Electronics World

DECEMBER, 1968
60 CENTS

IC FREQUENCY DIVIDERS & COUNTERS
TROUBLESHOOTING FET CIRCUITS
LASER DIODES
IC STEREO MULTIPLEX DEMODULATOR

SPECIAL

EW LAB TESTS

STEREO RECEIVERS

Now, what's the best way to play your records for under $80?

For years the AR turntable, at $78,* has been the only truly fine record playing mechanism you could buy for under $80.

A well informed audiophile, who wanted to save some money on his complete stereo system, bought the AR turntable. Period.

But now, if you're out to make an informed choice of a low cost turntable, you'll have to take one other product into consideration.

The new automatic Dual 1212. At $74.50.**

Just like the AR, the Dual 1212 exceeds every NAB standard for broadcast turntables in rumble, wow, flutter and speed accuracy.

But only the Dual lets you vary any of its speeds by 6%. That'll come in handy if you're pitch-sensitive.

The Dual has three speeds (including 78). The AR has two.

Just like the AR, the Dual will accept any currently available cartridge, and track it at its optimum stylus force.

But so that your cartridge will ride in the center of a stereo groove at low tracking forces, the Dual has built-in anti-skating compensation. (The AR has no equivalent device.)

And to protect your cartridge, the Dual has a cueing control that gently lowers the arm anywhere on your record. It also lets you conveniently interrupt play for a time, and then continue in the same place. (Again, no AR equivalent.)

The Dual is automatic. It can start or stop automatically. With one record or a stack of six. (The tracking force of the Dual arm won't vary from first record to last.) And even when you place its arm on a record by hand, the Dual will start turning automatically.

The AR is a manual turntable with no automatic features.

Your records will probably sound exactly the same played on whichever of the two turntables you choose.

So go to your dealer and see them both. And then decide which way you want to play records.

With a host of Dual convenience features, for $74.50.

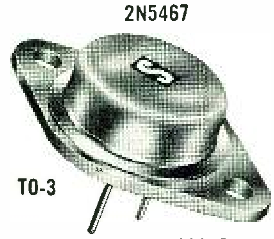
Or without them, for $78.

United Audio Products, Inc.,
535 Madison Avenue,
New York, N.Y.10022.) Dual

*Including base and dust cover. **Base and dust cover are extra.

700V
HIGH VOLTAGE NPN Silicon Power TRANSISTORS from Solitron

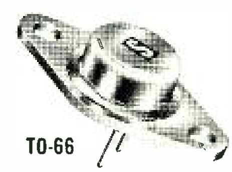
2N5467



TO-3

80W @ 100°C
1.25°C per W

2N5469



TO-66

40W @ 100°C
2.5°C per W

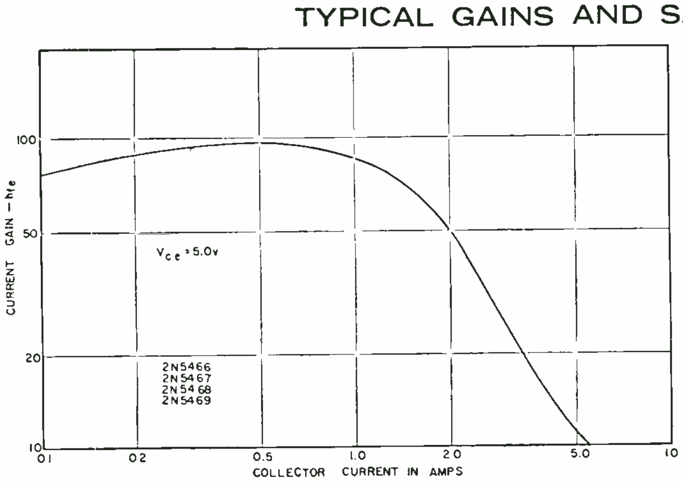
SPECIFICATION RATINGS:

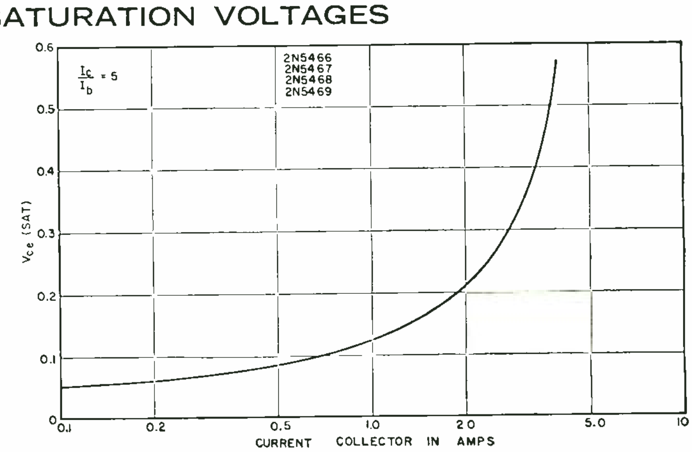
V_{CEX} = 700V min
$V_{CEO}(sus)$ = 400V min
h_{FE} = 15-60 @ 3.0A
$V_{CE}(sat)$ = 0.5V @ 3.0A

Also available in 500 Volt V_{CEX} versions, 2N5466 and 2N5468; all other specifications identical.

High voltage, triple-diffused silicon power transistors are now available from Solitron, with V_{CEX} up to 700 Volts. Typical applications include horizontal deflection circuits, ignition systems, CRT sweep systems, high voltage switching mode regulators, high voltage pulse amplifiers and high voltage pass series regulators. Priced low, they are available in TO-3 and TO-66 cases.

TYPICAL GAINS AND SATURATION VOLTAGES





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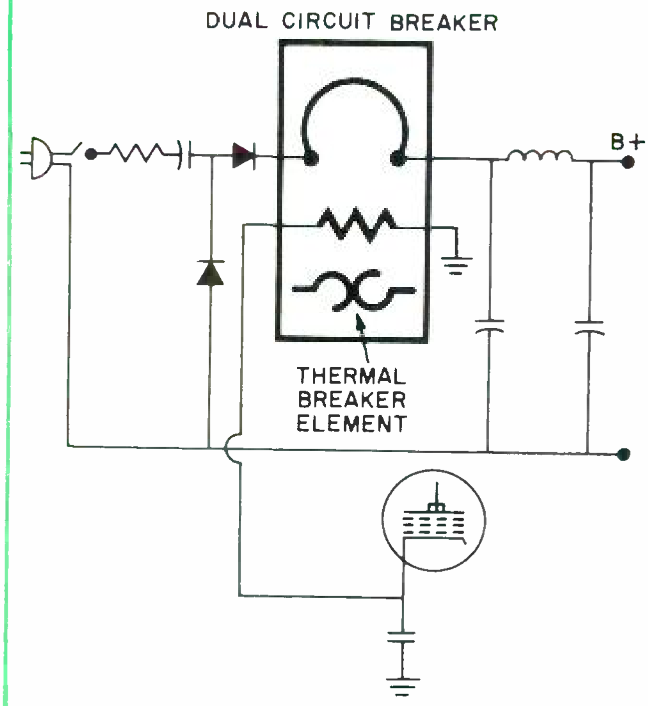
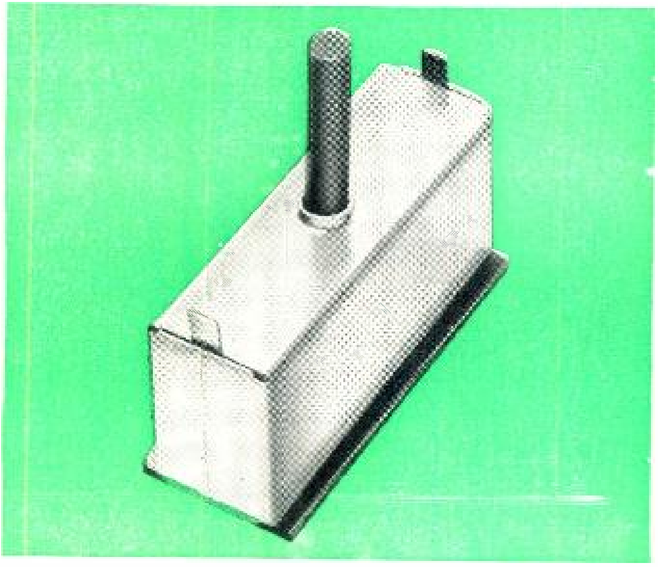
MALLORY **Tips for Technicians**

New circuit breakers for color TV



Typical hook-up for dual circuit breaker



Dual circuit breaker

Practically all the new color TV sets have a new kind of dual circuit breaker in them which you may not have run into before. Here's the story.

