystal-controlled vhf television signal at about 1 volt across 75 ohms.

The 2.5-GHz transmitter portion may be located some distance from the modulator, connected to it by coaxial cable. The transmitter accepts the vhf signal and beats it against a microwave oscillator whose frequency is chosen so that it produces an output on the assigned transmission frequency when it is added to the vhf signal frequency. Unwanted beat frequencies are trapped out. The output is fed to a traveling-wave tube for amplification, then sent via coaxial cable or waveguide up the tower to the transmitting antenna.

At the receiving site the signal is fed to a converter located on the mast with the receiving antenna. A local oscillator in the converter, crystal-controlled at the same frequency as the transmitter's oscillator, is beat against the incoming signal, leaving a difference signal which is the same as the vhf signal from the modulator. This vhf signal can



*Elements of a typical two-channel 2.5-GHz transmitter and receiver. 80% of transmitter's power is distributed in immediate vicinity; remainder goes to repeater for retransmission to the more distant school locations.*

*Typical scene in school's TV studio.*

*Student technician adjusts antenna.*

then be amplified and distributed via a vhf master-antenna system for reception on any ordinary TV receiver.

In school systems that transmit on several channels, a single fixed-frequency transmitter oscillator is used for all channels, with differences in transmitted frequency coming only from the differences in vhf carrier frequencies from the several modulators. Thus, one broadband 2.5-GHz receiver with one local oscillator can convert several signals to separate vhf channels.

Schools are relatively free to use systems as they wish, as long as they follow a few token rules of operation. They must use the facility principally for instructional and cultural material for formal education of students. During idle periods, however, the system can handle such administrative traffic as conferences with personnel, distribution of reports and assignments and exchange of data and statistics. Stations are not bound by any equal-time provisions or any limited hours of operation. They are, however, tied to technical standards like those of commercial broadcasters: including EIA sync, 525-line standard, amplitude modulation (A5) for transmission of visual signal, and frequency modulation (F3) for transmission of aural signal.

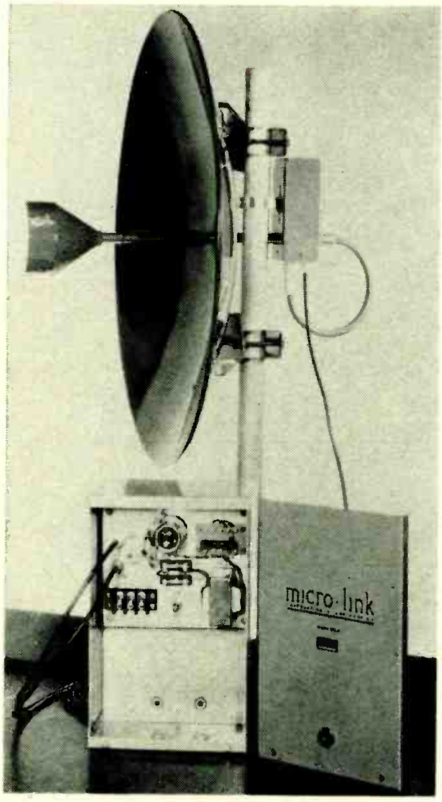
Vestigial-sideband transmission of the visual signal is not required, as in commercial television, but the lower sideband cannot exceed the amplitude of the upper sideband. Stations must maintain the 4.5-MHz sound carrier separation, maintain the visual carrier within 60 kHz and check (not measure) its frequency at least once a month. A roughly calibrated receiver is acceptable for measuring a submultiple of the carrier, usually accessible within the transmitter.

Call letters consisting of three letters and two digits (like KNZ-70) must be transmitted at sign-on and sign-off, and hourly during operation.

### What do you need to get in?

An operator with a Third-Class Radiotelephone Permit (no broadcast endorsement needed) may turn the transmitter on and off, make routine meter readings and adjust output power and modulation. A First- or Second-Class Radiotelephone licensee is required for any other tests, repairs or adjustments while the transmitter is in operation. Technicians with First's or Second's need not be employees of the school district, and may conceivably be outside technicians contracted for service.

The station must keep two logs. One, an operating log, must list the date and time of each period of operation and the time of any interruptions. The other, a maintenance record, logs all repairs, adjustments, maintenance, tests and equipment changes. The maintenance log must also show the date and time of these repairs, and the name and qualifications of the technician doing the maintenance.



*Micro-link Educational TV receiving antenna, down-converter and power supply.*

### Who is using the system?

Detroit, Michigan, is typical. Holder of a uhf (channel 56) license for several years, the school district had experimented with instructional television and found it effective but limited, due to its one-program-at-a-time restriction. In November 1965 they added two 2.5-GHz channels to the uhf channel. The district can now repeat programs during the day, which eliminates schedule problems due to different class times in the district's 60 schools.

The initial investment for transmission equipment was about $20,000 for the first channel and $15,000 for the second. A uhf channel of comparable coverage would cost about $50,000. Receiving equipment costs about $1,200 per school.

An installation at the University of California at Berkeley is broadcasting medical programs in color to hospitals in the San Francisco area.

The Catholic Schools of Brooklyn, N. Y. use two channels of 2.5-GHz to broadcast instructional programs produced by diocese personnel to 240 elementary and high schools in Brooklyn and Queens. Perhaps typical of large-school TV systems, diocesan studios are in one wing of a Catholic high school. Licensed for eventual 4-channel transmission, the system's remote-controlled main transmitter and 180-foot antenna are behind the school. A repeater transmitter with a 100-foot antenna is located on the roof of another Catholic high school in Queens.

Programs produced in the Brooklyn studios are recorded on videotape and later transmitted, two at a time, to the schools. Each program, averaging 22 minutes, is transmitted between 10 and 15 times each school year to accommodate the various school's schedules. Instructors use the programs to teach basics of such subjects as social studies, science, art and music. Program producers make no attempt to replace the classroom teacher. Rather, they plan programs to supplement a busy teacher with audio-visual materials he would normally not have time to obtain and edit for class use.

Brooklyn Catholic officials price their transmission system at about $15,000 per transmitter or repeater. They price school receiving systems at $1,000 per school for receiving antenna, tower and converter. The in-school master antenna system, a sophisticated three-cable network (one cable for commercial channels, one for diocese channels and one for programs originating in the school), averages about $100 per classroom.

In Houston, Texas, the Spring Branch Independent School District operates a two-channel system. A good example of a smaller network, Spring Branch spent $70,000 for studio, videotape and transmitting equipment, plus another $142,000 for receiving antennas, converters, master antenna systems and 325 receivers for the district's 24 schools.

The studio is a remodeled schoolboard meeting room. Students do camera work and videotaping on half-day schedules. A full-time TV engineer/technician handles technical operation and maintenance. Presently, Spring Branch uses one channel mainly for transmitting rented films and the second for locally produced programs.

Instructional Television Fixed Service has caught on. Florida, South Carolina and Nebraska are planning cables, repeaters and high-band microwave relays between central studios and regional transmitters in preparation for installation of a statewide 2.5-GHz service.

Because many educators with construction permits are completing their installations and actually broadcasting, other educators have been watching their programs and visiting their sites. Many of these "wait and see-ers" have filed for permits of their own. Educational television on 2.5-GHz is going places. END

# Making Up Resistor and Capacitor Decades

**By GLENN H. DORSEY**

RESISTOR AND CAPACITOR DECADES ARE standard in computers and measuring instruments such as bridges and meter multipliers. Commercial precision decades usually use individual exact values for each step, but it is possible to get the same decade values with only four precision resistors or capacitors. The small additional cost for the extra contacts needed on a rotary switch is much more than offset by the saving from being able to use fewer precision components. In 0.1% and .01% laboratory standards, the saving can be considerable.

For series resistors giving a decade from 0 (shorted) to 1 through 10, the classic 1-2-3-4 ratio of resistors can be used with a standard 2-pole 11-position rotary switch and some tricky connections. The simplified schematic of the switch and the four resistors is shown in Fig. 1 with a tabulation of the necessary connections. Fig. 2 shows connection details. Notice that the resistors are all permanently connected in series to the input and output terminals, while the switch contacts short out the unused values.

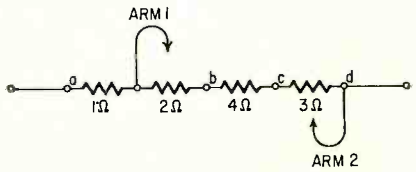


*Fig. 1—Simplified schematic of 1-2-3-4 series decading. Note that order of values is 1-2-4-3, Arms 1 and 2 are switch wipers.*

TABLE I

| OHMS | ARM 1 | ARM 2 |
|---|---|---|
| 0 | — | a |
| 1 | d | — |
| 2 | a | b |
| 3 | — | b |
| 4 | c | — |
| 5 | b | c |
| 6 | a | c |
| 7 | — | c |
| 8 | b | — |
| 9 | a | — |
| 10 | — | — |

Dash indicates no connection

Another series switching system that doesn't require special switch contacts or wiper arms is the all-series connection of 10 equal units. The switch arm shorts out up to 10 of the units to make a decade switch. This requires 10 resistors, but they are all of equal value (Fig. 3).

[An advantage of this approach is that the power dissipation of the decade is easy to figure. Assuming you use 1-watt resistors, the maximum dissipation with 1 ohm in-circuit is 1 watt; with 2 ohms, 2 watts, and so on. With the method of Figs. 1 and 2, the maximum dissipation is tricky to figure because the resistor values are unequal. For example, to get 3 ohms, the 1- and 2-ohm resistors are switched in series. If you apply 3 volts across the series pair, the 1-ohm resistor dissipates 1 watt but the 2-ohm resistor is forced to dissipate 2 watts. The maximum safe voltage that can be applied to the decade box when set for 3 ohms is 2.4 volts.—*Editor*]

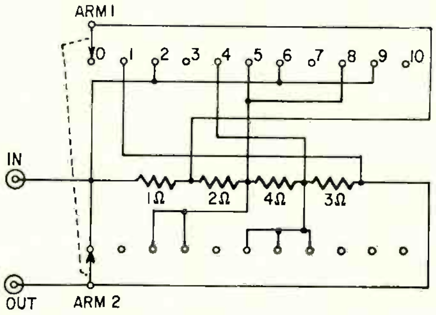


*Fig. 2—Full schematic of switching idea described in Fig. 1.*

The choice depends on the cost and availability of the precision resistors. Two to five decades are usually combined for laboratory decade boxes, one box usually starting with a lower decade of 0.1-ohm steps, and a higher-resistance box using 1,000-ohm steps. Laboratories sometimes keep each decade in a separate box, so that fewer decades are tied up in temporary bridges and breadboard test setups.

Capacitor and conductance (parallel-resistor) decade switches are different. The elements must be switched in *parallel*. Two sets of unit ratios will yield zero and 1 through 10 values with a 3-pole 11-position rotary switch: 1-2-3-5 and 1-2-2-6 (Table II). With a 4-pole rotary switch, unit ratios of 1-2-3-4 and 1-2-2-5 may be used for the same results. Four-pole, 12-position combinations for 0–11 are given in the last two columns. These different switching combinations are given so that decades can be designed around available values. Fig. 4 shows actual connections for a 3-pole 1-2-3-5 decade.

Parallel-resistor decades are used as conductance controls in computers, constant-current or constant-voltage supplies, feedback loops, etc. Conductance or impedance decades for any need can be designed by using a unit value as a starting point, then choosing the other values according to the ratios given in the tables.

Some decades, instead of going from 1 to 10, go only to 9, with the idea that the last unit between 9 and 10 will be supplied by the next smaller decade. This cuts the cost of the higher decades somewhat, especially if 0.1% or .01% laboratory standard values are used. On the other hand, some decades go to 11 units instead of 10, the extra step giving more flexibility in a great many applications. END

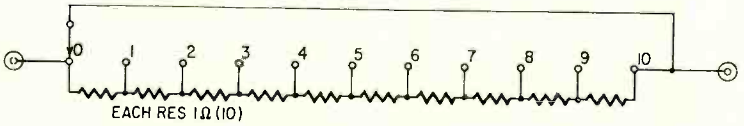


*Fig. 3—Simplest decade switch that requires 10 identical resistors—more expensive but sometimes more convenient than methods of Figs. 1 and 2.*

TABLE II

| Capacitance | 3 pole 1-2-3-5 | 3 pole 1-2-2-6 | 4 pole 1-2-3-4 | 4 pole 1-2-2-5 | 4 pole 1-2-4-4 | 4 pole 1-2-3-5 |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | 3 | 2-1 | 3 | 2-1 | 2-1 | 3 |
| 4 | 3-1 | 2-2 | 4 | 2-2 | 4 | 3-1 |
| 5 | 5 | 2-2-1 | 4-1 | 5 | 4-1 | 5 |
| 6 | 5-1 | 6 | 4-2 | 5-1 | 4-2 | 5-1 |
| 7 | 5-2 | 6-1 | 4-3 | 5-2 | 4-2-1 | 5-2 |
| 8 | 5-3 | 6-2 | 4-3-1 | 5-2-1 | 4-4 | 5-3 |
| 9 | 5-3-1 | 6-2-1 | 4-3-2 | 5-2-2 | 4-4-1 | 5-3-1 |
| 10 | 5-3-2 | 6-2-2 | 4-3-2-1 | 5-2-2-1 | 4-4-2 | 5-3-2 |
| 11 | | | | | 4-4-2-1 | 5-3-2-1 |

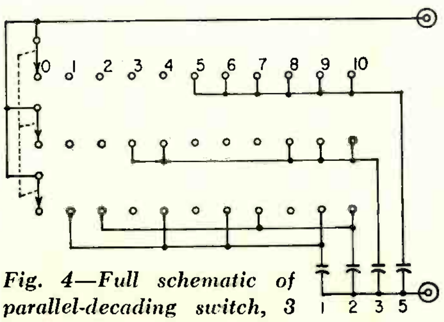


*Fig. 4—Full schematic of parallel-decading switch, 3 poles, 11 positions. Capacitors are shown, but this scheme can be used for paralleling resistors if you want extremely low values.*

# Zeroing-In Your Signal Generator

**A simple 5-MHz oscillator and a little patience will give you a calibrated generator you can trust**

**By M. R. GORDON**

LIKE ANY PRECISION INSTRUMENT, your rf generators—including dip meters and sweep/marker generators—must be accurately calibrated if they're to be useful. Here's how to avoid the common pitfalls in calibrating them.

Quartz-crystal oscillators are unquestionably the best secondary standard of frequency. An rf generator may have a built-in quartz-crystal oscillator, but if not, you can construct an external oscillator shown in Fig. 1. Parts layout is not critical. The rf choke is fixed in the original equipment. If you use a peaking coil with an adjustable core, you can trim the crystal frequency over a small range. A 5-MHz crystal is used. This oscillator provides useful harmonics to 200 MHz.

Various indicators can be used for calibration—an amplifier and speaker, an electron-ray (eye) tube or an oscilloscope. Since a scope has a sensitive vertical amplifier, and is readily available, let's take it first. In the simple test setup shown in Fig. 2-a, the demodulator probe detects the beat between the signal generator and crystal oscillator. Its output is fed to a scope, which may be operated on its internal sawtooth or on a 60-Hz sine-wave sweep. It may even be operated with no horizontal deflection. Most operators prefer 60-Hz sine-wave deflection, which gives the pattern shown in Fig. 2-b.

Between calibrating points, there is only a horizontal trace on the screen. As you approach a beat, the pattern builds up. At the zero-beat point, the pattern collapses abruptly to a horizontal line. If you pass the zero-beat point, the pattern suddenly builds up again. The zero-beat point is very critical—when you're there you know you're exactly on the crystal frequency or one of its harmonics.

The beginner often has difficulty deciding which crystal harmonic a zero-beat indicates. It isn't hard. Remember that the 5-MHz beat will be the strongest because 5 MHz is the crystal's fundamental frequency. Its second harmonic—10 MHz—will be the second strongest beat; 15 MHz will be third, etc. The strength of the beat signal is indicated by the height of the beat pattern.

If your rf generator is out of calibration, merely tune it to the strongest beat indication—5MHz on the dial. Most rf generators have trimmer capacitors for calibrating the instrument on each band. Adjust the correct trimmer to make the generator dial read *exactly* 5 MHz. Next, tune to the second strongest beat indication—at 10 MHz. Touch up that calibrating trimmer. In this manner, you can easily check out the generator at 5-MHz intervals over its entire range.

Next, you might wonder how the generator can be calibrated below 5 MHz, since the crystal oscillator in this example has no output below 5 MHz. Most rf generators have a substantial harmonic output. So, if a generator is set to 2.5 MHz, *its* second harmonic will zero-beat with the crystal fundamental. Below 5 MHz, the strongest harmonic beat occurs at 2.5 MHz (5 MHz/2), the next strongest on 1.666 MHz (5 MHz/3), then at 1.25 MHz (5 MHz/4), etc. By observing the sequence of strong beats, you can identify which harmonic you are working with. Note that if you reduce the scope gain sufficiently to make weaker beat patterns invisible, the possibility of confusion is reduced.

Since the crystal oscillator has harmonic outputs, as does the rf generator, it is obvious that harmonics can also zero-beat with harmonics—causing interharmonic beats. These are comparatively weak, but can be annoyingly apparent when the scope gain is turned up.

Table 1 shows calibration points over the entire range of a typical signal

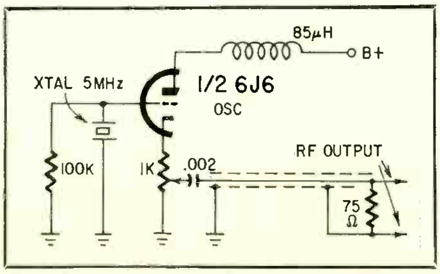


*Fig. 1—A very simple crystal calibrator.*

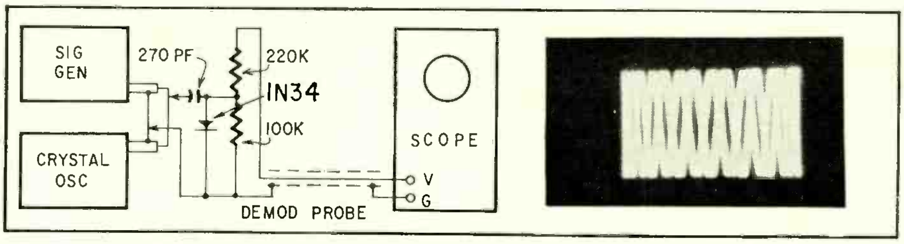


*Fig. 2-a—Diagram of test setup for calibrating signal generator; b—beat pattern.*

**Table 1—5-MHz Calibration Points**

| Band I | | | | Band II | | | | Band III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Var. Osc. Fundamental Megahertz | 2nd Harmonic Megahertz | Var. Osc. Harm. | Xtl. Osc. Harm. | Var. Osc. Fundamental Megahertz | 2nd Harmonic Megahertz | Var. Osc. Harm. | Xtl. Osc. Harm. | Var. Osc. Fundamental Megahertz | 2nd Harmonic Megahertz | Var. Osc. Harm. | Xtl. Osc. Harm. |
| *3.33 | *6.67 | 3 | 2 | *15.00 | *30.00 | 1 | 3 | *70.0 | *140 | 1 | 14 |
| 3.46 | 6.92 | 13 | 9 | 15.83 | 31.66 | 6 | 19 | 72.5 | 145 | 2 | 29 |
| 3.50 | 7.00 | 10 | 7 | 16.00 | 32.00 | 5 | 16 | *75.0 | *150 | 1 | 15 |
| 3.57 | 7.14 | 7 | 5 | 16.25 | 32.50 | 4 | 13 | 77.5 | 155 | 2 | 31 |
| 3.64 | 7.28 | 11 | 8 | *16.67 | *33.34 | 3 | 10 | *80.0 | *160 | 1 | 16 |
| *3.75 | *7.50 | 4 | 3 | 17.00 | 34.00 | 5 | 17 | 82.5 | 165 | 2 | 33 |
| 3.89 | 7.78 | 9 | 7 | *17.50 | *35.00 | 2 | 7 | *85.0 | *170 | 1 | 17 |
| *4.00 | *8.00 | 5 | 4 | 18.00 | 36.00 | 5 | 18 | 87.5 | 175 | 2 | 35 |
| 4.09 | 8.18 | 11 | 9 | *18.33 | *36.66 | 3 | 11 | *90.0 | *180 | 1 | 18 |
| *4.17 | *8.34 | 6 | 5 | 18.75 | 37.50 | 4 | 15 | 92.5 | 185 | 2 | 37 |
| 4.29 | 8.58 | 7 | 6 | 19.00 | 38.00 | 5 | 19 | *95.0 | *190 | 1 | 19 |
| 4.38 | 8.76 | 8 | 7 | *20.00 | *40.00 | 1 | 4 | 97.5 | 195 | 2 | 39 |
| *4.44 | *8.88 | 9 | 8 | 21.00 | 42.00 | 5 | 21 | *100.0 | *200 | 1 | 20 |
| 4.50 | 9.00 | 10 | 9 | 21.25 | 42.50 | 4 | 17 | 102.5 | 205 | 2 | 41 |
| 4.55 | 9.10 | 11 | 10 | *21.67 | *43.34 | 3 | 13 | *105.0 | *210 | 1 | 21 |
| 4.58 | 9.17 | 12 | 11 | 22.00 | 44.00 | 5 | 22 | 107.5 | 215 | 2 | 43 |
| *5.00 | *10.00 | 1 | 1 | *22.50 | *45.00 | 2 | 9 | *110.0 | *220 | 1 | 22 |
| 5.63 | 11.26 | 8 | 9 | 23.00 | 46.00 | 5 | 23 | 112.5 | 225 | 2 | 45 |
| *5.71 | *11.42 | 7 | 8 | *23.33 | *46.66 | 3 | 14 | *115.0 | *230 | 1 | 23 |
| 5.83 | 11.66 | 6 | 7 | 23.75 | 47.50 | 4 | 19 | 117.5 | 235 | 2 | 47 |
| 6.00 | 12.00 | 5 | 6 | 24.00 | 48.00 | 5 | 24 | *120.0 | *240 | 1 | 24 |
| *6.25 | *12.50 | 4 | 5 | *25.00 | *50.00 | 1 | 5 | 122.5 | 245 | 2 | 49 |
| 6.43 | 12.86 | 7 | 9 | 26.25 | 52.50 | 4 | 21 | *125.0 | *250 | 1 | 25 |
| *6.67 | *13.34 | 3 | 4 | 26.67 | 53.34 | 3 | 16 | | | | |
| 6.87 | 13.74 | 8 | 11 | *27.50 | *55.00 | 2 | 11 | | | | |
| *7.00 | *14.00 | 5 | 7 | 28.33 | 56.66 | 3 | 17 | | | | |
| 7.14 | 14.28 | 7 | 10 | 28.75 | 57.50 | 4 | 23 | | | | |
| 7.22 | 14.44 | 9 | 13 | *30.00 | *60.00 | 1 | 6 | | | | |
| *7.50 | *15.00 | 2 | 3 | 31.67 | 63.34 | 3 | 19 | | | | |
| 7.72 | 15.44 | 11 | 17 | *32.50 | *65.00 | 2 | 13 | | | | |
| | | | | 33.33 | 66.66 | 3 | 20 | | | | |
| | | | | *35.00 | *70.00 | 1 | 7 | | | | |
| | | | | 36.67 | 73.34 | 3 | 22 | | | | |
| | | | | *37.50 | *75.00 | 2 | 15 | | | | |

ASTERISK (*) INDICATES THE STRONGER CALIBRATION POINTS generator. The strongest beat in the tabulation occurs at 5 MHz, as would be expected, because this is fundamental vs fundamental.

As you tune the generator below 5 MHz, you will observe many interharmonic beats. A comparatively strong one occurs at 4.44 MHz. Here, the 9th harmonic of the rf generator is beating against the 8th harmonic of the crystal. Again, a weaker interharmonic beat occurs at 4.5 MHz. Here, the 10th harmonic of the generator is beating against the 9th harmonic of the crystal.

Consider the beat pattern at 15 MHz. This is a strong beat because the 3rd harmonic of the crystal is beating against the fundamental of the rf generator. A comparatively strong interharmonic indication occurs at 16.67 MHz, where the 3rd harmonic of the rf generator is beating against the 10th harmonic of the crystal. A weaker interharmonic beat occurs at 16 MHz. The 5th harmonic of the generator is beating against the 16th of the crystal.

If the rf generator had no harmonic output, no interharmonic beats could be obtained. A zero beat could then be found only when the generator fundamental was tuned to a crystal harmonic frequency. No ordinary rf generator is that pure. Of course, if the rf generator and crystal oscillator both had strong harmonic outputs to infinitely high frequencies, you would encounter an infinite number of interharmonic beats. Actually, crystal harmonics higher than the 50th are generally too weak to produce a scope pattern. Hence, the number of interharmonic beats you can reach with individual generators and crystal oscillators depends on their circuit characteristics.

In most shops, the accuracy of the secondary frequency standard (quartz crystal) is taken for granted. On the other hand, it is wise to calibrate the crystal oscillator occasionally against an extremely accurate primary standard, such as the National Bureau of Standards station WWV. Highly precise radio and audio modulating frequencies are broadcast from the WWV transmitter now at Ft. Collins, Colo. The station operates on 2.5, 5, 10, 15, 20 and 25 MHz. Calibration accuracy is maintained to 1 part in 100 million.

To calibrate a crystal oscillator, tune in WWV at a convenient frequency, such as 5 MHz. Place the crystal oscillator near the receiver, and adjust the quartz crystal for zero-beat as indicated by the falling squeal from the speaker. The quartz crystal in Fig. 1 can be tuned to some extent by a slug in the 85-μH choke coil, or by a trimmer capacitor connected across the quartz crystal. The more expensive crystal holders have an adjustable plate, which tunes the crystal by varying the separation between plate and crystal.

In any event, the crystal must be ground to a frequency that permits tuning through its nominal frequency (5 MHz in this example) when used in a specific oscillator circuit. Quartz-crystal manufacturers are traditionally cooperative in recommending suitable crystals to be used in a given oscillator circuit. Or you may prefer to buy a ready-made crystal calibrator, which operates at a precise and precalibrated frequency.

### Using TV-station carriers

Television broadcast stations maintain accurate carrier frequencies which can be used to calibrate vhf signal and marker generators. Connect an rf sweep generator and scope to the tuner of a TV receiver as shown in Fig. 3. Two resistors (R1-R2) attenuate the antenna signal, which is also fed to the tuner. The response curve is shown. The picture and sound carrier frequencies appear as markers on the response curve. The values of the two resistors must be chosen to give conveniently sized markers—try values ranging from 1,000 to 100,000 ohms. If the resistors are too small, the markers will be excessively large and the pattern will be contaminated with video information. If too large, the markers will be too small to be useful.

**Table 2—TV Station Markers**

| Chan. | Freq. (MHz) | Video-Carrier Freq. (MHz) | Sound-Carrier Freq. (MHz) |
|---|---|---|---|
| 2 | 54–60 | 55.25 | 59.75 |
| 3 | 60–66 | 61.25 | 65.75 |
| 4 | 66–72 | 67.25 | 71.75 |
| 5 | 76–82 | 77.25 | 81.75 |
| 6 | 82–88 | 83.25 | 87.75 |
| 7 | 174–180 | 175.25 | 179.75 |
| 8 | 180–186 | 181.25 | 185.75 |
| 9 | 186–192 | 187.25 | 191.75 |
| 10 | 192–198 | 193.25 | 197.75 |
| 11 | 198–204 | 199.25 | 203.75 |
| 12 | 204–210 | 205.25 | 209.75 |
| 13 | 210–216 | 211.25 | 215.75 |

Next, place the output cable from the vhf generator near the TV lead-in. A third marker will appear on the response curve, moving along the curve as the generator is tuned. When the generator marker reaches the same spot as the picture-carrier marker, the generator frequency is exactly equal to the picture-carrier frequency. This procedure provides spot checks of vhf frequencies on all active channels. Table 2 lists the frequencies provided by TV stations.

Beginners often mistakenly assume that, if an rf generator is accurately calibrated at one point in the band, the output frequencies will also be accurate at other points on the tuning dial. The ability to maintain accurate calibration over the entire band depends on the L-C ratio of the oscillator circuit. Some rf generators have oscillator tanks with both trimmer capacitors and coil slugs. If you turn the slug into the coil to increase the inductance, the original frequency can be restored by reducing the value of trimmer capacitance. But the dial will track differently at each end, and one end is affected more than the other.

Hence, you should make three spot checks—near the center of the dial on each band and near each end. If tracking is unsatisfactory, change the L-C ratio and recheck calibration. This can be rather tedious, but there's no other way to bring the tuning dial in at both ends and at the center. It is advisable to avoid calibration attempts at the extreme ends of the dial, as unavoidable "end" effects are sometimes encountered.

To adjust the L-C ratio, use the trimmer at the high-frequency end and the slug at the low-frequency end. If the oscillator coil does not have a slug, you can expand the spacing between the last few turns to reduce inductance (raise frequency), and vice versa. You will note that tanks are often space-wound near one end. Small self-supporting coils can be squeezed or compressed, as required.

Finally, note that oscillator tuning capacitors usually have a slotted plate. The segments are adjusted at the factory to obtain optimum tracking over all bands. This is necessarily a compromise adjustment which should not be changed in the shop.

No generator can be calibrated for complete accuracy on all bands. You can, however, be confident that all bands can be made to fall within rated accuracy by the calibration procedures explained above. END

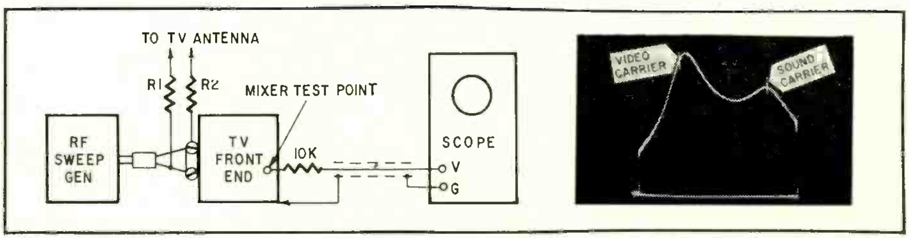
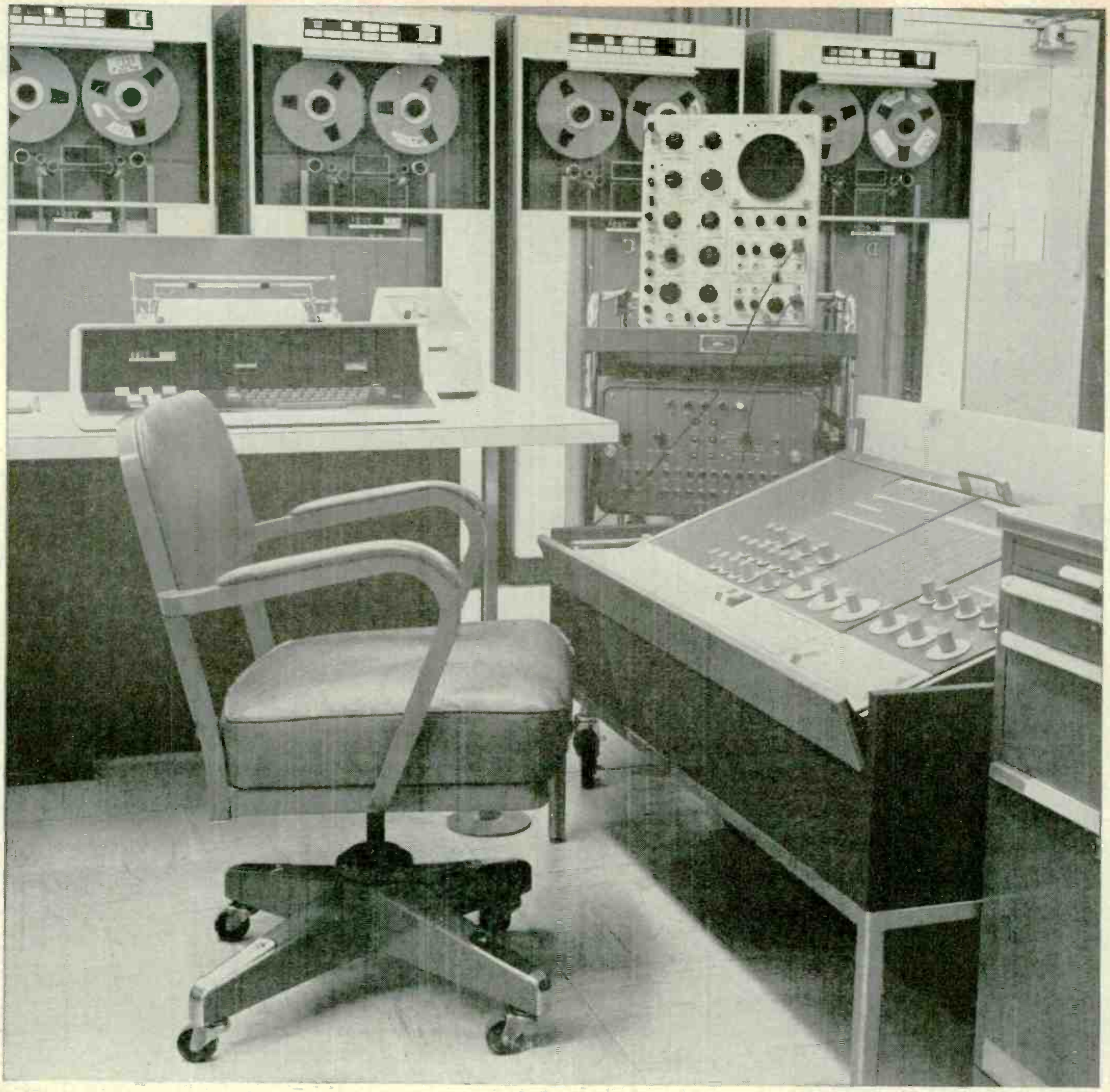


*Fig. 3-a—Calibrating setup for TV range; b—markers produced by TV broadcast signal.*



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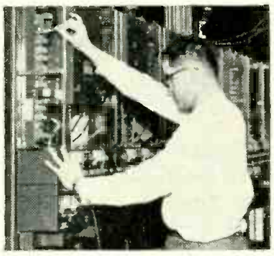

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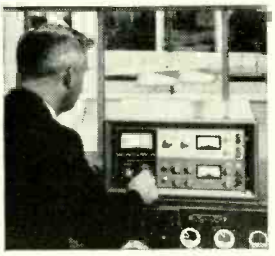

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# Build Yourself A Scope-Mobile

### Push-pull your scope where you need it with this wheeled wagon

By **JOHN A. TISO**

THE OSCILLOSCOPE IS VERY LIKELY THE most bulky item of test equipment you own. For many of us, bench and shelf space is a luxury that must be allocated like water on a desert. But proper use of the scope demands that it be located where it can be adjusted and viewed comfortably and conveniently.

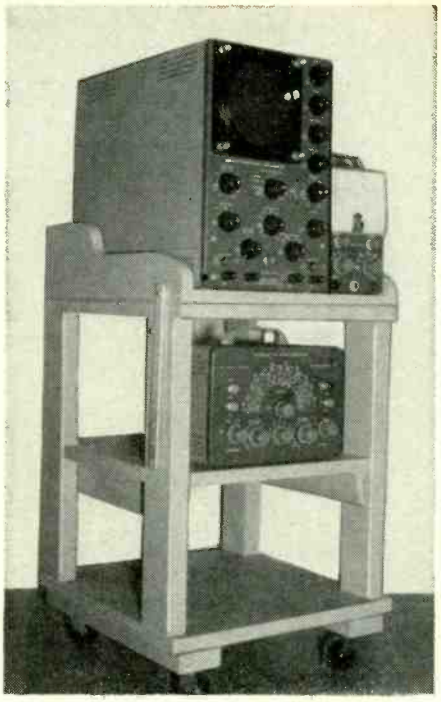
The Scope-Mobile gets the instrument off the bench, freeing valuable working space, and allows individual positioning for most comfortable operation. Additional benefits? Easy portability to any point in the shop, and extra space for instruments and accessories frequently used with the scope. There are, of course, commercially available scope racks, but they are intended for laboratory instruments and are expensive.