Remember back when black-and-white television used two fuses—one in the power supply input, and one in the horizontal output circuit? Next, in the interest of economy, the fuse in the horizontal output was eliminated. Then the designers switched to re-settable breakers, in the B+ line.

Along came color. Overload protection became necessary, because the horizontal circuits are more complicated, and more expensive components including the flyback transformer could be knocked out by a defect in the horizontal circuit.

The answer: a dual breaker which pops out from excess current in *either* the B+ or the horizontal output . . . in a single breaker case. It has two electrically isolated but thermally connected circuits, either of which can cause the B+ contacts to open.

The diagram shows a basic hook-up for the breaker. The thermal breaker element goes directly in the B+ line. A resistor inside the breaker, usually about 1.3 ohms, is connected between the cathode of the horizontal output stage and ground. This resistor is located so it will heat up the thermal breaker element.

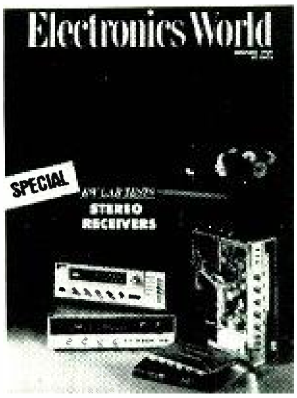
Along comes an overload in the B+. The thermal element pops the contacts open, in the usual manner. When there's excessive current in the horizontal output, the heating of the breaker's resistor has the same effect as a B+ overload, opening the contacts and removing voltage from the circuit.

Tip No. 1: breakers can fail because they get repeatedly reset into a fault. Check for gassy tubes and leaky capacitors before you replace the breaker, or you'll have the whole job to do over.

Tip No. 2: always replace with a Mallory breaker. We have three different dual breaker ratings in our line. They will replace the dual breakers in all existing color set applications. All are made to original equipment specifications. Your nearby Mallory distributor can supply you off the shelf. See him soon, or write to Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

REMEMBER TO ASK—*"What else needs fixing?"*

CIRCLE NO. 102 ON READER SERVICE CARD



THIS MONTH'S COVER shows some of the new solid-state stereo receivers that were surveyed and lab-tested for this annual round-up report on these important components. The vertical receiver at the right, shown here with its bottom cover removed, is the Scott 341. At the lower left is the Sherwood S-8800a. The remaining receiver is the Fisher 400-T. This receiver is similar to Model 250-T, which we tested, except that it has about 50 percent greater power output. For complete details on these, plus many more, see our lead article "EW Lab Tests of New Stereo Receivers." The pair of speakers in the background are the new Jensen TF-25's. These are two-speaker, two-way systems with 10-in air-suspension woofers and horn-loaded tweeters. ....
Photo by Dirone-Denner

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CONTENTS

MONTHLY FEATURES

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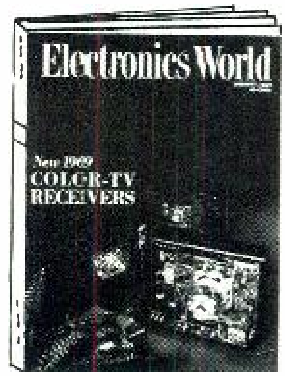
COMING NEXT MONTH



SPECIAL FEATURE ARTICLE:

COLOR-TV FOR 1969

You'll be "in" in 1969 if you have a small, portable color-TV set. Three 14" color-TV sets from RCA, Sylvania, and Zenith reflect this year's trend in television design. But size and cabinet design are not the only way manufacturers hope to attract buyers. In his feature article, Forest Belt discusses the Admiral, DuMont, Electrohome, G-E, Magnavox, Olympic, Panasonic, Philco, RCA, Setchell-Carlson, Sylvania, Toshiba, and Zenith sets and tells how they compare.

ADDING REMOTE SPEAKERS TO HI-FI STEREO SYSTEMS

Adding speakers to any solid-state amplifier is more than connecting a few wires. Careful consideration must be given to proper impedance match or an amplifier can be seriously overloaded.

FREQUENCY DIVIDERS & COUNTERS

In Part 2, the basics of IC logic elements are extended to complete counter and divider systems. Synchronous counters for division ratios from 2 through 10 are presented.

UNIQUE C-D IGNITION SYSTEM

A thoroughly tested system that has improved the performance of cars ranging from a 1960 Ford to a racing model. A complete circuit, parts values, and test results are included in the article.

TV SYSTEMS FOR TEACHER EDUCATION

Seeing oneself as others do is perhaps a most salutary experience for good teachers. A new teacher-training technique, called "microteaching," employs video tape recorders to help teachers improve their presentations.

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

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By FOREST H. BELT/Contributing Editor

Digital FM Tuning

The winter season is upon us, and attention turns to indoor entertainment—like hi-fi stereo. There's plenty to tell about, this season. One unusual device is a digital-tuned FM receiver. It is to be built by *C/M Laboratories* of Norwalk, Conn. We've only seen a display sample, but have learned a few things about its design.

The tuner is a 100-channel frequency synthesizer, picking out any desired FM frequency by matrixing certain crystals from among the 20 that form the synthesizer. The "dial" is merely four Nixie readout tubes, which glow to indicate the frequency selected. There are three ways to tune the receiver: signal-seeking, with the tuner halting at stations of preselected strength; manual multiple advance, in which the tuner scans rapidly across the FM band, stopping when the spring-loaded leaf switch is released; and manual single-step advance, also by spring-loaded leaf switch. The receiver is expected to be ready for delivery after the first of the year at a price of around $1000.

Armchair Stereo Tuning

Another innovation is remote control for music lovers. At least two companies have exhibited receivers with remote-control tuning: *Bogen* and *Fisher*. (The digital tuner mentioned above can probably be adapted to remote control quite easily.) *Bogen's* Model DB240 tuner has a signal-seeking dialing mechanism. The remote-control connects through a 10-foot cord. The listener can tune the receiver, control the volume, and see what station is tuned in.

Fisher's remote control works with the Model 500-TX 190-watt receiver. This receiver also uses a type of signal-seeking—which *Fisher* calls "Autoscan." This remote control also attaches by a long cord.

Smaller World of Stereo

Not long ago, compact cars went through a heyday. The upcoming year portends to be the year of the compact stereo. This time, though, "compact" doesn't always mean small size. It more often refers to a tuner, automatic turntable (or record changer), and amplifier that have been combined into one unit—sometimes called a control center. The speakers, although they are design-coordinated, are separate.

Compacts have been around a couple of years, but in limited numbers. This season, the number of models has increased sharply, undoubtedly through customer demand. Compacts are not just glorified portables. They are really high-performance stereo music systems. Some include cartridge-tape-playing facilities. A couple of models introduced at Hi-Fi Shows this fall can even record on or play back from *stereo* cassettes (also new).

Since stereo has become so much of a family affair, instead of the domain of the "buff", wives have been having more of a say about what the stereo system looks like. Not many of them get very enthused over component stereo, no matter how wide the response or how accurate the tracking. But the husband, who of course "knows" about these more important factors, has found a satisfying answer in the compacts. With the new stereo cassettes facing a boom, with good stereo recordings still selling by the millions, and with FM stations slanting their programs to the preferences of stereo families, it looks as if the compact-makers can look forward to a prosperous year.

Color Still Going Strong

Another home-entertainment product getting lots of attention nowadays is color-TV. Winter-season programming attracts more viewers than ever, with large prime-time blocks of not-very-old color movies. That bodes well for year-end set sales. EIA's "Discover Color TV" promotion is having its effect, too. With the Christmas selling season still to go, 1968 sales may total above 6.1 million. Dealers we've talked to expect a good year-end.

In components news, solid-state gets the most attention. *Varo, Inc.* keeps widening its line of semiconductor high-voltage rectifiers. The most significant lately is a voltage multiplier that takes a relatively low-voltage flyback pulse and builds it into as much as 45 kV. The multipliers could replace both h.v. rectifier and shunt regulator, since they're simple to regulate.

A new silicon power transistor from *Hitachi* will be used for horizontal and vertical deflection in mid-1969 TV models.

The color picture tube still makes news, too (besides the patent hassle of phosphors and shadow masks between *Sylvania* and *National Video*). There's a new implosion-proofing method developed by *Chicago Dial Co.*, a subsidiary of *3M*. Ordinary window glass is laminated to the tinted-glass face of an ordinary color CRT. A bonus is that x-radiation from the face is reduced, even under bombardment from beams with too-high voltage.

Service Shortage and Training

The electronics industry is still slugging away at creating new service technicians and upgrading others. A sister industry, electrical appliances, has mounted the same task.

For manpower, some companies are taking part in Project Transition, which is promoted by the Department of Defense: draftees about to be discharged are given concentrated courses that qualify them to go into beginner servicing jobs.

RCA Institutes, Inc. is managing another experiment—with hard-core unemployed in the New York ghettos. They follow a work-four-hours, study-four-hours schedule. Men who successfully complete the year's training get jobs with *RCA Service Co.* as apprentice technicians.

Consumerism Still Powerful Medicine

The "guardians" of the public are still with us, some self-appointed and some government-appointed. Hardly a week passes without some segment of the electronics field catching it. X-rays, warranties, service—all have been whipping boys. Everything has its good side, though, and the industry has been coerced into taking a close look at some practices.

Take servicing. With customers and manufacturers alike complaining about high costs, some concrete suggestions are evolving. An executive of one large retail chain, which is right now setting up its own servicing group, recommends test points in TV sets—brought out to a single socket into which a special analyzer can be plugged.

We know this idea has worked well for years in two-way radio, cutting maintenance and repair time by hours. It is used extensively in military electronics systems. Some set manufacturers have told us of research they're doing along these lines. We've done work on this in our own lab. A few companies hope to carry it even further and use a computer for the analysis.

The chief hold-back is, of course, cost. Yet, in the light of rising warranty expense, the extra dimes might be well spent. Add the sales value of truly less-costly servicing, and the whole idea gets even more attractive. This all adds up to just one more way to improve industry-consumer relations—not to mention easing the shortage of technicians.

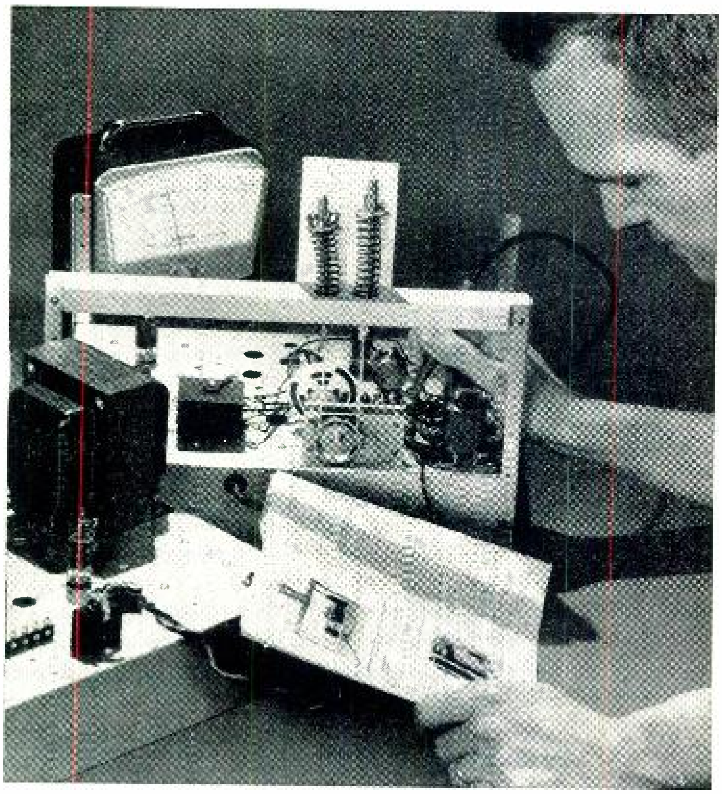
When a Transistor Isn't

The Federal Trade Commission finally identified what can be called a transistor in advertising radios and transceivers. A transistor can't be counted unless it detects, amplifies, or receives radio signals. If it's wired as a diode, it can't be counted as a transistor. Nor if it's in parallel or cascaded with another, unless you can prove it helps performance. That wording excludes a.g.c. transistors, a.f.c. transistors, stereo-light transistors, and any others that serve auxiliary purposes. (Watch the ad-language start saying "ten semiconductors"—meaning the equipment has five active transistors, three inactive ones, and a couple of diodes.)

Flashes in the Big Picture

Microsize entertainment products coming soon from Japan include 1½-inch TV, wrist-watch radio, and wireless stereo headset; all carry the *Panasonic* brand-name. . . . Modules for Quasar solid-state TV can be carried in service caddy supplied by *Motorola*. . . . Milestone recently passed: manufacture of three-billionth *RCA* receiving tube. . . . Pennsylvania legislature to consider technician licensing law in session just starting; drawn up by Pennsylvania Federation of Radio-Television Service Associations. . . . Two years is now standard picture-tube warranty for all imported color-TV sets. . . . To compete with cassettes, there is a "reelette," tiny flangeless 2-inch reel developed by *Newell Industries*; has 8 tracks and plays 14 minutes at 7½ in/s. . . . FCC plans to rule that u.h.f. tuners must be as easy to tune as v.h.f. tuners; gives industry not quite a year to comply. . . . Some *Sears*-brand (not *Silvertone*) TV sets are coming into the U.S. from Mexico. ▲

EXPERIENCE IS STILL YOUR BEST TEACHER



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NRI Has Trained More Men for Electronics Than Any Other School — By actual count,

the number of individuals who have enrolled for Electronics with NRI could easily populate a city the size of New Orleans or Indianapolis. Over three-quarters of a million have enrolled with NRI since 1914. How well NRI training has proved its value is evident from the thousands of letters we receive from graduates. Letters like those excerpted below. Take the first step to a rewarding new career today. Mail the postage-free card. No obligation. No salesman will call. NATIONAL RADIO INSTITUTE, Electronics Division, Washington, D.C. 20016.

L. V. Lynch, Louisville, Ky., was a factory worker with American Tobacco Co., now he's an Electronics Technician with the same firm. "I don't see how the NRI way of teaching could be improved."

G. L. Roberts, Champaign, Ill., is Senior Technician at the U. of Illinois Coordinated Science Laboratory. In two years he received five pay raises. Says Roberts, "I attribute my present position to NRI training."

Don House, Lubbock, Tex., went into his own Servicing business six months after completing NRI training. This former clothes salesman just bought a new house and reports, "I look forward to making twice as much money as I would have in my former work."

Ronald L. Ritter of Eatontown, N.J., received a promotion before finishing the NRI Communication course, scoring one of the highest grades in Army proficiency tests. He works with the U.S. Army Electronics Lab, Ft. Monmouth, N.J. "Through NRI, I know I can handle a job of responsibility."