## Construction

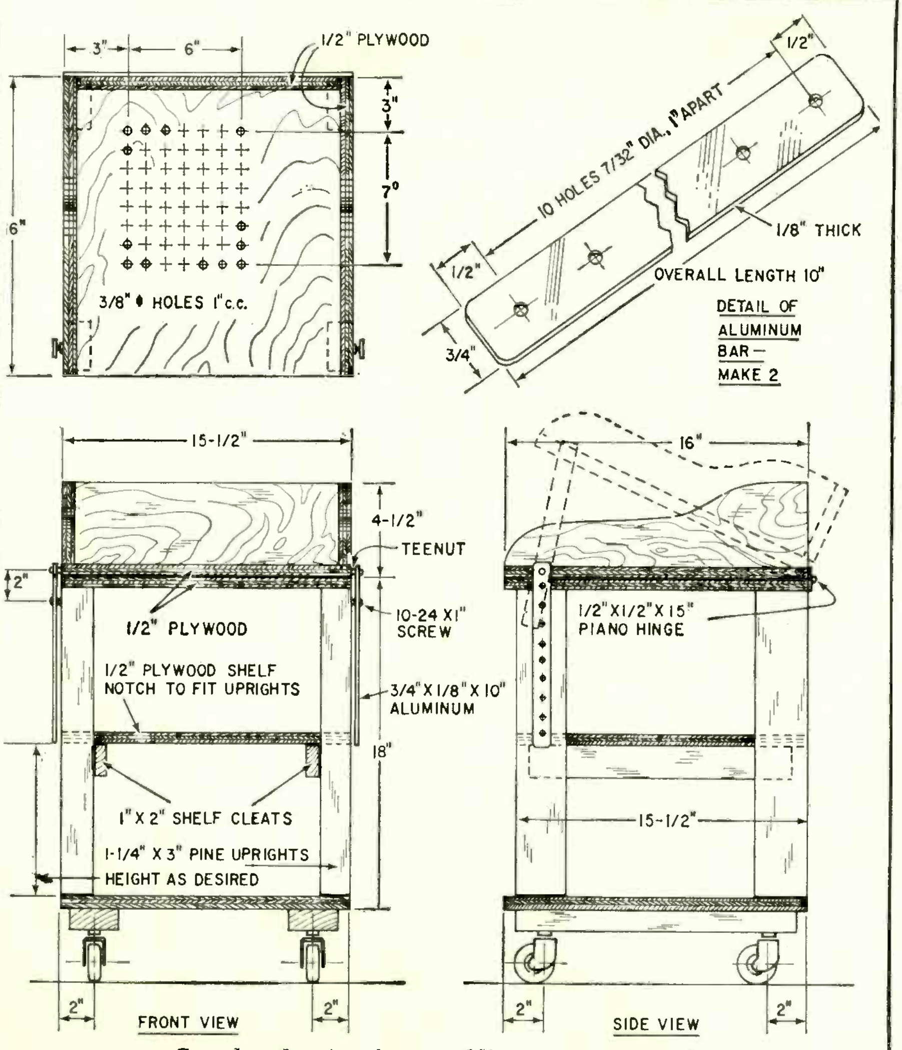
Dimensions and details, naturally, can be tailored to your own requirements. The unit pictured here was built to be used with a 5-inch service scope next to a desk-high workbench. It should work as well with many other arrangements. You will find that most 5-inch service oscilloscopes have overall dimensions pretty much alike.

All parts should be cut to size and rough-sanded before they are assembled with wood screws and glue. Use simple butt joints and check frequently to make sure that all parts are "square". Begin by making the lower section, which is like the framework for a box kite; that is, a top and bottom piece of ½-inch plywood separated by the four 1¼ x 3 x 17-inch uprights, one at each corner. The shelf is installed next, supported by the 1 x 2-inch shelf cleats, its exact location being determined by whatever you intend to put on it. A notch must be made at each corner of the shelf so that it will fit between the four uprights.

The adjustable tray is made separately and secured to the previously assembled lower section by a continuous



*With top down, Scope-Mobile is neat and compact. There's plenty of room for other instruments, like signal generator and vtvm.*



*Complete drawings for assembling your Scope-Mobile.*

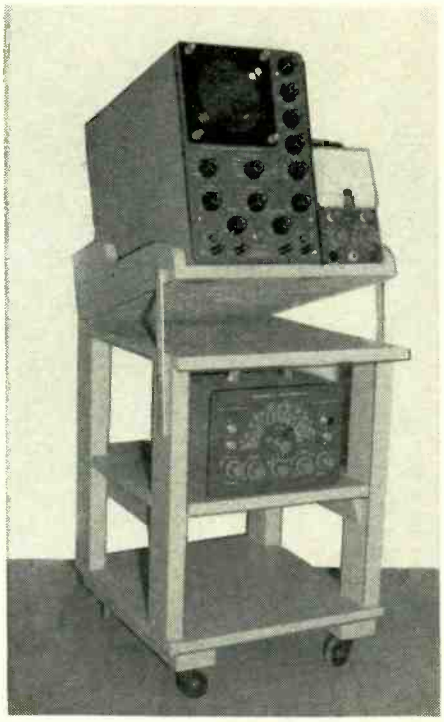
**BILL OF MATERIALS**

½-in. plywood:
  3 pcs 16 x 5½ in.
  1 pc 15½ x 15½ in. (shelf)
  2 pcs 16 x 4 in. (tray sides)
  1 pc 14½ x 4 in. (tray back)
1¼ x 3-in. pine:
  4 pcs 17 in. long (uprights)
  2 pcs 15 in. long (caster supports)
2 pcs 1 x 2-in. shelf cleat 14 inches long
1 aluminum bar ¾ x ⅛ x 20 in.
1 15½-inch length of ½ x ½-in. piano hing
4 casters 2-in. diam. or larger
4 Teenuts for 10-24 screws
4 10-24 x 1-in. round-head machine screws
Wood screws, glue, etc.

(piano) hinge at the rear, and with two aluminum bars, ¾ x ⅛ x 10 inches in the front. Adjustment holes are drilled every inch along the length of each bar (see detail). It's a good idea to clamp the bars together and drill the holes through both simultaneously to insure accurate alignment. Attach the bars as shown with machine screws and threaded metal inserts called Teenuts, which are driven into the wood. This will permit repeated adjustment of the tray angle without fear of stripping threads in wood.

### Final steps

After the tray is installed, check to see that the hinge doesn't bind, and that the adjustment holes line up properly. The holes drilled in the bottom of the tray (see top-view drawing) are not absolutely essential, but will help keep the scope cool when it is in use for long periods. Use casters at least 2 inches in diameter, readily available at any hardware store.

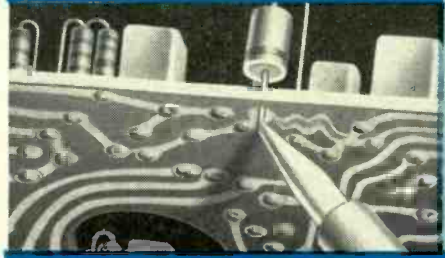


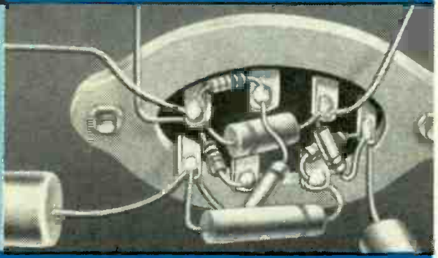
*With top up, scope and other instruments are angled just the way you want them for convenience and easy, glare-free viewing.*

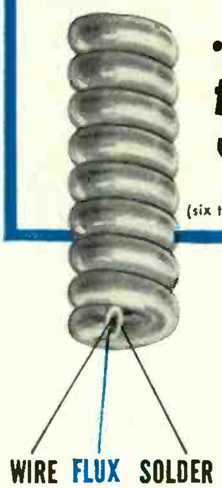
After assembly is complete, give the entire unit a thorough sanding with fine sandpaper and apply whatever finish pleases you.

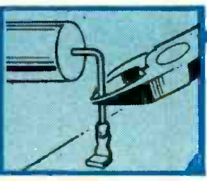
To use the Scope-Mobile, simply remove the lower machine screw going through each aluminum bar, lift the tray to the desired angle, replace the two screws through the nearest adjustment holes in the bars, and you're in business.

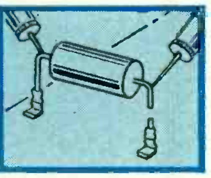
For a small initial investment, the Scope-Mobile will return fat dividends in efficiency, comfort and enjoyment while you work with your scope. END

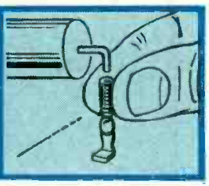


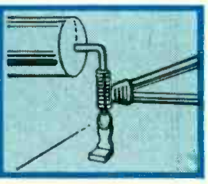












# EQUIPMENT REPORT

## *EICO 380 Color Generator*

*Circle 25 on reader's service card*

Among the many color generators available, here is a new one with a number of features that are different. On the front panel of the model 380, you'll find two sets of controls not common to color-bar generators.

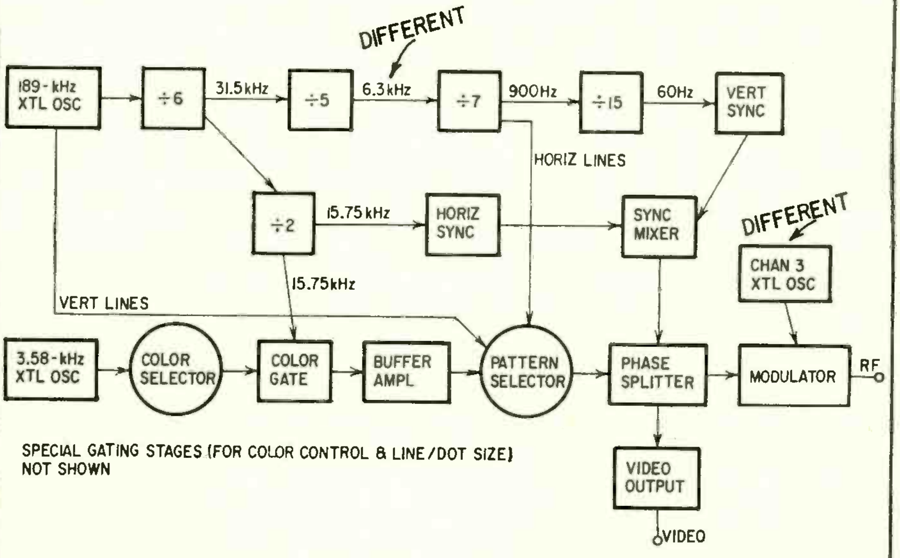
The set in the upper left corner are hold controls marked HORIZONTAL and VERTICAL. Some color-bar generators momentarily trip out of sync, especially under varying temperatures. For that reason the divider adjustment controls are placed somewhere accessible to the user. Often the user doesn't know how to set the dividers properly. (The instruction booklet generally tells how, but who reads that?)

On the Eico unit, the *horizontal hold* adjusts the rate of the first down counter, controlling the 31.5-kHz timing signal. The *vertical* control is in the last counter, the one whose output is 60 Hz. With these controls on the front of the unit, there is little trouble with pattern twist or jitter. If a divider does drift off while the unit is sitting on top of a hot color set, you just twist a front-panel control to bring it back into sync.

The other pair of controls, in the upper right corner, are SIZE controls. They control the size of lines and dots in monochrome video patterns. Labeled HORIZONTAL and VERTICAL, they control exactly that. With the FUNCTION switch set for dots and the unit connected to TV receiver the HORIZONTAL control will cut dot size to as thin as a single line of the raster. Two lines are better for most convergence, and sometimes you'd rather have a dot three lines thick. The width of the dot can be adjusted with the VERTICAL control.

If you want to see the action of these controls better, put horizontal lines only on the screen and turn the HORIZONTAL SIZE; then switch to vertical lines and adjust the VERTICAL SIZE. If you want to watch the effect of both, put a crosshatch on the screen.

The HORIZONTAL knob can make the horizontal lines or the dots 5 raster



*Simplified diagram of Eico 380 color generator. Count-down sequence is unusual.*

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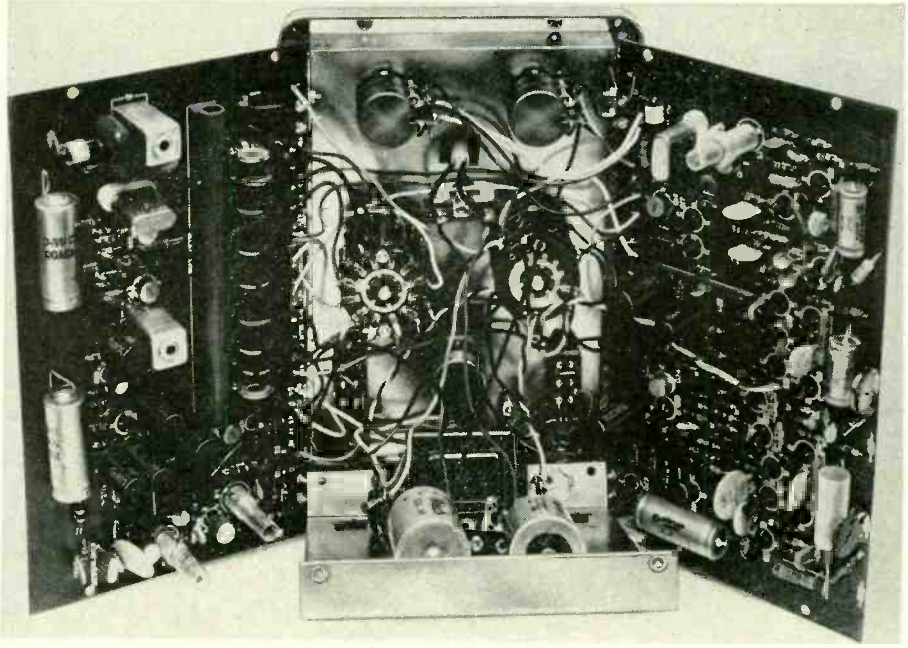

*Rear view of the Eico 380 color bar generator. Controls are on the front panel. Almost all other components are on circuit boards that are hinged so both sides are accessible.*

lines high. On the unit we analyzed, the VERTICAL control could almost triple the size of the vertical lines. The narrowest setting was about ⅛ inch, and the widest about ⅜ inch.

There's another feature: All transistor circuits except the power supply are mounted on two hinged printed boards. Removing four small Phillips screws lets them swing out. This accessibility makes it easy to reach the components for troubleshooting. With no schematic in the instruction booklet, however, only the simplest troubleshooting can be undertaken by the service technician.

The model 380 supplies an NTSC-type color pattern (a single bar), and can display yellow, red, magenta, blue, cyan, green and white. Q, I, R − Y, and B − Y signals are also available.

There are dot, crosshatch, vertical-line and horizontal-line patterns, as well as a blank-screen pattern for purity tests which eliminates the need to turn the contrast down to free the screen of snow.

The block diagram shows how part of the instrument works. You can see two of the circuit differences in this simplified sketch. Following the first divider, the 31.5-kHz signal is counted down first by a 5-step divider and next by a 7-step divider. The common thing is to divide first by 7 to obtain a 4,500-Hz signal, and then divide by 5 to reach 900 Hz. Eico has chosen to divide first by 5, resulting in a 6,300-Hz signal, then by 7 to reach 900 Hz for horizontal lines and for dividing further to 60 Hz for vertical sync.

Another important difference is in the channel 3 oscillator. Most generators use some sort of self-oscillating circuit that is adjustable to whatever channel is clear. In the 380, a special overtone crystal operates at 61.25-MHz—the picture carrier for channel 3.

Much of the Eico 380 operates like other color-bar generators. A 189-kHz crystal oscillator is the master timer. Transistor multivibrators count the basic signal down to the various frequencies needed for the different functions.

Vertical lines are taken directly from the 189-kHz oscillator, and horizontal lines from the 900-Hz counter. Horizontal sync comes from a 2-step divider that reduces the 31.5 kHz to 15,750 Hz; it is mixed with the 60-Hz vertical sync in a sync mixer and fed on to the video mixing circuits.

Chroma is developed by a 3.58-MHz crystal oscillator and fed to the color-selector switch, which taps the delay line. From there, the chroma signal is gated to form the wide bar of color and then sent through a buffer amplifier to the pattern selector. Special gating stages in the 380 give tight control of the color pattern.

After the pattern selector has chosen the desired signal pattern, it is fed to the phase splitter and mixed with sync, then fed to the demodulator where it is superimposed on the channel-3 carrier and coupled to a BNC rf connector.

One thing you won't notice on the model 380 is a sync output connector. If you want only sync, you can get it from the video output jack by switching the FUNCTION switch to COMP SYNC. Thus you can't use the sync to trigger or synchronize a scope directly.

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To be able to give you some hints about its operation, we put the model 380 to work on a color set. First was a crosshatch pattern. In fiddling with the hold controls we noticed a wavy effect—a sort of fast "breathing" of the line pattern. Same thing on dots. This occurred only if the VERTICAL HOLD control was not set properly. There are two or three settings of the control that result in almost-stable lines, but only one setting that provides solidly locked lines without this breathing or wavy effect.

Stability of the generator we tested was excellent. The vertical lines were as straight and true from bottom to top as could be. Synchronization of the pattern was rock-solid. This certainly is handy when you're trying to concentrate on a center dot. It's hard enough to keep up with the center dot from the back of the set, without its jumping around to different positions on the screen. A slight flag-waving at the top of the vertical lines when the unit was turned on cold disappeared every time after about 3 minutes of operation.

We found the best way to set the receiver's fine tuning was on a color pattern. Set the FUNCTION switch for color, and set the COLOR switch for yellow. Turn the fine tuning until color appears and the TV sound starts hissing (ignore buzz or hum). Tune back until the hiss just disappears; the hum will remain. If it annoys you, turn it down.

When you have set the fine tuning, adjust the color or chroma control of the set so the color bar isn't overly saturated with yellow. Adjust the receiver's phase (hue or tint) control for a rich yellow. To get it properly, turn the hue control toward red, and then come back just barely to yellow. If the hue control of the color set won't reach yellow, set it at mid-range and make internal phase adjustments according to the manufacturer's instructions.

When yellow is okay, rotate the COLOR switch to green. You should see green with no further adjustment of the TV receiver—provided your phase adjustments are correct.

You can use the 380 to adjust demodulators by the R – Y and B – Y method suggested by some color-set manufacturers. As an example: Feed an R – Y signal in to the set, connect 100K disabling resistors from the blue and green CRT grids to ground. Then adjust the demodulator for brightest red, with the hue or tint control centered.

The instruction manual with the unit tells how to service color sets, using the generator. There are three paragraphs on checking the generator with a scope, and some typical waveforms of the signals generated by the unit.—*Alan James*

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*Circle 31 on reader's service card*

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## Knight KG-685 Color-Bar Generator

*Circle 26 on reader's service card*

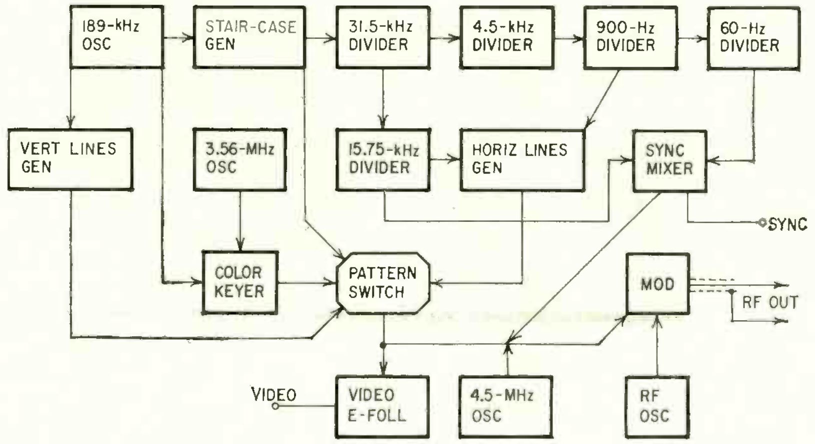
There are quite a few color/bar generators around now—enough so that one more wouldn't seem to be news. But this one, has something different—a staircase pattern for gray-scale tracking. Besides that, the KG-685 includes a small service light that can be clipped on the back of the set and turned on by a switch on the front panel.

Patterns provided by this unit include the staircase gray-scale pattern already mentioned, a blank-screen pattern for tuning, crosshatch, dots, vertical lines, horizontal lines, and a keyed-rainbow display with yellow-orange at the left and green at the right of the screen. The blank screen pattern is useful for purity checks; you don't have to turn the contrast down.