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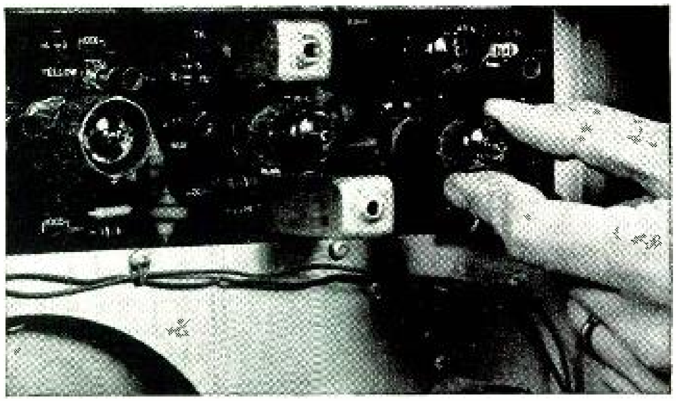

COLOR TV CIRCUITRY COMES ALIVE

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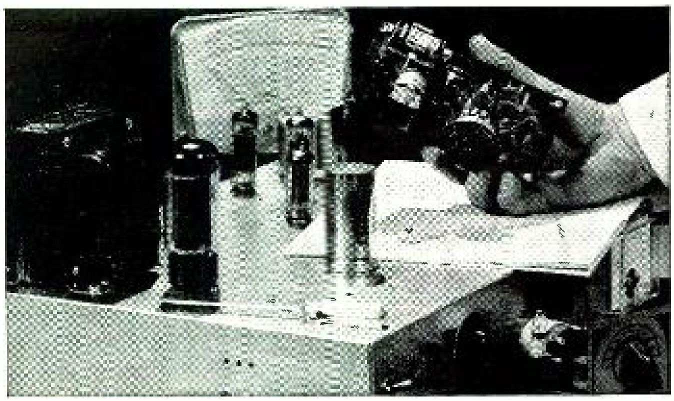
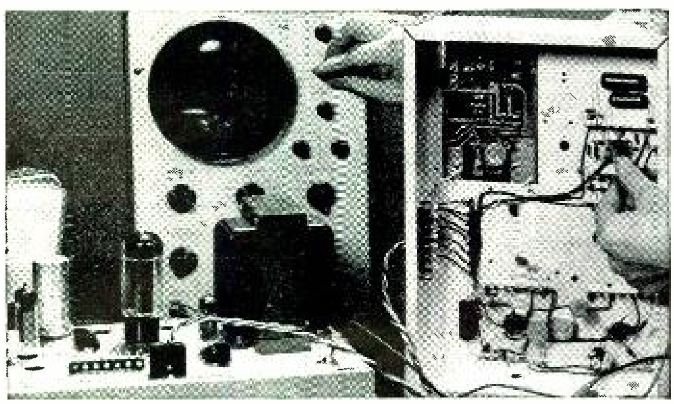


COMMUNICATIONS EXPERIENCE

comparable to many months on the job is yours as you build and use a VTVM with solid-state power supply, perform experiments on transmission line and antenna systems and build and work with an operating, phone-cw, 30-watt transmitter suitable for use on the 80-meter amateur band. Again, no other home-study school offers this equipment. You pass your FCC exams—or get your money back.



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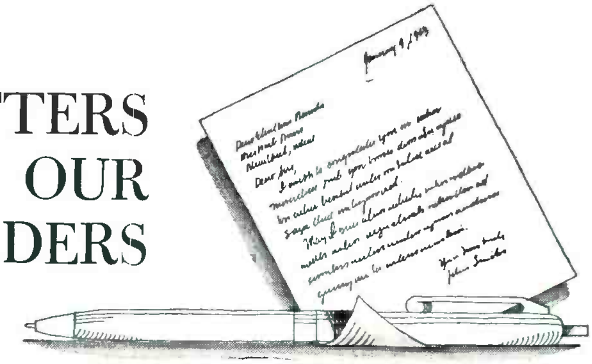
can be instantly demonstrated by you on completing the NRI course in Industrial Electronics. As you learn, you actually build and use your own motor control circuits, telemetering devices and even digital computer circuits which you program to solve simple problems. All major NRI courses include use of transistors, solid-state devices, printed circuits.

LETTERS FROM OUR READERS



ELECTRIC AUTOS

To the Editors:

Your recent article on electric autos has moved me to write on an important facet of the situation either forgotten or ignored in all such discussions. This is the problem of powering a heater for passenger comfort and windshield defrosting.

Having driven many miles in temperatures down to 45 degrees below zero, I am especially aware of this obvious need, and would estimate that a minimum of 1500 watts would be needed. This heavy power draw for interior heat alone obviously further restricts range and increases operating costs. Recirculation of interior air and insulation would reduce power requirements but increase cost and weight plus aggravate defrosting problems. Auto makers' comments on this aspect would be interesting.

RALPH L. CHARNLEY
Richfield, Minn.

* * *

INDUCTION BATTERY CHARGER

To the Editors:

Although it has been some time since you have run any articles on batteries and charging circuits, perhaps you can answer a puzzler that has been bothering me for some time. Recently I bought a G-E electric toothbrush which uses, I believe, a rechargeable nickel-cadmium battery to operate the mechanism. The thing that has me puzzled is the charging unit into which the brush-holder is plugged after use. The well into which the holder is placed has only a *single* contact, a post perhaps ¼-in in diameter. Just how is the charging circuit which is built into the base of the charging unit connected to the battery? The contact post is not a coaxial connector of any kind, and I'm sure it's just a single contact. Where's the other contact? Or is this a new kind of charging circuit?

MANNY RYAN
Chicago, Ill.

There is no other contact; as a matter of fact, the post is not even a single contact. Instead it is the core of a 117-volt a.c. solenoid that is mounted in the charger base unit, and this is really not a complete charger at all. When the charging unit is plugged in, a magnetic field is set up by the solenoid in the core. By induction, this is coupled to another pickup coil/transformer in the base of the hand-held toothbrush unit. The induced voltage is then rectified by a diode and applied to the built-in nickel-cadmium cell through a two-transistor charging circuit. This circuit cuts off or reduces charging current when the cell becomes fully charged. Note that the entire charging circuit, except for the 117-volt coil, is in the toothbrush holder itself. The cell voltage is the usual 1.2 volts for nickel-cadmium types and the maximum charging current is 100 mA. It takes about 24 hours to fully recharge a completely discharged cell. The cell should be capable of about 2500 charge-discharge cycles.—Editors

* * *

RFI FROM C-D IGNITION

To the Editors:

Your magazine has carried a number of articles on capacitive-discharge ignition systems. These are supposed to have a very high voltage and a fast rise time. But nowhere have I ever seen any mention of possible increase in radiated noise that may interfere with mobile radio equipment. Any comments?

TOM LAMB, K8ERV
Mansfield, Ohio

We have not heard any comments from our readers on this particular problem. If you have had any experience with radio-frequency interference from either transistor or capacitive-discharge ignition systems—to mobile radio equipment or even to the car's broadcast radio—let us hear from you.—Editors

* * *

ELECTRONIC INTRUSION ALARMS

To the Editors:

I refer to your articles on "Electronic Intrusion Alarms" in the September and October issues of ELECTRONICS WORLD. These are very good articles, as are so many articles that comprise your magazine, which is highly regarded here by our engineering department.

We are a small company that has specialized in intrusion alarms for the past 20 years. We would appreciate being added to your list in the article as a maker of all types of intrusion alarms and supplies. Our equipment covers

residential and commercial usage as well as motor vehicles and other applications.

MARK WAXMANN
Chief Engineer, Alarms Div.
Eastern Electronics
28 Weymouth St.
Albany, N. Y. 12205

Our directory was not intended to be all-inclusive, but merely to show a large number of representative companies. Still another manufacturer who has written to us with a description of his intrusion alarm equipment is Electro-Nite Co., *Comly & Decatur Rds., Philadelphia, Pa. 19154. We are sure that both these companies will be glad to supply our readers with details on their products.—Editors*

* * *

AMPEX TAPE RECORDER

To the Editors:

In your June, 1968 issue, you published a test report on the *Ampex* AG-500-4 tape recorder. The absence of an index counter was mentioned as "an inconvenience" on several occasions in the report.

You need not let this be a deterrent as a four-digit resettable counter (Part #4012201-02) is available from the factory at a cost of $35.00, if you feel this is necessary on a professional machine.

C. E. HARPER
Gately Electronics
57 W. Hillcrest Ave.
Havertown, Pa. 19083

* * *

IS IT A TRAP?

To the Editors:

I recently purchased a *Fisher* Philharmonic stereo console. In examining the back of the unit, I noticed a folded-dipole FM antenna stapled to the back cover. Connected to the center of the dipole there is what appears to be a shorted stub about 4-in long. Is this some sort of trap or something for FM images, aircraft transmitters, or what?

HERMAN PLOTNICK
New Hyde Park, N. Y.

Upon checking with the Fisher *engineering department, we learned that the shorted stub is not a trap but is used as an impedance-matching section for the folded dipole. It seems that with the particular type of dielectric material used and with the way in which the antenna has to be folded to fit the back of the console, the center impedance is somewhat reactive (capacitive) and higher than the desired 300 ohms. By using a small shorted stub, which acts as an inductive reactance, the antenna reactance is tuned out and the impedance drops to the proper value. This reduces the v.s.w.r. and improves the performance of the built-in FM antenna.—Editors* ▲

Reflections on the news

James E. Webb's Resignation . . .

as Director of the National Aeronautics and Space Administration points up that agency's unhappiness over recent budget cuts and Webb's personal disgust with certain Congressmen who have chosen to make NASA their own personal whipping boy. Webb was named director of the space agency 7½ years ago by President Kennedy and, under his leadership, NASA prospered. The agency's budget zoomed from $967 million in 1961 to more than $5.2 billion in 1965. Thus, for a time, NASA's rapid growth made it appear as if the good old USA would be "first" in the eyes of the world as well as in the hearts of its "country-men." Now, the administration has limited the NASA budget request to $4.37 billion, the lowest in six fiscal years. Congress has lopped $370 million off that, and another $100 million will go as part of the $6 billion spending cut ordered by Congress as part of the President's tax bill. The result—almost every NASA program except the manned moon landing (still scheduled for next year) has either been cancelled or drastically curtailed. For example, simultaneously with Webb's announced resignation, a NASA news bulletin proclaimed the termination of production of the 205,000-pound thrust H-1 engines used in the booster stage of the Saturn 1B rocket. These engines, built by the *Rocketdyne Division* of *North American Rockwell Corp.*, were originally intended for use in missions following the manned lunar landing.

Siding with James Webb, we too are not satisfied with our present space program. While we cut back, the Russians accelerate. The day after Webb's resignation Russia launched a rocket to the moon (Zond 5) and returned it to earth—the first step in a manned moon landing. Being first is a matter of national pride as well as international prestige and, in many instances, it is as potent a weapon as a gun.

Hospitals . . .

will have to be more automated if they are to provide medical services at reasonable cost. Inflation plus serious manpower shortages have combined to make the job of getting people well quickly a most difficult undertaking. This opinion was advanced by Dr. John N. Dempsey, vice-president for science and engineering at *Honeywell, Inc.*, during a talk before the American Hospital Association. He noted that the average cost per patient-day tripled between 1950 and 1965, and that salaries accounted for two-thirds of all hospital costs.

Automation and new advances in medical electronics have indeed aided patient care. It is doubtful that General Eisenhower would still be alive if it were not for these new techniques. But we doubt that an electric eye and an electrode will ever really replace a nurse's sweet smile and soft touch.

But The Electronics Industry . . .

is failing medicine, charges Irving Weiman, vice-president of *Electro-optical Systems, Inc.* "It is failing to differentiate between the clinical physician's needs and the needs of the research physician, and it is failing to communicate with the medical profession as a whole," he says. Apparently he feels that industry has not learned to market products that extend the physician's skill and maximize his activities as well as those which reduce the routine work of nurses and technologists. He claims the difficulty is communication. Engineers who do not understand medicine oversell the capabilities of lasers, IC's, biochemical probes, etc.; and doctors do not understand the potential of technology.

Most Prosthetic Devices . . .

act on muscle power. The newest artificial limb, however, is computerized and "thinks" into movement by above-the-elbow amputees.

The device, which is a joint development of Massachusetts General Hospital, Massachusetts Institute of Technology, Harvard Medical School, and the *Liberty Mutual Insurance Co.*, is said by doctors to be the most sophisticated artificial limb ever devised. It uses natural electrical signals (about 0.001 volt) which are generated in the amputee's stump to motivate the limb. According to the doctors, the Boston Arm as it is called, can be actuated with varying degrees of force and speed. The signals are picked up by electrodes attached to the artificial arm, amplified, and fed to a tiny analog computer consisting of eight operational amplifiers. The computer controls an electric motor which operates the arm.

There are more than 100,000 amputees in the U.S. and many of them could use the Boston Arm. The problem is will they be able to afford it? The developers say that the price of arms should be within reach of all amputees, about $1000, but probably substantially less.

Digital Computer . . .

systems have changed some industrial processes through more effective control. But acceptance of computerized process control has been a long time arriving. Extremely high equipment cost was partially to blame, but more importantly, added programming expenses made the acquisition of a computerized process controller prohibitive for many companies. Thus, by the end of 1967, only about 700 control computers were installed and in use throughout the United States.

Recently, the *Honeywell Computer Control Division* introduced a new computer for industrial control. At first glance it would seem that this system, with a few minor variations, is pretty much like other controllers. However, *Honeywell* has added a wrinkle that makes this system worthy of note. Readers may recall that the November issue of this magazine took note of the tremendous shortage of trained computer programmers. Well that added wrinkle that we spoke about is a functional software package which makes every process engineer a potential computer programmer. The functional software is called Controlware 1, and it allows a user to implement his system by simply filling in tables. In fact the company claims that a program for data acquisition and digital data control for process control applications can be written in as little as two weeks.

This supposed breakthrough in software won't solve the programmer shortage. It will, however, enable many companies to take a second look at their control applications. As a result, the market potential for computerized industrial controls should rise.

Microwave Ovens . . .

may be dangerous to health—at least some Congressmen think so. Now the National Center for Radiological Health is taking a close look at microwave ovens to see if they give off harmful radiations. The reason for all this concern is the rapid rise in popularity of the devices for home use. Some estimates have placed upwards of 50,000 ovens in homes by 1970.

In the frequency range where microwave ovens operate, the eyes and skin surfaces are extremely susceptible. For example, damage may occur to internal organs when the body is exposed to microwaves of 150 to 1200 MHz; to the eye in the 1000 to 3300 MHz region; to the eye and top layers of the skin in the 3300 to 10,000 MHz area; and to skin surfaces at frequencies over 10,000 MHz. This is just some of the body damage which researchers say is possible from overexposure to microwaves. Studies are proceeding in this country and Russia particularly, to come up with meaningful standards. One big problem for the National Center is to develop a portable instrument which measures the power density of stray emission.

Some Thoughts . . .

about things going on. Electronics on the John F. Kennedy CVA-67, the country's newest attack carrier, cost about one-fifth of the total ship's construction price. The $72-million spent for shipboard electronics includes an automated carrier landing system (ACLS) and an automatic equipment test facility (TEAMS). . . . The failure of the *Communications Satellite Corp.*'s Intelsat III to achieve orbit reduced but did not stop world-wide TV coverage of the Olympic games. Backup systems involving NASA's Applications Technology Satellite (ATS-3) and Early Bird came to the rescue. . . . The search for faster computers goes on. *RCA* has announced the development of a laser computer 100 times faster than present systems. . . . Proposed restrictions on airport operations at New York, Chicago, and Washington bringing cries of outrage from airlines and General Aviation alike. (First time these two groups have agreed on anything in a long time.) For example, under the proposed rule, only 80 operations per hour would be allowed at Kennedy—70 for air carriers, 5 for air taxis, and 5 for other General Aviation planes. Unpopular as it is, the rule is the first concrete step that the FAA has taken to relieve air traffic congestion around metropolitan areas. . . . Last year's Japanese electronics output totaled $3.4 billion, up 32.2 percent from 1966. Japanese exports of electronic products to the U.S. also continue to rise. In 1967 they totaled $532 million, a 12.6 percent increase over the 1966 level of $464 million. . . . The most powerful radio station in South America is operated by Accion Cultural Popular, an educational institution which uses radio to provide learning opportunities for Colombians living outside the big cities. The transmitter was built by *Continental Electronics Manufacturing Co.*, a subsidiary of *LTV Electrosystems, Inc.* . . . On January 1st the National Bureau of Standards expects to change the value of the U.S. legal volt by 1 part in 100,000. According to NBS, the new value represents a more accurate measurement of the voltage of standard cells in terms of the theoretical unit of e.m.f. derived from the basic mechanical units of length, mass, and time. ▲