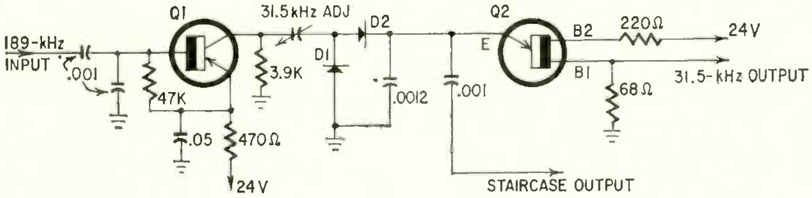
The KG-685 includes a simple gun interrupter, with separate switches for each color. 100K shunt resistors are connected to the color CRT grids through a color-coded cable. A black lead in the same cable connects to ground.

The KG-685 can be connected either to the antenna terminals of a receiver, with the signal fed into channel 2 or 3, or composite video and sync can be taken from a pin jack on the front of the unit and fed directly into the television receiver following the video detector. If you use the generator's rf output, a slug-tuned oscillator permits setting it to an unused channel. For testing the unit, we used channel 3 in the New York area, since it is vacant.

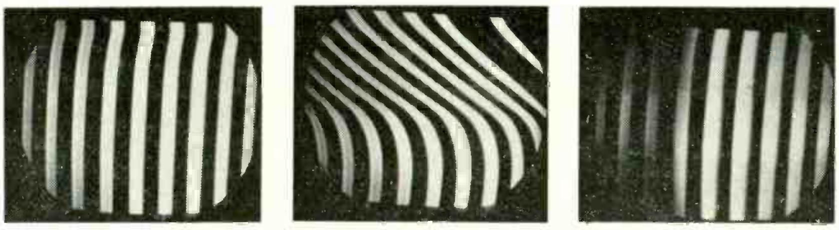
In the counting circuit, a 189-kHz crystal-controlled transistor oscillator initiates the chain, an arrangement common to most modern color generators. The staircase signal is developed before the signal is sent into the dividers, as you can see from the block diagram. The staircase is shaped by two diodes, using the emitter circuit of the first unijunction divider as a discharge path. The schematic shows the arrangement. The 189-kHz pulses are shaped in Q1 (an ordinary transistor driver) and fed through an adjustable capacitor to a pair of diodes. Unijunction transistor Q2 is a 6-step divider. Diodes D1 and D2 act with the input circuit of Q2 to create two 6-step rising waveforms for each horizontal line. They can be fed to the pattern-selector switch and mixed with sync to form a gray-scale video signal with 12 shaded bars. The Q2 unijunction divider also develops a 31.5-kHz



*Block diagram of the Knight KG-685 color bar generator.*



*Schematic of the staircase gray-scale pattern generator.*



*Left and center photos show a vertical hook that grew worse as the generator warmed up. Normal pattern at right was obtained by touching up the 31.5-kHz tuning control inside the rear of the instrument, using a small tuning tool.*

output that is fed along to succeeding unijunction dividers.

Horizontal lines are taken from the 900-Hz divider, and are gated by the 15,750-Hz divider. Vertical lines come directly from the 189-kHz oscillator. A 3.56-MHz crystal-controlled oscillator develops the offset-subcarrier rainbow pattern. With a signal from the 189-kHz oscillator fed to the color keyer, a rainbow bar pattern is developed by cutting the 3.56-MHz oscillator signal off and on as it is fed to the pattern switch.

The horizontal lines, staircase signal, vertical lines and keyed color signals are all available at various contacts of the pattern switch. The switch, as it is turned to its various positions, selects the pattern or combination of patterns for the modulator. As in most pattern generators, a diode connected at one point of the pattern switch makes the crosshatch pattern into a dot pattern by clipping out the horizontal and vertical lines and leaving only the intersections.

Sync is made up from signals from the 15,750-Hz and 60-Hz dividers. Sync is fed into the modulator and to the video output along with a video signal.

The 4.5-MHz oscillator is also coupled with video and sync, but is activated only when a switch on the front panel is turned on. The adjustable vhf oscillator feeds the modulator and combines with whatever composite video signal is chosen by the pattern switch. The output vhf signal is fed to a fixed rf cable—no connectors.

Power supply is a full-wave rectifier, with output regulated by a transistor and Zener diode. The pilot lamp is in series with the regulator.

The little service light is a No. 44 lamp connected to a 6.3-volt ac winding on the power transformer.

When we hooked the KG-685 to a color receiver, we noticed a hook at the top of the screen whenever we were showing vertical lines. In the instruction booklet, Knight says this is normal. It got worse in the unit that we had. It looked at first like the left-hand photo, and soon like the center photo. The receiver's horizontal hold control only made it worse. Turning the generator off and back on straightened the lines temporarily, but the cycle soon became annoying.

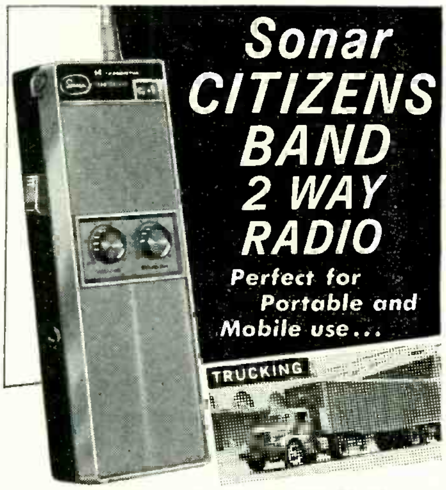
With a tuning tool, we touched up the 31.5-kHz frequency adjustment. This stopped both the twist *and the original hook at the top*. The final result was the solid pattern you see in the right-hand photo.

Once that slight adjustment was made, the KG-685 was as stable as any unit we have ever used. We didn't run the unit through true heat-and-cold tests, but a service technician carrying the unit in out of the cold and setting it on top of a warm color receiver might experience a bit of this divider-frequency shift.

The instruction manual with the unit is unusually thorough. Four pages of color photos show how to use the KG-685 for purity, static convergence and dynamic convergence setups. Most of the book is devoted to step-by-step instructions—complete with check-off boxes—on how to service a color receiver. A very complete maintenance section, plus a schematic and parts list, show how to maintain the KG-685—including adjusting counters and calibrating other adjustments. If you set the counters in the KG-685, follow the sequence exactly.

The manual winds up with a thorough circuit description and a section on trouble-shooting the instrument. With this manual, you won't likely have to send this unit back to the factory for adjustment or repair.—*Larry Allen*

Price: $89.95



# NEW SEMICONDUCTORS, MICROCIRCUITS & TUBES

This month we have a rather exciting range of new devices varying from microminiature amplifiers and a new color picture tube to several new diodes. The new development in color tubes has perhaps the most immediate interest to service technicians and owners of color TV sets.

An RCA development, the new rectangular color tubes have a temperature-compensated shadow-mask assembly which overcomes problems caused by expansion while the CRT is warming up. This eliminates the usual warmup period required before convergence and color-temperature adjustments can be made. In tubes produced prior to development of the new assembly, the electron beam register changes as the CRT warms up, each time the set was turned on. This results in a period of impure color and whites. In the new tubes, increase in shadow-mask temperature—due to electron bombardment—causes the mask to move minutely closer to the screen to maintain good color registry.

The new shadow-mask assembly will be used in all new RCA 25-, 19- and 15-inch color tubes, marketed under the RCA *Perma-Chrome* trademark.

### HF AND UHF NOISE DIODE

The Signalite 6144/TT-1 noise diode is designed as a noise source for hf and uhf measurements and matches 50-ohm coax cable. Its coaxial construction provides wide-band operation into either tuned or untuned circuits.

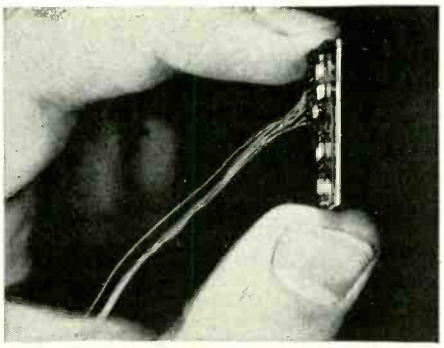
Maximum anode voltage ratings: 300 volts dc, 100 mA; maximum dissipation 30 watts. Heater rating: 3.2 volts ac or dc, 2.5 amps. Frequency range up to 3,000 MHz. Dynamic impedance 16,000 ohms minimum. Overall length 2.9 in. diameter 0.375 in.

Available from Signalite, Inc., Special Products Div., 1933 Heck Ave., Neptune, N. J.

### IC AND MICROELECTRONIC AMPLIFIERS

The Westinghouse WC 183 integrated circuit is a low-power audio amplifier for radio, recording and paging system, dictating equipment, hearing-aid and other battery-powered audio applications. The amplifier, consisting of an 8-transistor balanced circuit with internal dc feedback, is fabricated on a single monolithic silicon chip. A three-stage class-A high-gain preamplifier is followed by a class-B output stage for an overall gain of 75 dB and 55% efficiency.

An optional rolloff capacitor limits response to voice frequencies for communications. A simple external feedback network can be added to extend response well beyond the audio range for hi-fi applications. Input and output impedances are compatible with available mikes, cartridges, and speakers. Quiescent current drain less than 1 mA from 1.5-volt battery.

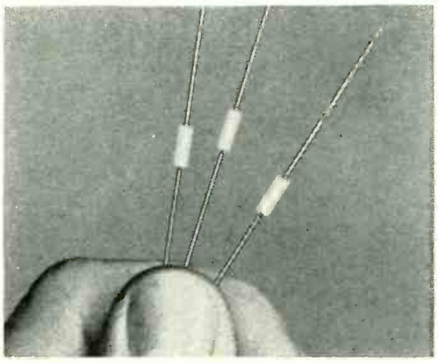


The WC 183 is available from Westinghouse distributors for $10.50 each in lots of 1 to 49.

Solitron Devices' TMS 1301 hybrid microelectronic dc amplifier occupies less than 0.1 cubic inch. It is especially designed for applications where conventional IC amplifiers are difficult to stabilize. The amplifier operates from a 24-volt center-tapped dc supply and has a minimum dynamic range of ± 8 volts. Bandwidth is 1 MHz and gain is 1,000 with 4 mV input. The TMS 1301 sells for $195.00.

### HIGH-SPEED TRIGGER FOR SCR's

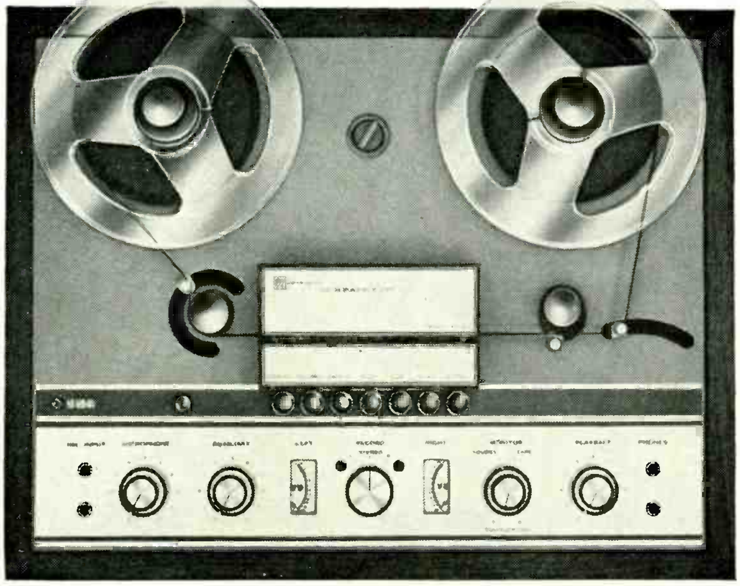
The Ovonic Threshold Trigger (OTS) is a new type of semiconductor trigger device for solid-state power control. Developed by Energy Conservation Devices, 1675 W. Maple Road, Troy, Mich., it features inherent symmetry and exceedingly fast switching speed. The basis of the OTS is a new semiconductor material that is vacuum-deposited as a thin film between two conductors. This thin film can be instantly changed from a high-impedance blocking state to a low-impedance conductor and back again simply by varying the applied voltage above or below a threshold level.

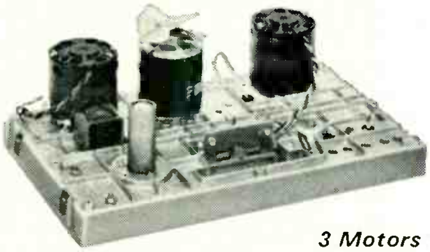


With switching speed less than 2 nsec, OTS's insure fast high-current pulses for quick gating of SCR's. The fast switching also allows smaller capacitors and simpler pulse transformers in trigger circuits and permits OTS's to be used well above 60 Hz.

OTS's are ideally suited for a wide-range of solid-state power control applications. Their symmetry makes them well suited for ac applications involving inductive loads such as fluorescent light dimmers, motor controllers and circuits with transformers. Other possible applications include staircase and square-wave generators and transient suppressors. OTS's are available with threshold ratings of 10, 20 and 30 volts. END

# How To Get A $570 Stereo Recorder For $400





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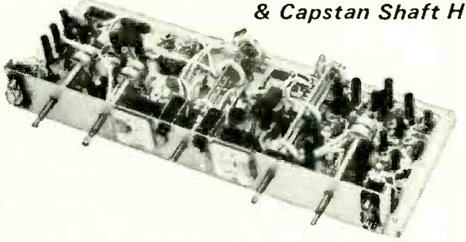

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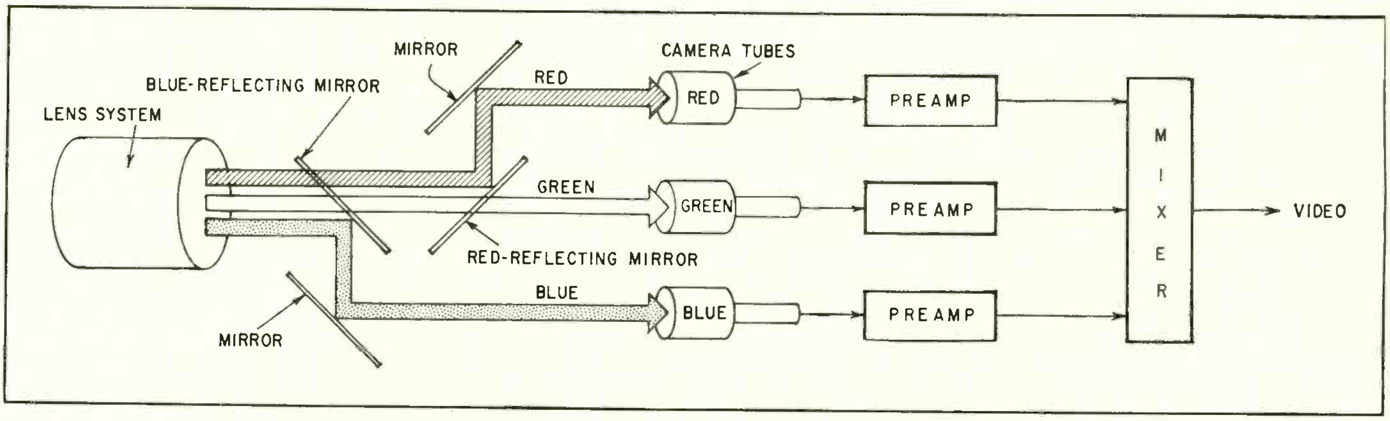


# ABC'S OF COLOR TV

**Wanna know more about color? If so, here's an article that'll clue you in**

**By JACK DARR**

A LOT OF WORDS HAVE BEEN WRITTEN ABOUT COLOR TV. Sad to say, most of them have been long and unfamiliar. With the help of some hairy mathematical formulas, they bred a huge litter of confusion among you men who have to work with color TV sets. Right? So, here is an article that covers the same basic principles, but in words of one syllable or less. Any math you find will be of the "my wife's checkbook" variety.

To service color TV sets, you have to know *how* they work: the basic principles. Actual circuitry is pretty simple, just as it is in black-and-white. Some of you more advanced men may think we're getting a little childish at times, but if you already know all about it, what are you doing reading this article, huh?

### Where The Color Signal Comes From

A black-and-white TV camera makes a picture by changing the light values of the scene into electrical signals. White is full output, black is no output. This is the *video* or brightness signal.

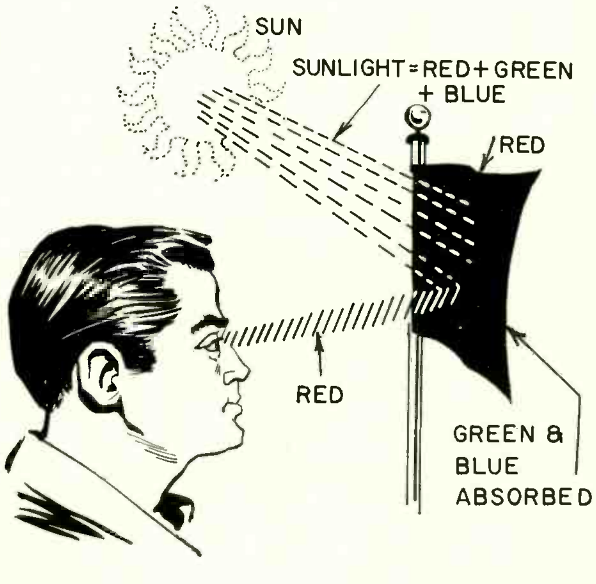
In color TV we need something else. Besides telling how bright an object is, we've got to tell what *color* it is. We still need the b-w signal, so that we can pick up the color signal on a b-w set. (This is "compatibility.") We have to have the color signals, too, and we have to put them in the same "space" (same band of frequencies) we once used only for b-w. So, we pull a sneaky: we make a b-w signal out of the color signals themselves!

A color camera has not one tube but three. With a system of special mirrors, each tube sees only one color: red, blue or green. At the receiver, the picture tube is a 3-in-1 type, almost like three tubes in one bottle. It can make red, green or blue pictures on the same screen with three independent electron guns.

Those are the two ends of our system. Now, let's see what we have to do to make not only color pictures, but black-and-white pictures too, using only red, green and blue light.

### Colors of Different Kinds

First, let's talk about colors. Paint, ink and dye are *subtractive* colors. When white light—which is *all colors*—falls on a red flag, everything *but* the red is absorbed—subtracted. Only the red is reflected, so we see red. Red is a *primary color* in paint or ink or dye—one that we can't get

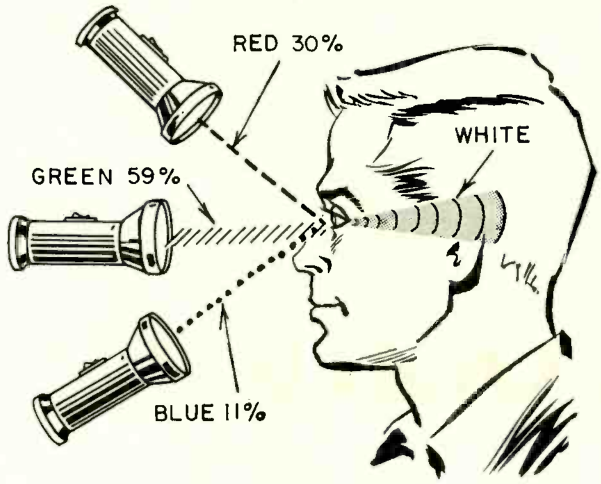


by mixing any two other colors.