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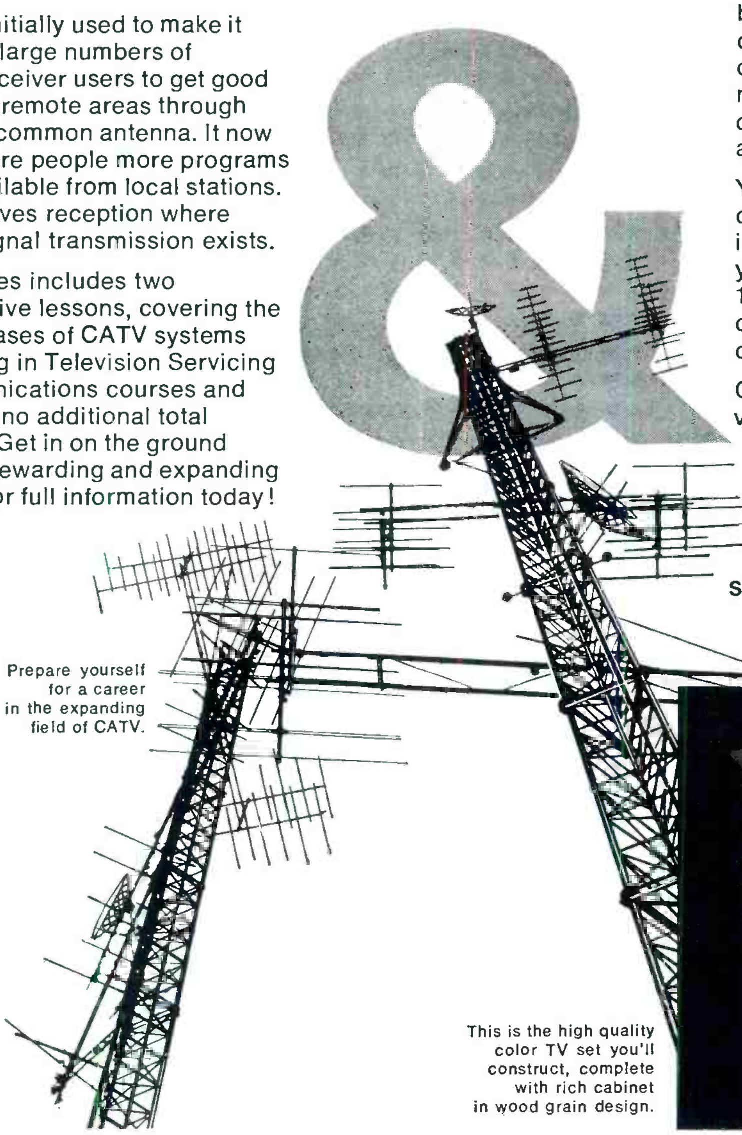

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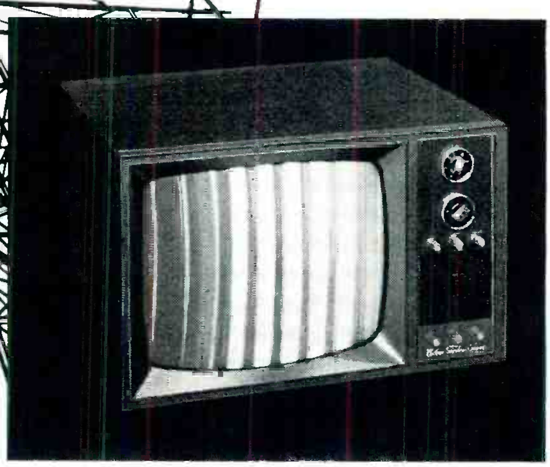

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RCA

EW Lab Tests of NEW STEREO RECEIVERS

By JULIAN D. HIRSCH / Hirsch-Houck Laboratories

Here are the results of our laboratory measurements on sixteen of the newest solid-state models along with a description of important circuit innovations.

SINCE our last comprehensive survey of stereo receivers (ELECTRONICS WORLD, December, 1967), most of the then-current models have been superseded by new or improved versions. For the present survey, we have again selected representative models from the lines of the leading manufacturers of stereo receivers, and have tested them under identical, controlled conditions.

The complete test procedure was described in the December, 1967 article, and the interested reader should refer to that report for detailed descriptions of the tests. The current group of receivers were tested in exactly the same manner.

Normally, we prefer to present our test results in graphic form, with extensive comments on other aspects of the receiver's performance. This would require a prohibitive amount of space for the sixteen receivers covered in this report so we have listed key performance parameters and design features in tabular form.

Since our test conditions often differ from those of the various manufacturers, our ratings may not agree with published specifications. However, since we tested all units under identical conditions, direct comparisons are possible.

All power and distortion measurements were made with 8-ohm loads, driving both channels simultaneously, and with a 120-volt a.c. supply. The continuous sine-wave power (per channel) was measured at the level which gave 2% total harmonic distortion (THD) at 30 Hz, 1000 Hz, and 20,000 Hz. Then, at 1000 Hz, the THD was measured at outputs of 0.1, 1.0, and 10 watts. Footnote 3 following the distortion figures (usually at 0.1 watt) indicates that hum or noise masked the much lower harmonic distortion.

At maximum gain, we measured the 1000-Hz input required for 10-watts output, on the Aux and Phono inputs. Hum and noise were measured relative to 10-watts output, at standardized reference gain settings which are more typical of normal operating conditions than are the maximum settings. These gains correspond to inputs of 1.0 volt (Aux) and 10 millivolts (Phono) for 10-watts output.

The RIAA equalization error is expressed in terms of the maximum deviation from the ideal curve, between 30 and 15,000 Hz, referred to the 1000-Hz level. The maximum available power into 4-ohm and 16-ohm loads was expressed as a percentage of the 8-ohm power capability.

FM sensitivity was measured in accordance with IHF standards. It was expressed as *usable sensitivity* at 98 MHz. FM (mono) distortion was measured with a 1000-μV input signal, with a deviation of 75 kHz at 400 Hz.

The frequency response of the FM tuner is expressed as a deviation from the ideal response, from 50 to 15,000 Hz, relative to the 400-Hz level. FM-stereo separation was measured at 50 Hz, 400 Hz, and 10,000 Hz, and is the average of both channels.

The balance of the table lists certain design features and the various operating controls and outputs.

Compared to last year's group of receivers, the current models show several clear design trends. Last year several receivers used nuvistor tubes in their FM front-ends. Tubes are now completely absent from solid-state receivers, most of which have FET FM front-ends for superior sensitivity and freedom from cross-modulation. Many receivers now use integrated circuits (IC's) in their i.f. and limiter sections. The superior limiting characteristics of these devices is responsible for a measurable and audible improvement in their effectiveness in weak signal reception. Although at present only the *Heath* AR-15 uses crystal filters

Scott 341 (right), Fisher 400-T (top left), and Sherwood S-8800a.