But we're dealing in *light*, and we have *additive* colors. The primaries are different. Mix blue and yellow *paint*, and you get green. Mix blue and yellow *light*, and you get white! In light, green is a primary color, and yellow is a mixture of red and green! The phosphors on a color picture tube make light in three primary colors: red, blue and green. Actually, we could use any other three primaries that when mixed together would produce white.

In color TV we can make any imaginable color just by using different proportions of our three primaries. You can actually make more colors than you can with the finest printing inks! The big problem here, of course, is to make a pure white using only *colored* light. (Black is pretty easy. All we have to do is turn everything off!)

After some little trouble, the engineers found out that they could make white if they used a mixture of 30% red, 50% green and 11% blue light. The odd percentages come out that way because of the response of the human eye to light of different colors. We see this odd-numbered mess as a nice pure white!



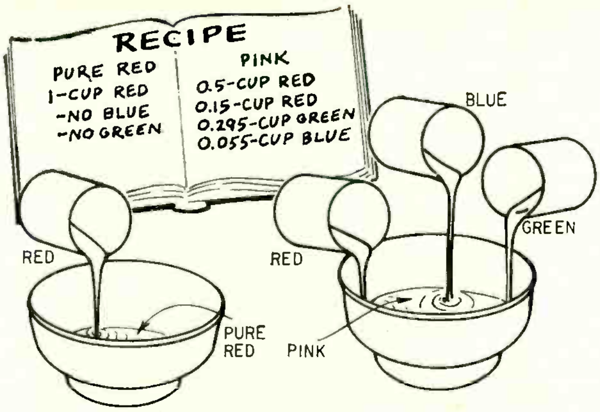
So, all we need to do is operate all three electron guns in the color picture tube together, keeping them in that 30–59–11 proportion, and vary their intensity as a group the same as we would the single gun of a b-w picture tube. Then we come out with a nice black-and-white picture. Now we can watch b-w programs on a color TV set, and the systems are compatible.

### Making the right colors: saturation

There's one more thing we have to do in color programs: not only reproduce a color (hue) like blue or orange or purple, but also reproduce how *bright* that color is. Red, for instance, can come in any of many shades from a deep, rich rose-red to a pale pink. The redness of a red, or the blueness of a blue, is called *saturation*. For pure red we just turn the red gun full on and turn the other two off. But if we need a pink we have to "add some white" to the red. This is like mixing paints.

Let's say that our color is a "half-saturated pink." All right, we've got 50% red and 50% white. Turn the red gun on to half of its maximum intensity. That's that 50% of our pink. Now, we need half white. Well, white is 30% of our 59% green and 11% blue, as we said before. So, we divide these figures in half, and get 15% red, 29.5% green, 5.5% blue (which still makes white because the proportions are unchanged). We add that mix to the red signal already there, and we get a beautiful pink rose, sweater, nose or whatever the thing is.

This method works with all colors or combinations of colors. Our percentages always come out 100%; here, we have 50% pure red, plus (15 + 29.5 + 5.5 = 50) 50% white, which adds up to 100%, even in my wife's checkbook.



This is saturation. All it means is how much white there is in a particular color. The percentage of saturation is the ratio of pure color to white, and that's all there is to it.

In a color TV circuit, we have a color control. All this does is increase the "volume" of the color: full on, maximum color; half on, half "volume" on the color. Works just like a volume control does in the sound.

### Adding the color signals

Our camera and transmitter output must be arranged so that no matter what kind of receiver we use, we get a good picture. So, we use the *combined* color signal as a b-w (video) output. The value of this signal, at any given instant, is the equivalent of a b-w signal. This is actually what you'd see if a color camera were looking at a scene that was all black-and-white or if a b-w camera were looking at *this* scene!

On a color program, the color signals will vary, of course, according to the color of the object the camera's seeing. However, the *instantaneous total* value of the camera's output still corresponds to the *brightness* of the object —in other words, *is* a b-w video signal. However, we have to add in the *color* information—the information that is the *difference* between the output of the red, the green and the blue camera tubes—and do it in such a way that it won't interfere with the regular b-w video signal.

We can't add it as another AM signal. That would be like pouring milk and water into the same pitcher and trying to pour milk out of one side and water out of the other. So, we change them to a form that we can mix and then separate later on. We use *phase modulation* instead of *amplitude modulation*.

At the transmitter, we use two *balanced modulator* circuits, plus a *subcarrier oscillator* at 3.579545 MHz (called 3.58 MHz from now on). We feed the red and blue color signals into these, having delayed one of them 90° in phase or, in effect, made it a fraction of a microsecond later than the other. The modulators convert the original color signals into (in effect) frequency-modulated signals. The subcarrier is cancelled out in each modulator. All we get out is the sidebands: the only information-carrying part of each signal. The carrier itself is not transmitted, to save postage. This sounds like a bad joke, but it's true. If we did transmit the unmodulated carrier, it would not only use up some of our transmitter power, but also create beat frequencies and other odd effects. We've got enough of those to contend with as it is.

But we'll need that subcarrier when we get to the receiver, for use as a reference. You can't say a signal is "90° lagging" unless you have a *reference point!* It's got to be 90° *from* something. So, we build a crystal-controlled 3.58-MHz oscillator into the receiver and lock it in phase with the one at the transmitter by sending along little samples of the 3.58 MHz that generated the nonsuppressed sub-

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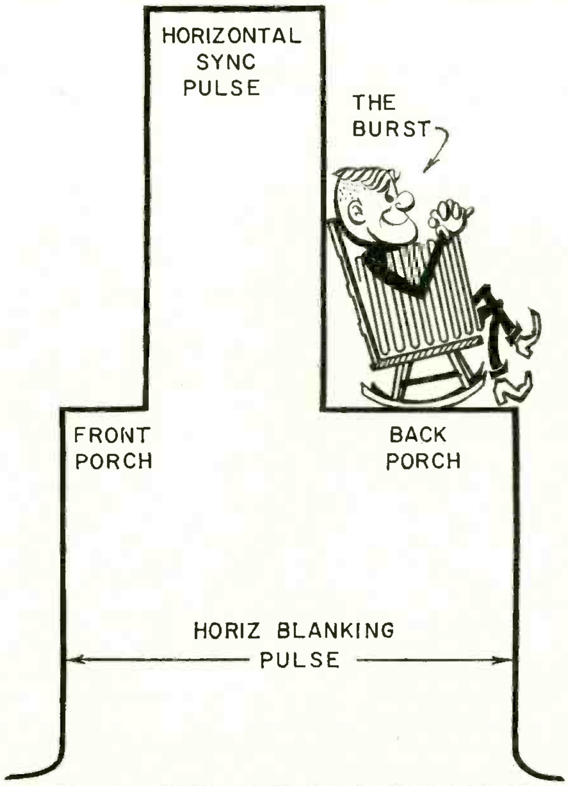
*Circle 39 on reader's service card*

carrier. These are little shots, about 8 cycles each, and they're sent sitting on the back porch of each horizontal sync pulse. At the receiver, this *burst* is separated from the rest of the TV signal and fed into a phase-detector circuit that controls the receiver oscillator.



Now we have reinserted the 3.58-MHz signal, and can separate the phase-modulated signals. For example: If we had two marching bands, one in red uniforms and the other in blue, marching at the same speed, we could run them together so that every other man had a different color uniform. First a red bandsman, then a blue one, then another red one, and so on.

If we want to get them separated again, all we have to do is stand alongside and grab every other man and make him turn aside, as the band goes past. Which color bandsman we get depends on *when* we grab. This is a matter of timing, which is another way of saying *phase*. We can put a circuit in the receiver that will do the timing for us, comparing our "grabber" to the reference in the TV transmitter so we can separate the red and blue signals.

Now, we can—. What? Someone asked, "What happened to the green? You're separating only red and blue! We've got to have some green, haven't we?" Yes, indeed. I thought you'd never ask! We want to save all the TV-signal space we can. So we send *only* the red and blue signals from the transmitter! However, we can get the value of the

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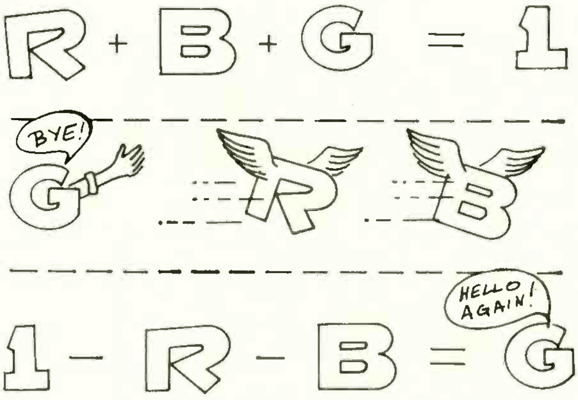
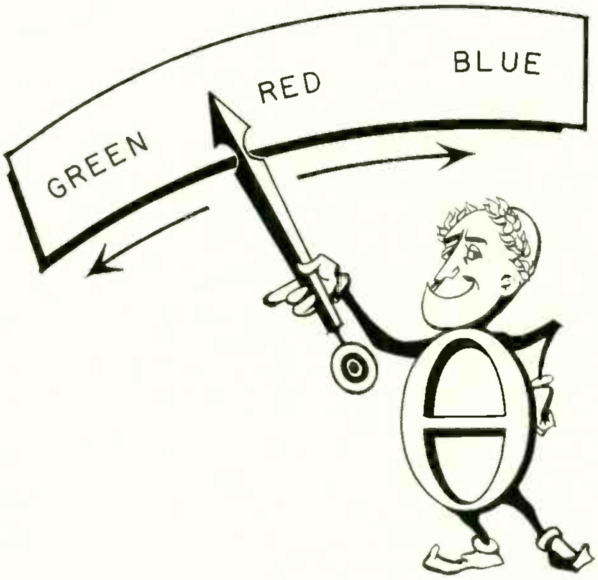
green signal back by an operation that is theoretically pretty ingenious, but actually pretty easy.

Our "whole signal" out of the camera is red, blue and green, right? If we take away the red and blue, we have green left. We can say that the whole signal equals 1. (Or, if you want to, the *video.*) In the receiver, we have our two signals, red and blue. So, we simply "subtract these from 1," and use the value we have left as green, which it is! This mixing and unmixing is a process you can call *matrixing* if you like long words, and it used to take about 9 tubes and a hatful of parts. Now, we do it with 3 little triodes and about 12 parts.



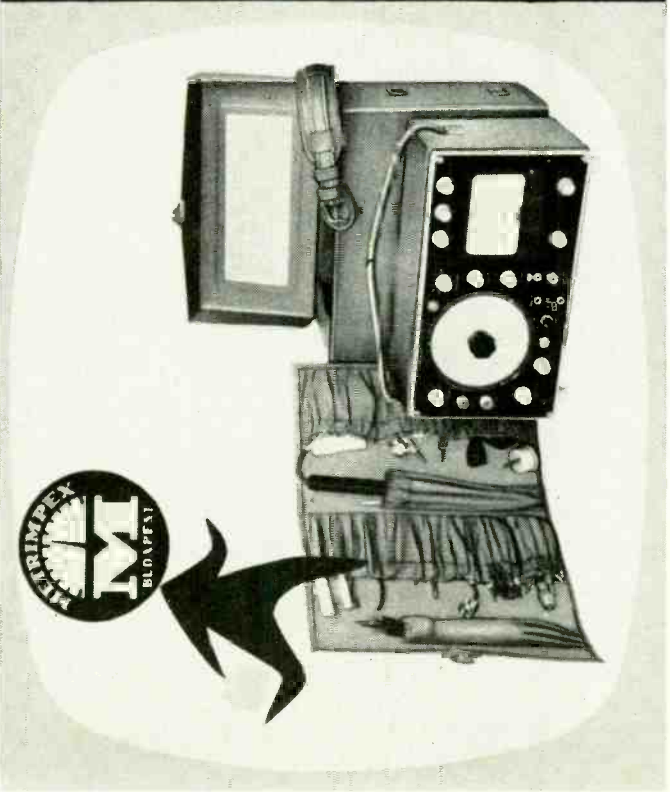
There is one more control besides the COLOR control on a color-TV receiver that affects the color. It is called HUE or TINT and about the best we can say is that it affects "the color of the color"!

When we get to the receiver, the color signals are in the form of phase-related signals. These are compared to a locked-in reference-oscillator signal, and the *phase* of each signal tells it what color to be. The *amplitude* tells it how *much* color to be (saturation) but it's the phase that determines *what* color (hue) it will show—red, green, purple, etc.



So, we add one more control—the HUE control. All it does is vary the phase of the reference oscillator signal just a wee bit. It doesn't take much; only a very few degrees of shift make the colors change a lot.

In all color sets, we use the color of a human face for our reference. In any other colored object, we don't really know whether it's a bright red or a pink, but we do know about what people ought to look like. So, to get the hue control set properly, we simply turn it until the people look people-colored, and there we are. END



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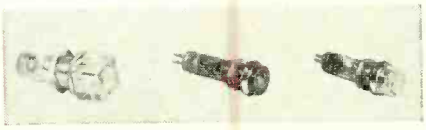

**PILOT LIGHTS,** *BND series* (left in photo) available in high and low intensity; mount in ⅜-in. hole. *BNE* and *BNF* series (center and right in photo) have similar characteristics; *BNF* lens system extends farther beyond panel. All operate on 75 Vac.—**Alco Electronic Products**

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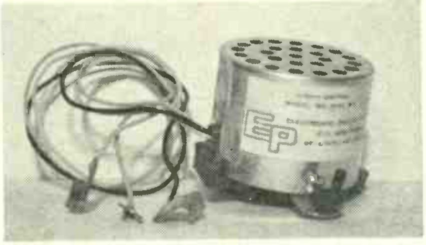

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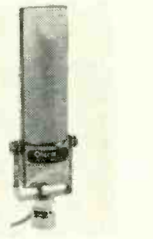

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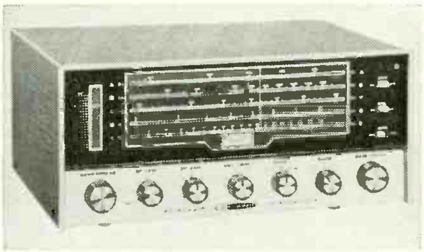

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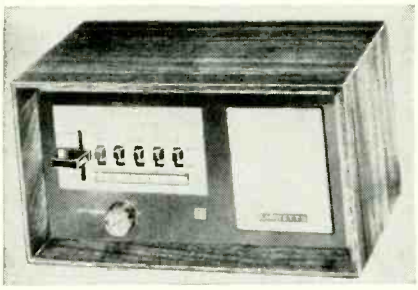
**6-STATION INTERCOM,** *Model MPI-6*, can handle 3 private conversations or 6-station conference. Master-to-remote enables master station to communicate with up to 5 remotes separately or in 6-station conference. Master unit has 5-station selector control, 3-way talk–listen–dictate switch and volume control. 117 volts ac, 60 Hz. 8 lb.—**Lafayette Radio Electronics**



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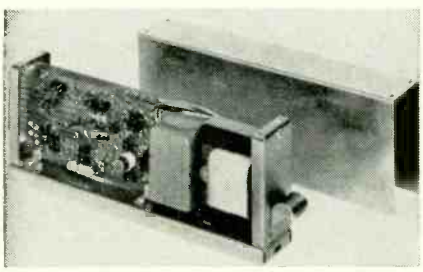

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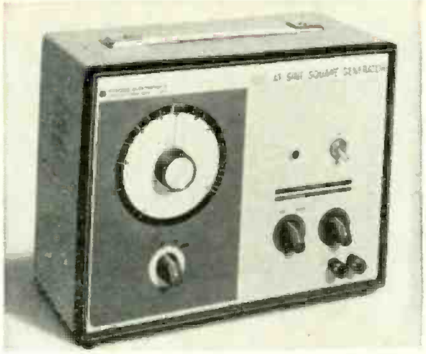

time 0.15 μsec; output 0–10 volts peak-to-peak into 600 ohms. Power: 117 volts ac, 50–60 Hz, 50 watts. 8¼ x 11¼ x 7 in., 15 lb.—**Precise Electronics**

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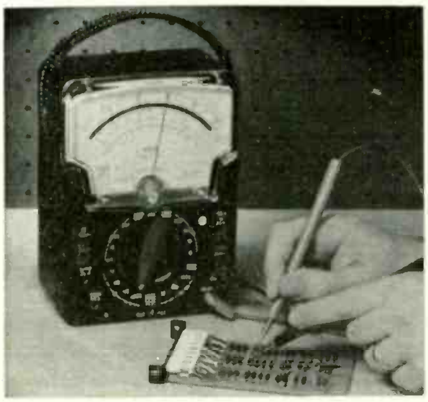

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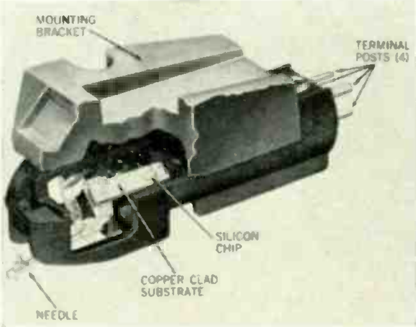

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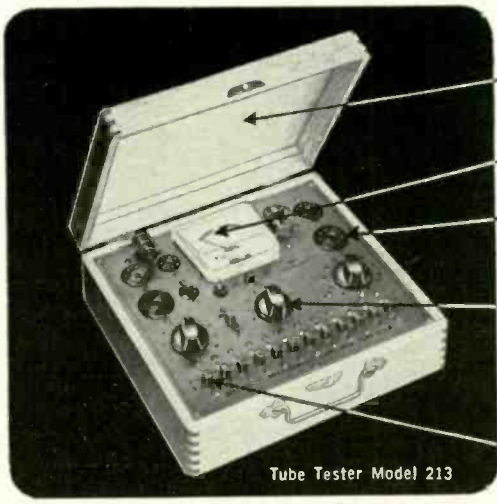

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| 6JE6 | 2.42 |
| 6JH6 | .70 |
| 6JU8 | .96 |
| 6K6GT | .70 |
| 6KF8 | 1.02 |
| 6L6GC | 1.27 |
| 6S4A | .68 |
| 6SJ7GT | 1.11 |

| Type | Asst'd.* 50 or More |
|---|---|
| 6SL7GT | .96 |
| 6SN7GTB | .70 |
| 6SQ7GT | 1.02 |
| 6T8A | .91 |
| 6U8A | .88 |
| 6V6GTA | .59 |
| 6W4GT | .66 |
| 6W6GT | .77 |
| 6X4 | .46 |
| 6X5GT | .60 |
| 6X8A | .86 |
| 7AU7 | .70 |
| 8AW8A | 1.00 |
| 8CG7 | .67 |
| 8FQ7 | .67 |
| 10DE7 | .91 |
| 12AD6/ 12GA6 | .74 |
| 12AT6 | .50 |
| 12AT7 | .82 |
| 12AU6 | .57 |
| 12AU7/ ECC82 | .68 |
| 12AV5GA | 1.28 |
| 12AV6 | .46 |
| 12AV7 | .97 |
| 12AX4GTB | .73 |
| 12AX7/ECC83 | .68 |
| 12AX7A | .68 |
| 12AZ7A | .82 |
| 12B4A | .87 |
| 12BA6 | .46 |
| 12BE6 | .48 |
| 12BH7A | .83 |
| 12BL6 | .82 |
| 12BQ6GTB/ 12CU6 | 1.20 |
| 12BY7A | .87 |
| 12C5/12CU5 | .79 |
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| 12CU5 | .79 |
| 12CU6 | 1.20 |
| 12DQ6B | 1.13 |
| 12DT5 | .88 |
| 12GA6 | .74 |
| 12SA7GT | 1.25 |
| 12SK7GT | 1.14 |
| 12SN7GTA | .73 |
| 12SQ7GT | 1.07 |
| 12V6GT | 1.07 |
| 12W6GT | 1.07 |
| 13EM7/ 15EA7 | 1.39 |
| 15EA7 | 1.39 |
| 16AQ3 | .77 |
| 17AX4GTA | .87 |
| 17D4A | .87 |
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| 35L6GT | .70 |
| 35W4 | .30 |
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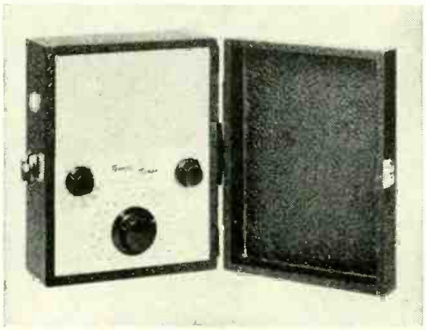
**ELECTRONIC TUNING DEVICE/METRONOME**, the *Tempo-Tuner* comes in 3 models, *8179* for band, *8180* for orchestra, *8181* for guitars. Each unit has 4 preset reference tones most useful in its specified application plus a 5th reference tone variable in pitch over 2½ octave range. Output jack for PA and hi-fi. Volume switch controls both tones and metronome sound. Battery-operated, 7 x 6 x 3¼ in.—**H. & A. Selmer, Inc.**



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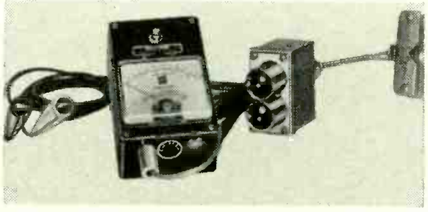

**TACHOMETER**, *model 36R-12V*, designed for rpm measurement of diesel engines in field or shop, is powered from battery for the equipment being tested. Reads 0-12,000 rpm by pointing head at any revolving object. Head has magnets for easy mounting in any location.—**Pioneer Electric & Research Corp.**

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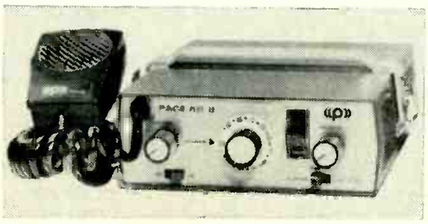
**23-CHANNEL CB TRANSCEIVER**, called *PLUS 23*, 5 watts input with 100% modulation. Incorporates MOS FET in receiver section. "S" signal strength displayed on back-lighted 1½-in. edgewise scale, factory-calibrated to read S9 at 100 mV. 22 silicon transistors, heavy noise-clipping switch, external PA jack. 6¾ x 2⅜ x 8⅜ in.—**Pace Communications Corp.**



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**VIDEO TAPE RECORDER**, model *TCV-2020*, is deluxe model of Sony's original unit. Timing device can be preset, turns machine on automatically to record television program for later viewing. Video camera available. Walnut cabinet. —**Sony Corp. of America**

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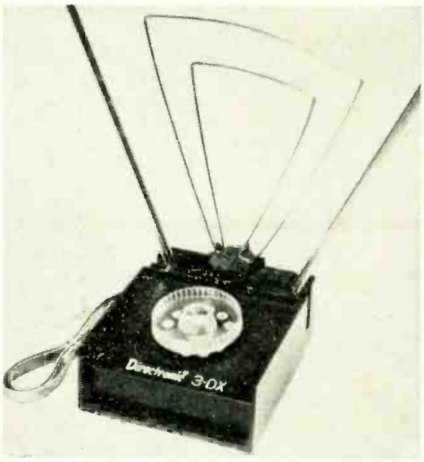

**ALL-CHANNEL ANTENNA**, *model 3DX-83*, the *Deluxe Directronic* with *Rotor-Dial* for directional uhf tuning. Rotates uhf phasing elements 360° for best reception. Vhf Beam Selector has 12 positions. Brass finish. Two sets of double leads connect uhf and vhf antenna circuits separately to terminals on TV set.—**Snyder Mfg. Co.**

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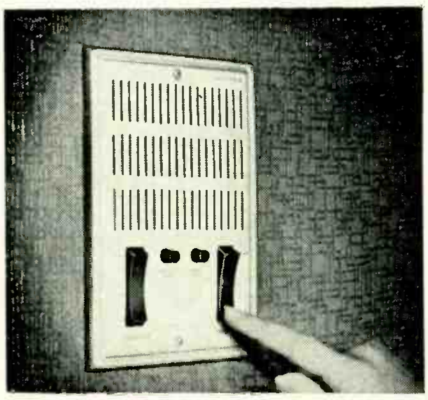

**INTERCOM**, *model TA-2*, apartment-house intercom features 2 independent door-opener buttons, volume selector, built-in fanning strip. Recessed in wall, mounts in A-PR-2 back box for wall opening 4⅛ x 6½ x 3¼ in.—**Talk-A-Phone Co.**

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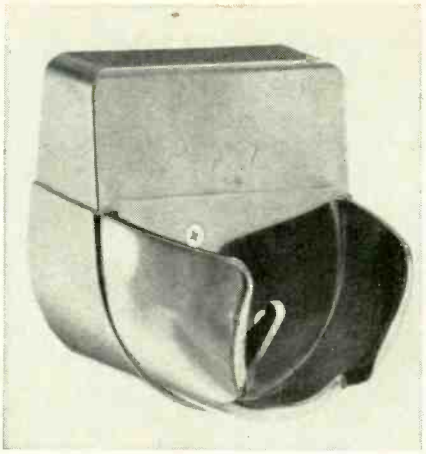

**HANDSET CRADLE SWITCH**, *Part No.'s 14412G (black), 14512G (beige)* accommodate all standard tele-

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**STEREO HEADPHONES**, *model PH-108*. Each foam-rubber padded ear-cup houses miniature dynamic speaker. Impedance: 8 ohms. Response: 40 to 12,000 Hz.—**Olson Electronics.**

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**WORK POSITIONERS**, *Line-Master series LM-200.* Chrome-plated, preloaded to hold position while unlocked. Dry-lubricated speed thread operates at 6 turns per inch. Multipurpose vise jaws have nonslip face on one side and V-grip on reverse. Available with lead wire holder.—**Sandefur Engineering Co.**

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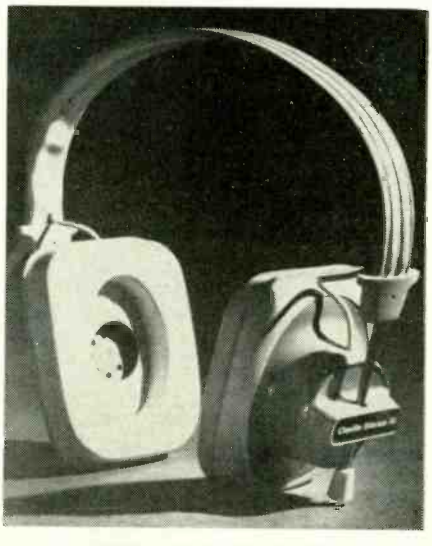

**STEREO HEADPHONES**, *Clevite Stereo*, have two ¾-in. speakers, 5-year warranty, cushion earpieces. Frequency response is 20–18,000 Hz; impedance matches 4-, 8-, 16-ohm amplifier outputs. Normal listening level attained with 1-mW input power per phone; distortion less than 1%.—**Piezoelectric Div., Clevite Corp.**

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**8-TRACK CARTRIDGE TAPE-PLAYER COMBINATION**, *model 1630-8L*, with standard reel-to-reel tape recorder. Compatible with standard tape recording. Features 8-track stereo playback with manual or remote-control track selector, plus 4-track stereo and monaural record and playback on reel-to-reel operation. 4 speeds including 1⅞ ips. 2-circuit stereo headphone jack; automatic motor shutoff at end of tape.—**Roberts Electronics**

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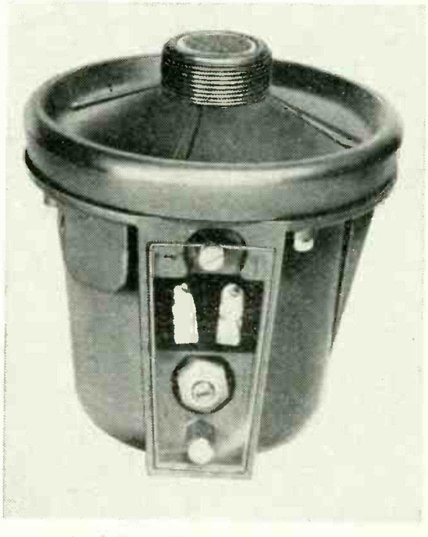

**PA DRIVER UNIT**, *PD-30T*, has built-in transformer and watts/impedance switch, can be used as replacement driver on any industry-standard horn having 1⅜-in.-18 threads. 30 watts continuous power, 40 watts equalized to frequencies above horn cutoff. Response 120–14,000 Hz. Sound level, 126 dB measured 4 ft on axis with horn at 30 watts input. Switch positions on 70.7-volt line: 1.8, 3.7, 7.5, 15, 30 watts; on 25-volt line: 1.8, 3.7, 7.5, 15 watts. Impedances: 2,500, 1,300, 666, 333, 167, 89 45 ohms. 4¾-in. diameter x 4⅞ in.—**Atlas Sound** END

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# NEW LITERATURE

*All booklets, catalogs, charts, data sheets and other literature listed here are free for the asking with a Reader's Service Card facing page 76 and circle the number of items you want. Then detach and mail the card. No postage required!*

**AMPLIFIERS CATALOG,** 8 illustrated pages, specs on line of solid-state amplifiers, assembled and kit-form. Special section on "What to Look for in Amplifier Specifications," explaining importance of intermodulation distortion measurements and square-wave analysis in quality determination.—**Acoustech, Inc.**

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**LAMINATIONS CATALOG,** *PD-122A,* 92 pages, revised and expanded. Diagrams and specifications covering laminations for transformers, motors, transformer hardware, drawn metal cans and cases, mgnetic shields, plus special magnetic products.—**Arnold Engineering Co.**

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**BOOKLET,** "Temperature and Radiation Effects on Permanent Magnets." 16 pages. Information from company's research labs and government reports, plus 11 pages of schematic diagrams and tables.—**General Magnetic Corp.**

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**SILICON N-P-N POWER TRANSISTOR BROCHURE** on RCA 2N3878, 2N3879 (formerly development type Nos. TA2509, TA2509A) and 40375, which is a 2N3878 factory-attached on heat radiator for free-air operation. 13 loose-leaf-punched pages of characteristics and graphs of maximum operating areas.—**RCA Electronic Components & Devices**

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**STANDARD TRANSFORMERS CATALOG** for 1966. 39 universal-punched pages of commercial, military, TV/radio replacements in the Stancor line.—**Electronic Marketing Div., Essex Wire Corp.**

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**COLOR-TV COMPONENT GUIDE,** *ETR-4286,* pocket-size, 66 pages, covers 35 manufacturers of TV sets. Lists by individual chassis, G-E replacement capacitors, diodes, transistors, rectifiers, crystals, receiving tubes, picture tubes.—**General Electric Electronic Components**

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**TECHNICAL BULLETIN,** *MCT181,* "Techniques for Testing Thermistors," 8 pages. Covers resistance, temperature coefficient of resistance, voltage, time for thermistor to pass certain current after application of voltage in given circuit, dissipation constant, thermal time constant.—**Victory Engineering Corp.**

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**REPLACEMENT COMPONENT SELECTOR,** *200GLD.* Looseleaf-punched, 64 pages. Features dc aluminum electrolytics, capacitor hardware, ceramic capacitors, mica capacitors, paper and film tubulars, ac capacitors, radio interference filters, relays, vibrators, power supplies, antenna rotator systems. Indexed.—**Cornell-Dubilier Electronics.**

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**TECHNICAL BROCHURE,** 6-page foldouts, describes the DMS-3200 digital measuring system and 4 plug-in units: dc voltmeter, 1-MHz counter, ohmmeter, capacitance meter.—**Hickok Electrical Instrument Co.**

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**MINIATURE AUDIO CONNECTOR CATALOG,** *No. C-503.* Illustrated 8-page foldout gives specs, prices, mating chart for more than 90 plugs and receptacles in Switchcraft/Preh line.—**Switchcraft, Inc.**

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**FERROXCUBE ENGINEER,** Vol. 8, No. 1. Contents: "Part I, Matching Memory to Application"; "Designing Power-pulse and Square-Wave Transformers"; ". . . of Magnetic Moment"; "The Economics of Recording Heads"; "Part II on Application-Specified Cores/Planes/Stacks"; "The Great Schmoo Controversy."—**Ferroxcube Corp.**

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**BOOKLET,** "Installation Instructions for Wiring with Scotchflex Brand Flat Cable System." 10 pages, shirt-pocket size.—**3M Co.**

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**LIGHTWEIGHT HEADSETS,** *model RE-200* miniature dynamic earphone element. 4-page brochure describes how you can design your own headsets with the RE-200 element, 4 mike elements, various cords and accessories.—**Roanwell Corp.**

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**TECH NOTE,** *JTN-4A,* "How to Design Speaker Enclosures." One page, with resonant-frequency and duct-tube-length tables.—**Jensen Mfg. Div.**

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**1966 CARTRIDGE REPLACEMENT MANUAL,** *SAC-25,* 24 pages, 3-hole-puncched. Cross-references 5,700 cartridges in two sections: Sonotone cartridges to competitive cartridges; Sonotone cartridges to phonographs. *Free limited time.*—**Sonotone Corp.**

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**REPLACEMENT COMPONENT SELECTOR,** 65 pages, revised, includes addition of 16 major replacement products now marketed through this firm's General Line Distributors.—**Cornell-Dubilier Electronics Div.**

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**TOOL CATALOG,** 20 pages, universal-punched, shows complete line of solid- and slip-joint pliers, alloy wrenches, snips, wrench sets, punches, chisels.—**Kraeuter Tools.**

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**ELECTROLYTIC CAPACITOR REPLACEMENT MANUAL,** *K-108,* new edition, covers 389 makes from Acme to Zephyr. Includes TV sets, home, auto, portable radios, tape recorders, antenna rotators manufactured from 1947 to November 1965. 64 pages.—**Free from** *Sprague Distributor,* or **10¢** from **Sprague Products Co., Marshall St., North Adams, Mass.**

**SILICON RECTIFIER HANDBOOK,** 216 pages. Describes and analyzes rectifier circuits for both single and multiphase systems, rectifier voltage multipliers and circuits for regulation, arc suppression, other specialized applications.—**$1.50** to *Technical Information Center, Motorola Semiconductor Products,* Box 955, Phoenix, Ariz. 85001.

**POT–TRIMMER–DIAL CATALOG.** 120 pages of precision controls with photos, diagrams, specs. Each precision and trimming potentiometer shown in cutaway form.—Write directly to **Amphenol Controls Div.,** 120 S. Main St., Janesville, Wis. 53545

END

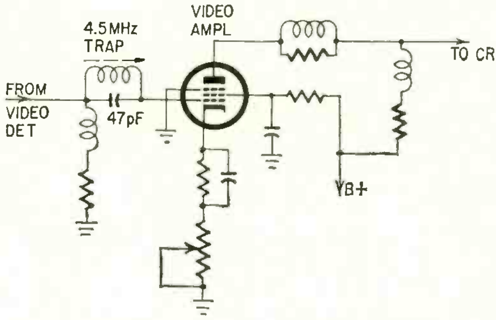
# TECHNOTES

### THE CASE OF THE GOOD/BAD CAPACITOR

While aligning a DuMont RA-113 TV set, I found it impossible to adjust the 4.5-MHz trap in the grid circuit of the video amplifier. The trap consists of a fixed 47-pF mica capacitor and an adjustable inductor in a parallel-resonant circuit. I removed the capacitor and checked it only to discover that it had the correct value and no leakage.

My suspicion then turned to the inductor. It too appeared to be good. Its 12 turns (wound in a single layer on the coil form) were evenly spaced and did not touch at any point. The adjustable core was intact and moved freely inside the coil form when the adjusting screw was turned.

Continuity measurements and visual inspection do not always tell the whole story of the condition of an inductor, so I decided to make some further checks. I connected a new 47-pF capacitor across the coil and used my grid-dip oscillator to see if the combination would resonate at 4.5 MHz. To my surprise, it did. I then connected the 47-pF capacitor from the set across the coil and repeated the test. It was now impossible to obtain a resonance indication on the gdo at any frequency. There was no doubt now: the capacitor was bad. Yet, it had passed all tests on my capacitance checker with flying colors. Replacement of the capacitor permitted adjusting the trap.



After pondering the matter for some time, I came up with what seemed a logical explanation for the discrepancy between the results of my capacitance checker and the actual condition of the capacitor. The basis for the explanation lies in the difference between the frequency at which my capacitance checker tests capacitors (60 Hz) and the frequency at which the trap is adjusted. The capacitor probably had a high internal series resistance due to poor contact between the capacitor plates and the plate holding tabs. At the 60-Hz test frequency, the reactance of the capacitor was so high (56.5 megohms) that it swamped the series resistance, causing the capacitor to check good. At the trap frequency of 4.5 MHz, however, the reverse was true, with the result that the capacitor acted essentially as a resistor. Under this condition, resonance could not be obtained and the trap could not be adjusted.