RECEIVER	Cont. Power Out. per Chan. (into 8 ohms) @ 2% THD 30 Hz (W)	1 kHz (W)	20 kHz (W)	THD @ 1 kHz 0.1W (%)	1W (%)	10W (%)	Audio Sens. for 10-W Out. Aux. (mV)	Phono (mV)	Hum & Noise re 10 W Aux (dB)	Phono (dB)	RIAA Equaliz. Error 50-15,000 Hz (dB)	Max. Power re 8-ohm Level 4 ohm (%)	16 ohm (%)	IHF Usable Sens. (μV)	FM Distortion at 75-kHz Dev. (%)	FM Freq. Resp. 30-15,000 Hz (dB)
ALLIED 395	42	55.5	66	0.12	0.07	0.10	92	1.0	−77.5	−70	+1.5, −1.5	121	60	1.6	0.84	+4.3, −2.1
ALTEC 711B	27.9	30+[5]	30+[6]	0.37	0.22	0.12	290	4.5	−80	−59	+4.5, −0	142	54	1.7	0.30	+0.8, −2.7
BOGEN DB250	11.3	20.8	24	0.35[3]	0.19	0.14	180	1.9	−79	−62	+0.8, −0	135	68	2.8	0.52	+1.0, −1.7
EICO 3570	12.8	19	19.3	0.25	0.14	0.18	200	3.5	−70	−62.8	+0.5, −0.5	150	54	3.4	1.8	+1, −0.9
ELECTRO-VOICE 1181	13.3	21.5	24.3	0.33[3]	0.39[3]	0.48	155	2.3	−78	−59	+0.5, −1.0	139	50	2.5	1.8	+2.8, −2.0
FISHER 250-T	22.2	30.2	37.3	1.00[3]	0.35[3]	0.14	90	1.0	−76	−70	+1.0, −1.0	92	63	3.0	0.82	+2.0, −0.2
HARMAN-KARDON 520	18.9	23	18	0.21[3]	0.10	0.05	180	1.9	−75.5	−75	+2.0, −1.0	142	63	1.75	0.72	+2.8, −1.2
HEATH AR-15	60+[2]	70	60+[2]	0.20[3]	0.11	0.12	110	1.6	−70	−51	+1.0, −1.0	120	60	1.45	0.55	+0.3, −3.9
JVC NIVICO 5003	38	51	46	0.23	0.15	0.13	50	0.8	−81	−72	+4.0, −0.5	75	64	4.5	0.65	+0.9, −6.8
KENWOOD TK-88	20	32	35.8	0.40[3]	0.24	0.18	83	2.5	−85	−54.5	+0.5, −2.0	116	65	2.0	0.48	+2.0, −1.0
LAFAYETTE LR-1500T	32	50	44.5	0.25[3]	0.18	0.20	265	4.6	−79	−52	+2.5, −0.5	156	56	3.0	0.55	+0, −1.3
PIONEER SX-1500T	37	51	66	0.12	0.09	0.06	88	1.1	−77.5	−70	+1.3, −1.3	126	66	1.4	0.66	+4.3, −0.9
SANSUI 2000	24	32.2	40	0.32[3]	0.13	0.13	86	1.5	−71	−70	+0, −2.0	123	70	2.1	0.91	+0.8, −1.8
SCOTT 341	13	18	21.2	0.62[3]	0.29[3]	0.21	430	5.3	−73	−64	+1.7, −0.5	146	60	2.3	0.78	+0.1, −1.4
SHERWOOD S-8800a	22	41.5	44.5	0.65[3]	0.20	0.09	125	1.4	−85	−82	+0, −0.5	144	59	1.9	0.62	+1.9, −0.9
UNIVERSITY 120A	30	35.8	44.5	0.17[3]	0.21	0.09	250	2.2	−80	−67	+0.7, −3.8	150	57	2.5	0.75	+0.4, −2.9

Notes: 1 Unless indicated, price excludes cabinet; 2 Actual distortion at 60 W = 0.3%. Not measured at 2% THD; 3 Lower distortion masked by hiss, hum, or noise; 4 Powered, drives speaker directly; 5 Actual distortion at 30 W = 1%. Not measured at 2% THD; 6 Actual distortion at 30 W = 1.1%. Not measured at 2% THD.

in its FM i.f. amplifier, other manufacturers may follow suit. The low-priced *Bogen* DB250 achieves some of the benefits of this design approach with ceramic filters.

All the receivers in this group have effective protection for their output transistors, either by electronic means or by speaker line fuses. None was damaged in any way by our tests, in which they were operated at or above their rated power outputs for appreciable periods of time. All the receivers have automatic FM-stereo switching and stereo indicator lights, outputs for connections to a tape recorder, and front-panel stereo headphone jacks.

In many cases, the receiver tested is one of several offered by its manufacturer at different price levels. The following discussion of the individual receivers will indicate when other models are offered by the same company, where such information is available to us.

Allied 395

This handsome receiver is *Allied's* "top-of-the-line" model. It features an FET front-end and four IC's in its i.f.

Allied 395

section. The speaker connectors are polarized plugs, with insulated covers which minimize the possibility of accidental shorts. It also has electronic circuitry which protects the output transistors against shorts and overloads.

Other receivers in the *Allied* line include the 355, with slightly less sensitivity and less than half the power output of the 395, at $180. The $150 Model 335 has still lower FM sensitivity and power output than the 355.

Altec 711B

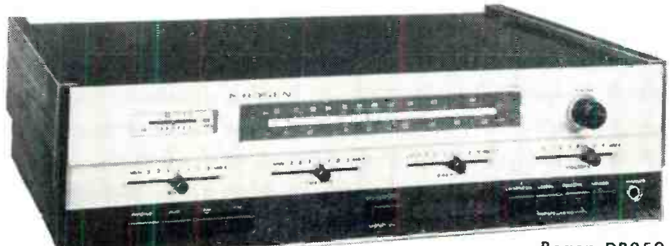
This receiver, reviewed last year and subsequently re-

Altec 711B

tested later, has an FET front-end and an IC i.f. amplifier. It is still the only stereo receiver manufactured by *Altec*, and as a study of its performance data will show, it ranks among the best of the group of receivers being tested for this year's report.

Bogen DB250

The *Bogen* DB250 is an entirely new design from that manufacturer, with novel features and circuitry not found in other receivers in its price class. Instead of the usual knob-operated rotary controls, its tone controls, volume control, and balance control are linear slide-operated potentiometers, oriented horizontally. Their settings can be evaluated at a glance. The front-end uses FET's and IC's are used in the FM i.f. amplifier. The FM tuner features ceramic filters, which share with the much more expensive crystal filters the elimination of alignment requirements. They also



Bogen DB250

FM Stereo Separation 50 Hz (dB)	400 Hz (dB)	10 kHz (dB)	Tuning Indicator	AM	FM Muting	Noise or Scratch Filter	Rumble Filter	A.F.C.	Center Chan. Out.	Tape-out. Jack	Tape Mon. Switch	Size (in.) W	H	D	Price ($)	Comments
20.2	25.8	17.5	Meter	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	16	$5\frac{1}{2}$	$13\frac{3}{4}$	300	Includes case.
24.8	34.8	13.5	Meter	No	Yes	Yes	No	No	Yes	Yes	Yes	$16\frac{3}{4}$	5	$11\frac{1}{4}$	400	
20.7	22.1	13.0	Meter	Yes	No	No	No	No	No	Yes	No	$16\frac{1}{2}$	$4\frac{1}{2}$	$12\frac{1}{2}$	280	Includes case; ceramic filters.
25	29	16.4	Meter	No	No	Yes	Yes	Yes	No	Yes	Yes	16	$4\frac{1}{8}$	9	170 (kit) 260 (wired)	Includes case.
21.6	24.3	9.9	Meter	No	No	No	No	Yes	No	Yes	No	$14\frac{3}{4}$	$3\frac{7}{8}$	$10\frac{1}{2}$	200	
26.7	29.8	16.7	Meter	Yes	Yes	No	No	Yes	No	Yes	Yes	$15\frac{1}{2}$	$5\frac{1}{4}$	$12\frac{3}{4}$	300	Push-button tuning also.
15.8	29.3	15.3	Meter	No	Yes	Yes	No	No	No	Yes	Yes	$15\frac{1}{2}$	$4\frac{5}{8}$	$12\frac{1}{2}$	315	
28.8	39	23.3	Meter	Yes	Yes	Yes	No	No	No	Yes	Yes	$16\frac{7}{8}$	$4\frac{3}{4}$	$14\frac{1}{2}$	340 (kit) 525 (wired)	Crystal filters.
24.3	28.3	14.2	Meter	Yes	Yes	Yes	Yes	Yes	No	Yes	No	$20\frac{3}{4}$	$5\frac{7}{8}$	$14\frac{1}{2}$	340	Sound-effects tone controls (5 bands).
22	30	20.8	Meter	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	$16\frac{1}{2}$	5	$12\frac{1}{2}$	290	Includes case.
33.1	38.7	20.8	Meter	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	$16\frac{3}{4}$	5	$14\frac{1}{2}$	300	Includes case.
22	27.1	23.4	Meter	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	$15\frac{3}{4}$	$5\frac{1}{2}$	$13\frac{3}{4}$	360	Includes case.
19.8	38	19.9	Meter	Yes	Yes	Yes	Yes	No	No	Yes	Yes	$16\frac{1}{4}$	$4\frac{7}{8}$	$13\frac{1}{4}$	300	
23.6	24.1	18.0	Meter	No	No	No	No	No	No	Yes	Yes	15	$4\frac{1}{2}$	$11\frac{7}{8}$	250	
26.8	29.3	15.4	Meter	No	Yes	Yes	No	No	Yes[4]	Yes	Yes	$16\frac{1}{2}$	$4\frac{1}{4}$	14	400	
23.5	29.1	16	Meter	No	Yes	Yes	Yes	No	Yes	Yes	Yes	$16\frac{3}{8}$	$4\frac{1}{2}$	12	380	