The moral is clear: Capacitors used in rf circuits are best checked by substitution.—*Peter J. Profera, W2YAX*

### EICO 950A R-C BRIDGE

I recently experienced a puzzling problem with an EICO model 950A R-C bridge and comparator. Test voltage and electrolytic ranges worked perfectly, but the "eye" tube acted strangely on resistance, capacitance and comparator ranges. As the proper reading was approached from the left-hand side of the dial, the eye would open as expected, but it would not close again when this point had been passed. Voltage

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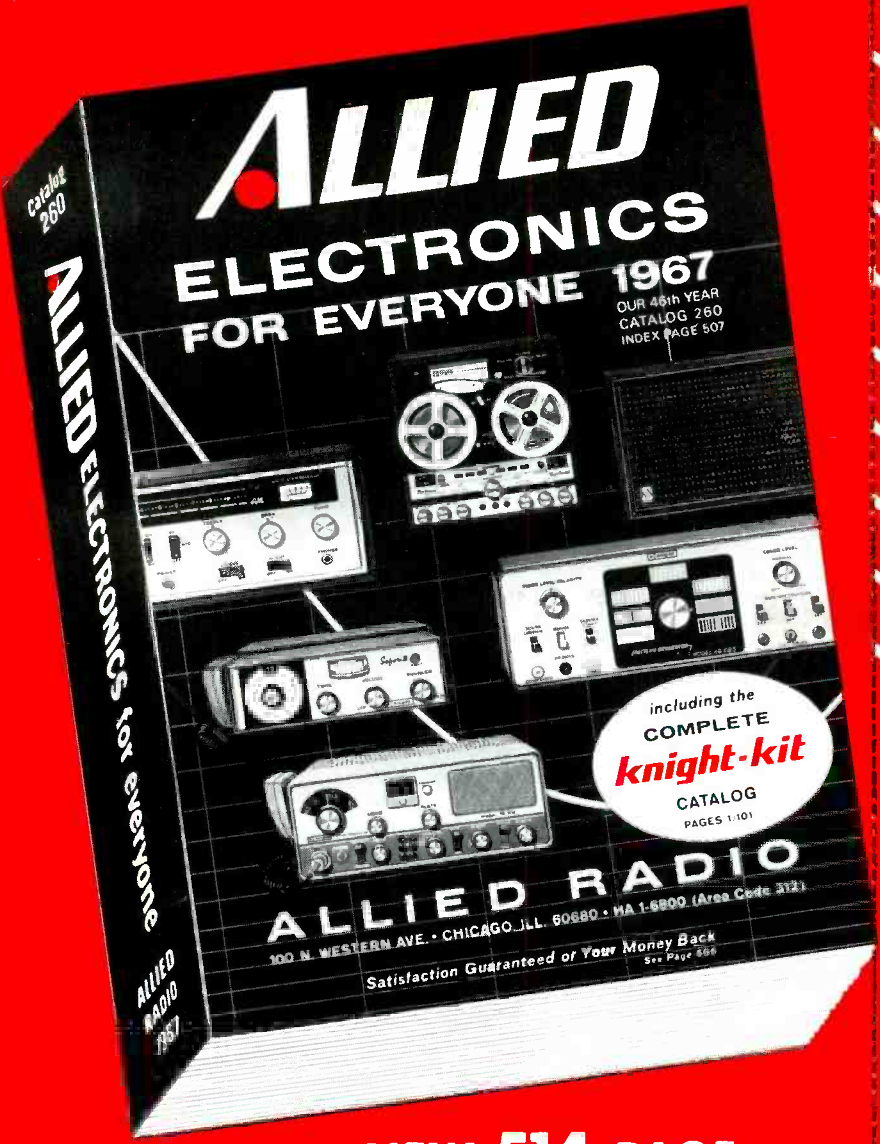

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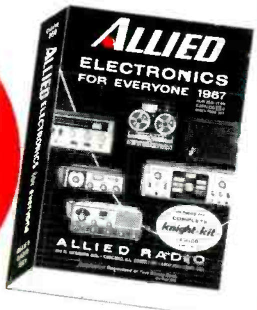

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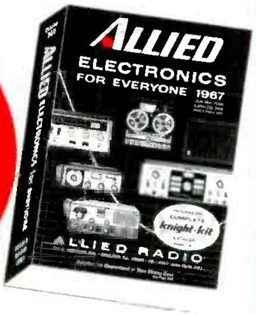

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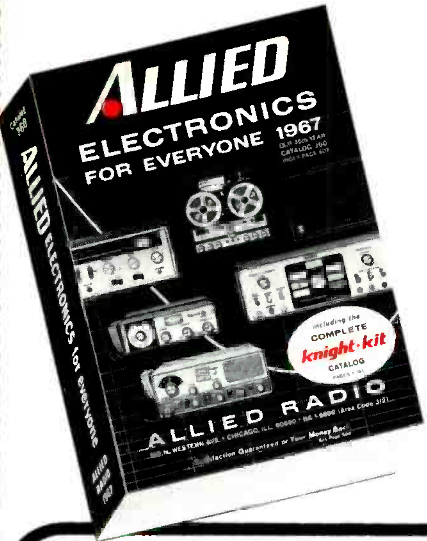

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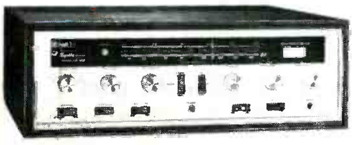

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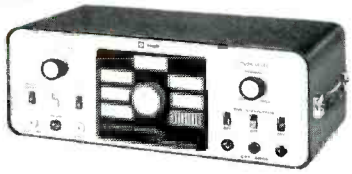

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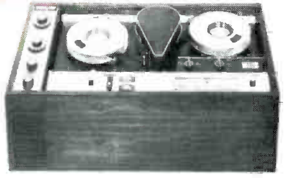

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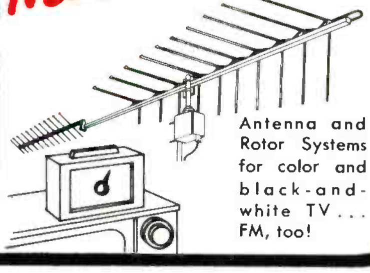

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*DO A FRIEND A FAVOR—give him this card to send for his FREE ALLIED CATALOG* and resistance checks revealed nothing abnormal. A bit of reasoning gave a solution. The eye-tube filter capacitor (4 μF 150 volts) had opened. Dc plate voltage, therefore, was present at the eye tube only half the time (the rectifier is a half-wave-connected 6X5). When the bridge was unbalanced and the "difference" voltage applied to the eye-tube grid was out of phase with the pulsating plate supply, the eye could not close, because it was not even glowing! Its fluorescence pulsated on and off 60 times a second, along with the plate supply voltage. Replacement of the capacitor cured the trouble.—*Garry Boross*

### NO SOUND FROM TRANSISTOR PORTABLE

When transistor radios don't work at all, try the earphone jack. When the earphone is plugged in, the speaker is disconnected through a spring leaf on the jack which sometimes become dirty or tarnished. Clean it with contact cleaner or scrape it lightly.—*Jerry Jensen*

### CRT REPLACEMENT: OLYMPIC 3P41

The picture tube in this model is mounted with four corner angle brackets and an adjustable ring. These parts are coated with a compound to keep them from loosening during shipment.

To avoid breaking the plastic brackets, dissolve the compound before loosening the hardware to replace the tube. Almost any shop solvent will do.—*Olympic Service Bulletin 65-3.*

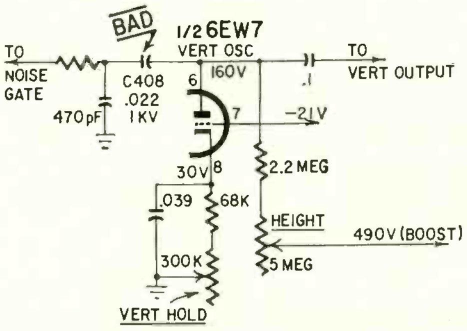
### BROWN ELECTRONIK RECORDER MODIFICATION

Anyone who has had to remove the chart-tensioning mechanism of Brown Electronik recorders knows the grief involved in assembling the spring-loaded ball bearing into its nylon housing. Try this:

Drill a hole through the nylon ¼ inch from the opening and at a right angle to it. A No. 50 bit is about right. Compress the spring and insert a small solid wire into the hole. Put the ball in place and secure it with a piece of tape. Install the assembly, pull out the tape and wire, and the job is complete.—*William P. Turner*

### ADMIRAL 19UE8B WITH STRANGE VERTICAL

This one had intermittent vertical trouble. The bottom of the raster would pull up about 4 inches and the top would spread out. Voltages checked OK. But when any test instrument was connected to the circuit, the set would return to normal. The symptoms seemed like those from shorted turns in the vertical output transformer. I changed the transformer and the set worked perfectly for 3 days. Again the trouble came—and went.

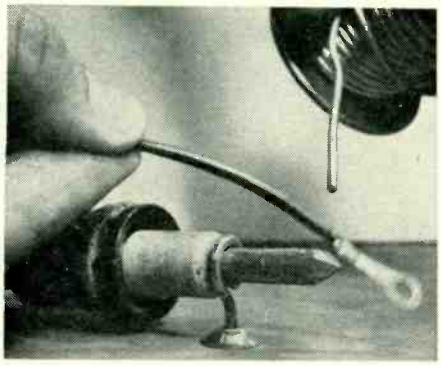


Parts were pushed and prodded in the vertical section, but nothing showed. When a test prod touched any part of the circuit, the set would return to normal. This sounded like a capacitor being shocked into proper operation. I placed a soldering iron near the capacitors to see if one might be defective. Sure enough, C408 was the culprit. *Replace it with a 1,600-volt unit.*—*Homer L. Davidson* END

# TRY THIS ONE

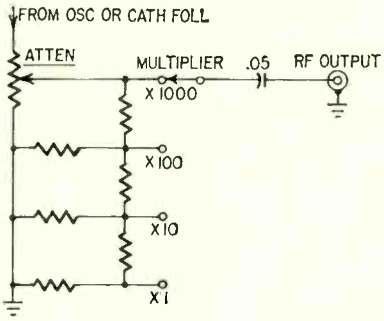
### HOOK HOLDS SOLDERING PENCIL

When you have a "three-hand" soldering job and no way to hold the pencil or iron steady, try this: Put the pencil or iron tip through a cuphook screwed into the bench top. If necessary, pinch the cuphook with pliers to give it a closer fit over the tip.—*John A. Comstock*



### ADD BLOCKING CAP TO RF GEN

Most inexpensive rf signal generators are usually without a blocking capacitor in the output lead. Service data usually remind you to use a blocking capacitor in series with the hot lead of your rf generator. But what if you forget, and connect the generator direct to a B-plus point? More than likely you would do considerable damage to your rf generator. I installed a .05-μF 600-volt capacitor permanently in my Eico model 315 rf generator. The schematic shows how to install one. It applies to most service generators in that price range.—*George E. Lytle*



### REPLACING A MYSTERY RESISTOR

If you run across an open wirewound power resistor that needs replacing, and it's marked only with somebody's part number, or not at all, try this.

With one or two whacks of a sharp knifeblade, chip away a bit of the porcelain outer sheath as nearly in the center of the resistor as you can. Several turns of the resistance element should be bared. Then, with your ohmmeter, measure the resistance from the midpoint to the "not-open" end. Double the reading, and there's the value of the whole resistor to within 5% or 10%. —*David Wilder*

### MORE PRECISE AUDIO LOAD

The "Tote-A-Load" described by William F. Kernin in the March RADIO-ELECTRONICS ("Make a High-Power PA Load," p. 78) can be improved by changing the switch to a 2-pole 3-position unit. Mr. Kernin shows two forms of the load box, one providing 4 and 8 ohms, the other 8 and 16. With a 2-pole 3-position switch, all three load values are available in one unit (see the diagram). Power levels remain the same as in Mr. Kernin's units: 150 watts at 4 and 16 ohms, 75 watts at 8 ohms. If more power is needed for large installations, 50-watt resistors will provide 150 watts at 8 ohms, and 300 at 4 and

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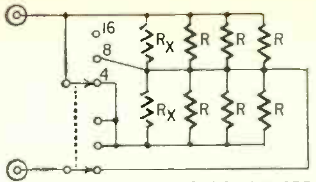
*Circle 120 on reader's service card*



R=25Ω/25W; $R_X$=200Ω/10W-SEE TEXT

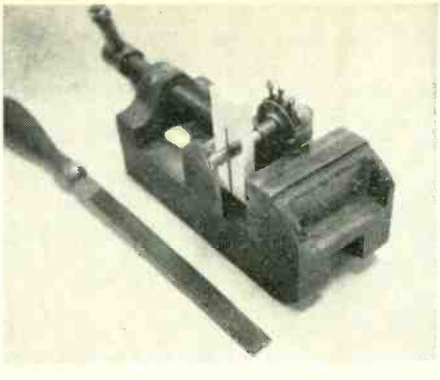
16 ohms. Incidentally, if one of the original circuits is used where only two load values are needed, switch S need not be a spdt as specified, but can be a spst type.

This unit will not only be useful as described in Mr. Kernin's article, but also as an external load when using a wattmeter for measuring the output of a high-power amplifier. For instance, the Heath Audio Analyzer's internal load resistors are rated at 25 watts continuous or 50 watts intermittent, the Eico 261 ac Volt–Watt Meter has internal load resistors rated at 40 watts, but both instruments are calibrated up to 150 watts for use with external load resistors. With several stereo amplifiers running 60 to 100 watts per channel, external load resistors are necessary. As Mr. Kernin indicates, the 4-, 8-, and 16-ohm loads are actually about 4% high if 25-ohm resistors are used. This is less than the normal tolerance of most power resistors. If a bridge is available, the resistance of each parallel group of three resistors can be measured and $R_x$ (see diagram) calculated to bring each group to exactly 8 ohms. Assuming each of the large resistors is exactly 25 ohms, $R_x$ should be 200 ohms to bring the nominal values to exactly 4, 8 and 16. If high accuracy is desired, 1% power resistors are available (Allied Radio Corp.) but are rather expensive. For most uses, standard power resistors will be accurate enough to give a good indication of the power of the amplifier.

If a wattmeter is not available, the equation given by Mr. Kernin is correct for a sine wave ($P = E^2/R$), and there is no reason for "the hi-fi boys to shudder." If the load resistance is known, the voltage across the load can be measured, and the output is a good sine wave, the power calculated by this equation should agree with that measured on a wattmeter.—*W. J. Stiles*

### SHAFT-CUTTING ACCESSORY

The photo shows a handy tool that I developed as an aid to cutting and finishing switch and potentiometer shafts. It is made from a 2-inch square of ¼-inch aluminum stock. Drill a ¼-inch hole in the center. Hacksaw a slot from one edge through the center a short distance beyond the hole.



When the tool is inserted in a vise as shown, you can clamp a control shaft and finish it without damaging the control.—*Carmelo Cocozzelli* END

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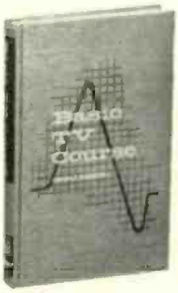

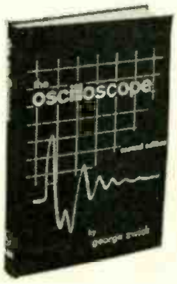

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# WHAT'S YOUR EQ?

These are the answers. Puzzles are on page 40.

**Tapered Network**

If the first section of the network is removed, the remaining portion looks like Fig. 1. This new network is identical to the original except that each of the resistors has been multiplied by ½.

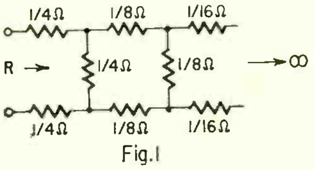


Fig.1

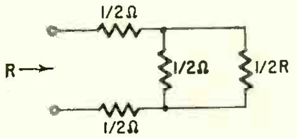


Fig.2

By a basic theorem of scaling, if a resistive network has all of its resistors multiplied by a constant factor, the input resistance will also be multiplied by the same factor. Thus, the input resistance of the modified network is ½R. The original ladder can then be drawn as in Fig. 2.

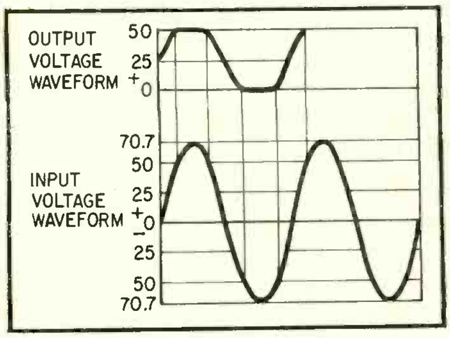
$$R = 1 + \frac{\frac{1}{2} + \frac{1}{2}R}{\frac{1}{4}R}$$

$$R^2 - \tfrac{1}{2}R - 1 = 0$$

$$R = \tfrac{1}{4}(1 + \sqrt{17})$$
$$= \text{approx. } 1.28 \text{ ohms}$$

**? ? ? Circuit**

When the ac input voltage is zero, both diodes conduct. R2 and R3 are effectively in parallel, forming an effective resistance of ⅔ megohm between point A and ground. Since R1 is in series with this ⅔ megohm, the output at point A is 25 volts.



When the ac input voltage rises to +50 volts or more, the left-hand diode stops conducting and the effective resistance between point A and ground is 2 megohms (R2). The voltage divider (R1–R2) limits the maximum output voltage to +50 volts—just half the input.

As the ac input voltage drops below zero, the current through R3 and the left-hand diode increases. This decreases the current through the right-hand diode and, as a result, the output voltage decreases. When the ac input voltage reaches −50 volts or more, the right-hand diode is nonconducting and the output voltage is zero.

**More Rows**

Mr. T. A. Kasinski came up with this variation to the solution of the "Which Row" puzzler (Oct. '65).

It is possible to determine which row contains the 200-ohm resistors not only from five, but from *six* rows.

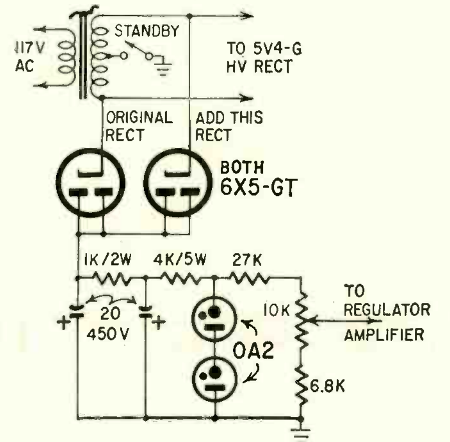
Do not connect this sixth row at all. If your measurement is 1,500 ohms, the sixth row contains the 200-ohm resistors. If the measurement is greater than 1,500 ohms, the original solution applies. END

# NOTEWORTHY CIRCUITS

## REDUCE RIPPLE IN HEATHKIT PS-3

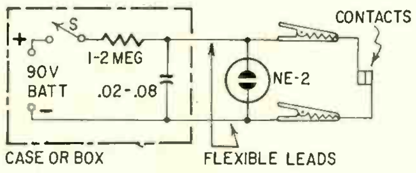
The Heath PS-3 (as well as some other regulated power supplies) obtains negative grid bias for the regulator amplifier from a half-wave rectifier. The voltage is filtered and then regulated by two VR tubes in series. VR tubes are not perfect regulators so a few tenths of a volt of the power-supply ripple appears across them. The ripple is fed to the grid of the amplifier, and consequently appears in the output.

One way of reducing this ripple is by converting the half-wave rectifier to full-wave by adding another rectifier tube as shown on the diagram. (If you wish to use a solid-state rectifier, you must replace the existing rectifier tube as well, to maintain symmetry.) This increases the fundamental ripple frequency from 60 to 120 Hz, making the filter more effective. This change increases the supply voltage, so it may be necessary to increase the resistance in series with the VR tubes to maintain the correct VR-tube current.—*Charles Erwin Cohn*



## BREAKER-POINT CHECKING AID

In a military overhaul depot, mechanics working on aircraft magnetos had difficulty checking breaker-point spring tension. The procedure required that the contacts "break" or open within rigid spring-tension limits. This was checked with a spring-tension gage and a battery-powered lamp as a continuity checker. The light was in the battery box on a shelf above the workbench.



Two things were wrong with this arrangement. One was that the indicator light was out of the mechanic's line of vision when he was watching the tension gage. The second was that the "contact open" indication was the *extinguishing* of the light. In most tests, the *presence* of an indicating signal is preferable.

I suggested the simple circuit shown. Its advantages are that the lamp suddenly lights when the points open, and that the lamp may be mounted on one of the clips attached to the contact assembly. In this way, the lamp is directly in line with the tension gage and is much more readily observed.

The breaker points short the lamp when closed. When they open, striking voltage appears across the lamp and the circuit oscillates. A switch is shown but is not needed because battery drain is very low, even with the test clips shorted.
—*A. W. Edwards*

## VHF–UHF TV COUPLER

A pair of couplers are needed whenever you want to use a single lead-in with separate vhf and uhf TV antennas. See Fig. 1. Here is a coupler (Fig. 2) that you can build in just a few minutes. I built mine on 3 x 1½-inch perforated boards.

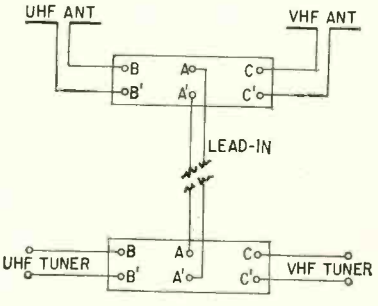


Fig.1

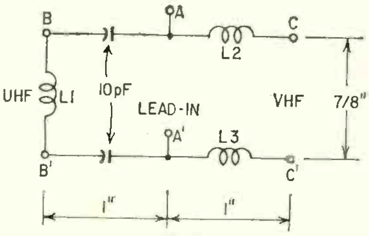


Fig.2

All coils are wound with No. 20 enameled wire around ⅛-inch forms. L1 consists of 8 turns spaced to occupy ⅜ inch. L2 and L3 are each 18 turns spaced to ⅝ inch. The capacitors are tiny ceramic units.—*Bennett C. Goldberg*

END

# NEW BOOKS

THE RADIO AMATEUR'S VHF MANUAL, by Edward P. Tilton. *American Radio Relay League, Newington, Conn. 06111. 6½ x 9½ in., 318 pp. Paper, $2*

This latest addition to the ARRL roster of technical publications is written especially for the ham interested in 50 mc and above. Mainly theory, design and construction of tuners, converters, exciters, frequency multipliers and amplifiers, test instruments and antennas for use between 50 and 500 mc, but includes material on circuits and equipment up to 2,300 mc. Well illustrated in the usual QST/ARRL-Handbook style.

PRINCIPLES OF COMMUNICATION ENGINEERING, by John M. Wozencraft and Irwin Mark Jacobs. *John Wiley & Sons, Inc., 605 3d Ave., New York, N. Y. 10016. 6 x 9¼ in., 720 pp. Cloth, $17.50*

This senior-year-college or first-year-graduate textbook discusses, in its first chapters, information theory, randomness and probability theory in language that can be understood by many students at lower levels.

HOW TO BUILD PROXIMITY DETECTORS & METAL LOCATORS, by John Potter Shields. *Howard W. Sams & Co., Inc., 4300 W. 62 St., Indianapolis 6, Ind. 5¼ x 8½ in., 128 pp. Paper, $2.50*

The book is largely devoted to the type of proximity detectors used in intruder alarms for activating window displays, etc. One chapter treats elementary metal locators, and another is devoted to advanced metal locators, including some interesting material on Hall-effect devices as metal locators, and on one that responds only to moving ferrous metal objects.

VIDEO TAPE RECORDING, NEW MARKETS AND PRODUCTS, by Cris H. Schaefer, Cedric L. Suzman & Assoc. *Hobbs, Dorman & Co., Inc., 441 Lexington Ave., New York, N. Y. 10017. 7½ x 10¼ in., 104 pp. Cloth, $12*

The book is aimed at the layman or businessman, with a brief introduction describing technical features of video tape recorders and the differences between various recorders now in use or projected for the future. The book was written before the present low-priced video tape recorders (Ampex, Sony, etc.) appeared on the market.

CLOSED-CIRCUIT TELEVISION HANDBOOK, by Leon A. Wortman. *Harold W. Sams & Co., Inc., 4300 W. 62 St., Indianapolis, Ind. 46206. 5½ x 8¾ in., 286 pp. Cloth, $6.95*

Begins with the camera (after a short introductory chapter) and goes through to the monitor or display tube in the first two chapters. Nine other chapters are devoted to system expansion, recording, and applications such as education, industry and research. There is a chapter on circuits, one on microwave relays, and another on lenses, lighting and wiring.

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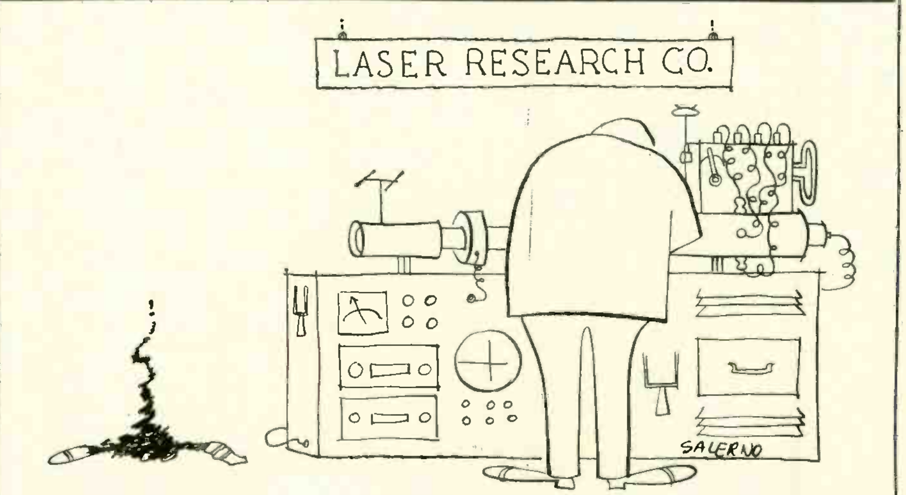

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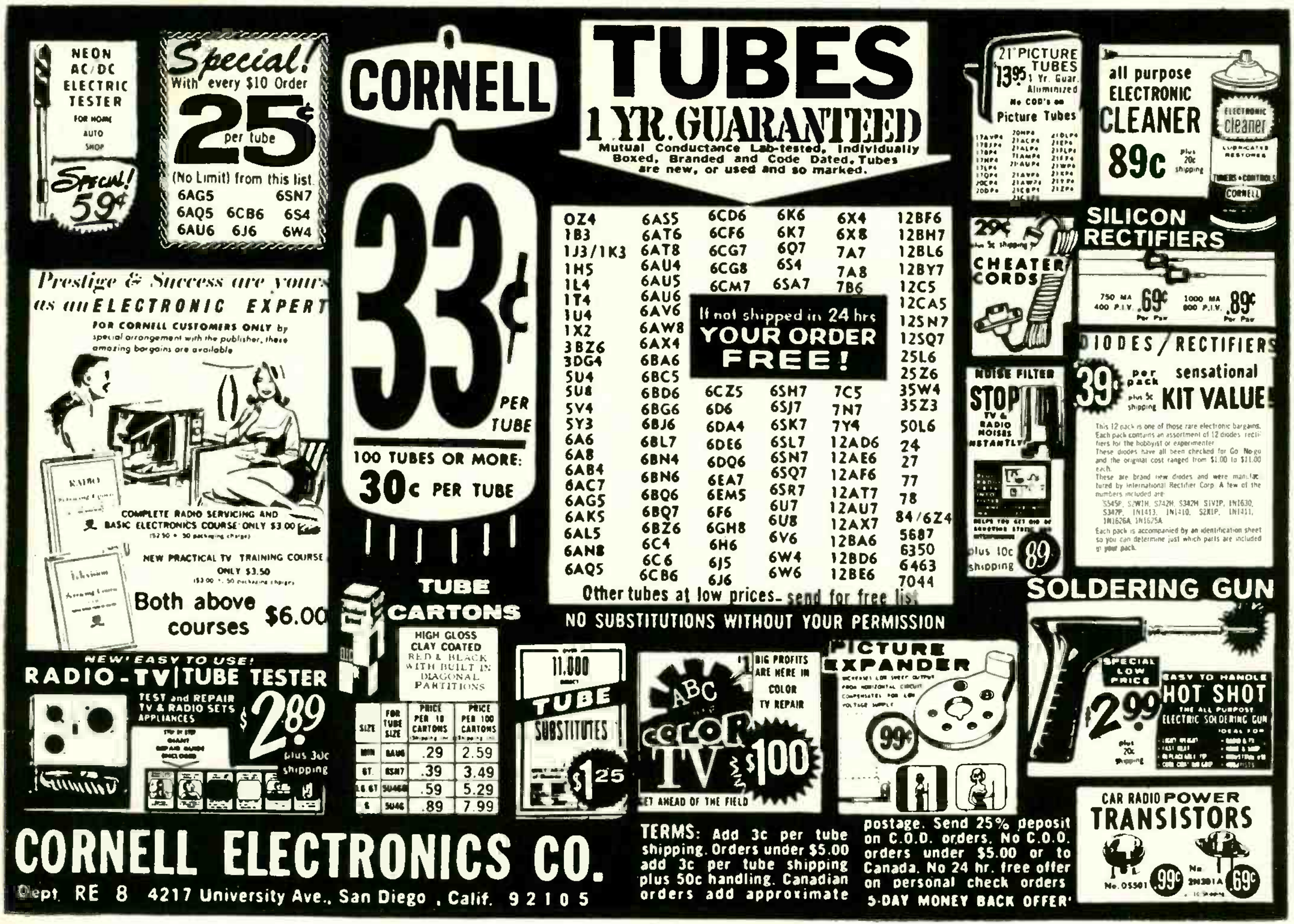
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6AT6
6AT8
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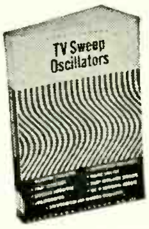


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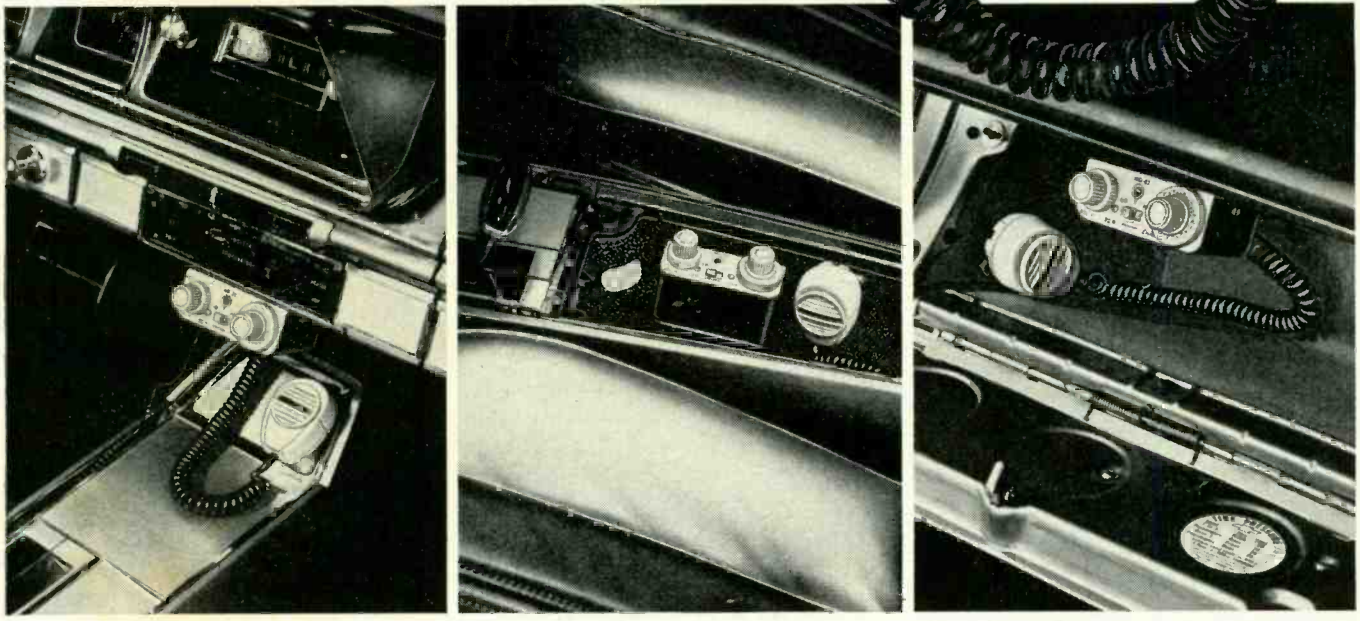

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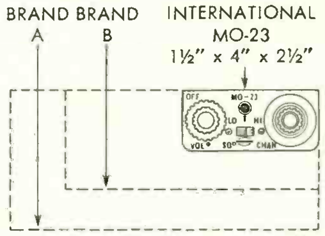

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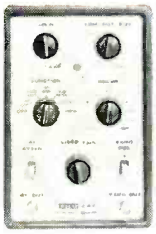

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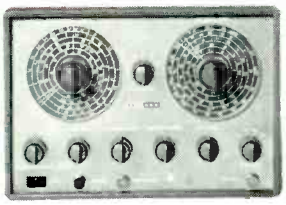

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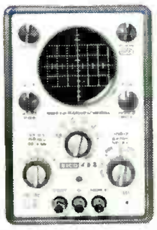

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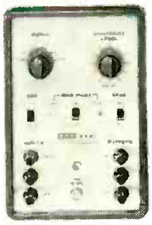

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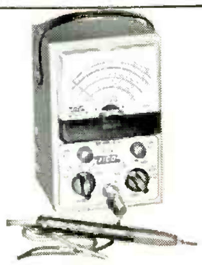

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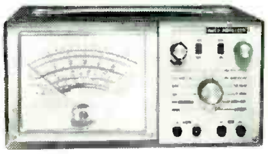

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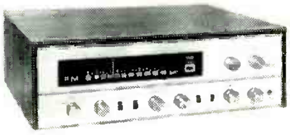

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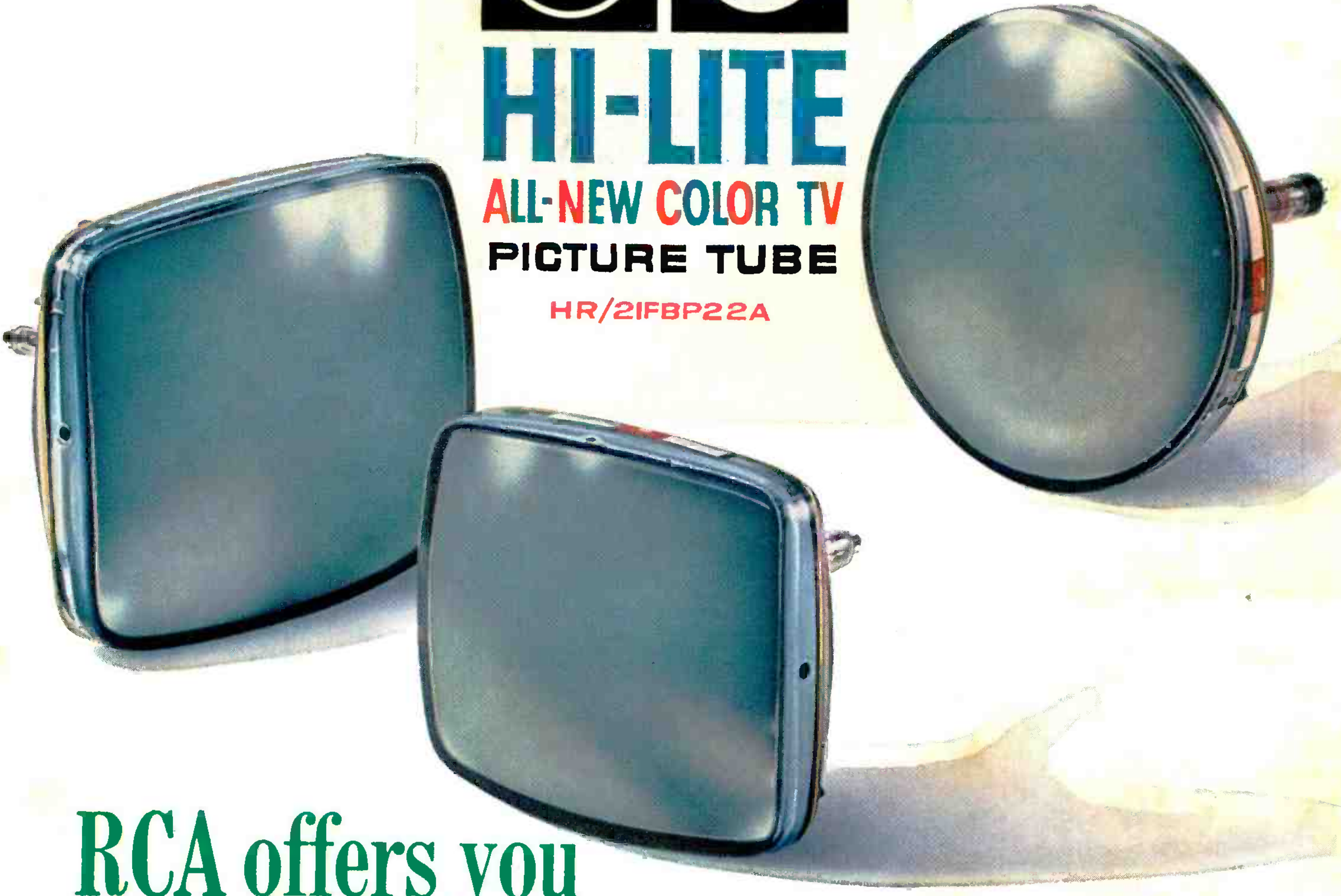

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RCA Hi-Lite picture tubes are all-new...glass, gun, the works! They're RCA's best...the same quality...the same tubes...that go into original equipment sets. And because they incorporate the latest technological advances of the world's largest color picture tube manufacturer, you literally "up-date" your customer's color set each time you install one. Here is picture brightness and color fidelity at its finest, available for the service trade in 19-inch and 25-inch rectangular and 21-inch round tube types.

RCA Electronic Components and Devices, Harrison, N. J.

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