Appearance, operating convenience, serviceability, and reliability cannot, of course, be tabulated here. These factors are also important in determining price, which has been rounded off to the nearest whole-dollar figure.

have selectivity characteristics intermediate between conventional i.f. transformers and crystal filters. The AM tuner has a mechanical i.f. filter which offers the same advantages in AM reception as the ceramic filters do on FM.

Bogen also uses a balanced-bridge FM detector which they claim offers the lowest FM distortion of any receiver in its price class.

Eico 3570

The *Eico* 3570 is a combination of the separate tuner and amplifier previously introduced by this manufacturer. Within its exceptionally compact cabinet is housed a moderately sensitive FM tuner, and a very clean amplifier capable of almost 20 watts output per channel. Lacking only an AM tuner, FM muting, and center-channel output, it contains a full complement of operating controls.

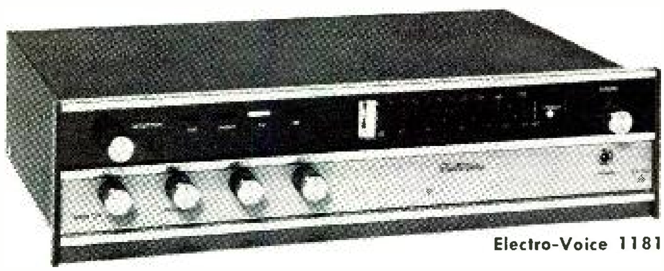
Eico has available as separate components the two main portions of the receiver listed in our table. These are the 3200 FM-only tuner at $100 in kit form or $140 wired, with metal case, and the 3070 amplifier at $100 in kit form or $140 wired, with metal case. Also, similar to the receiver

Eico 3570

tested, except for the addition of AM, is the 3770. This receiver sells for $190 as a kit, or $280 wired, with metal case.

Electro-Voice 1181

The *E-V* 1181 is the smallest of this group of receivers and in the interests of economy a number of "frills" such as AM reception, muting, filters, loudness compensation, center-channel output, and tape-monitoring facilities have been omitted. Nonetheless, all the essentials of a good FM receiver have been retained, including excellent sensitivity and power output sufficient for most requirements.



Electro-Voice 1181

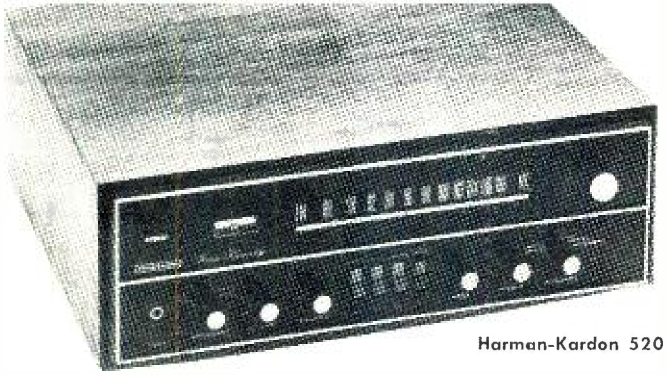
Electro-Voice also has available the Model 1182, which is similar to the receiver in our table except for the addition of AM. Price of this unit is $222, without cabinet.

Fisher 250-T

The latest *Fisher* receiver is the 250-T, an exceptionally compact unit with several unusual features. In addition to having a dual 30-watt amplifier, FM stereo and AM tuners, and virtually all control features expected of a fine stereo receiver, it has a five-channel push-button FM tuner which allows instantaneous selection of any preselected stations at the touch of a button. Each push-button is concentric with a small knob which varies the voltage applied to a voltage-variable capacitor. Pressing any of the buttons replaces the conventional FM tuner with the voltage-tuned front end. A small dial adjacent to each button indicates the frequency to which it is tuned.

A sixth button disengages the preselected portion of the receiver and restores normal manual tuning. The knob surrounding it turns on the a.f.c. In spite of these added features, the *Fisher* 250-T is one of the more compact receivers of the group tested. Rumble and scratch filters are the only significant control functions not found in the 250-T.

The other *Fisher* receivers are more conventional in design except for the 160-T which is lower powered than the 250-T and has only the preselector tuner. With the exception of the top-of-the-line 700-T and the 400-T (which is similar to the 250-T except that it has 50% more power output), all the conventional receivers are somewhat less powerful than the 250-T. They include the FM-only Models 500-C and 500-T and FM-AM Models 175-T, 550-T, and 800-C.



Harman-Kardon 520

Harman-Kardon 520

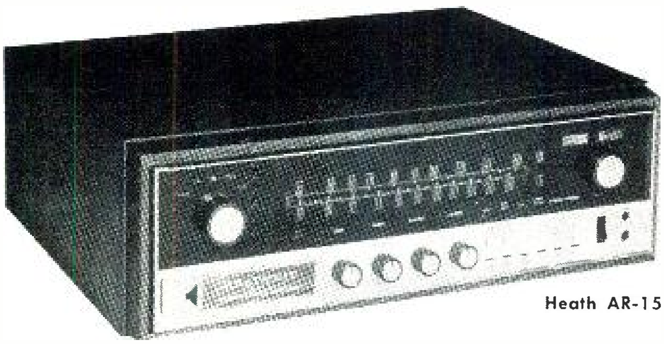
The *Harman-Kardon* 520, though one of the lower powered receivers of this group, has excellent FM sensitivity and extremely low audio distortion. Its audio power bandwidth is also superior to many of the receivers tested, so that its power is available at low distortion over the full audio range. It lacks only AM reception, a rumble filter, and center-channel output, among the features we have tabulated. Like the *Heath* AR-15, *JVC* 5003, and *Sansui* 2000 receivers, the *Harman-Kardon* 520 has a black opaque dial face which remains opaque until the receiver is turned on.

Harman-Kardon also has available the Model 530 which is similar to the receiver in our table except for the addition of AM. Price of this receiver is $349, without cabinet.

Heath AR-15

The *Heath* AR-15 was covered in last year's survey, but is included here because it still offers one of the highest levels of audio and FM tuner performance, combined with numerous unique circuit and control features.

The AR-15 has an FET front-end and was the first re-



Heath AR-15

ceiver to offer an IC i.f. amplifier. It uses permanently tuned crystal filters in the i.f. amplifier, making it the most selective, as well as one of the most sensitive FM receivers available today.

The audio amplifier section is extremely powerful, making it in every way comparable to or better than any combination of separate tuner and amplifier.

Heath has available as separate components the FM tuner and amplifier sections of the receiver listed in our table. The tuner is the AJ-15, which sells for $190 in kit form without cabinet and the amplifier is the AA-15, which sells for $170 in kit form without cabinet.

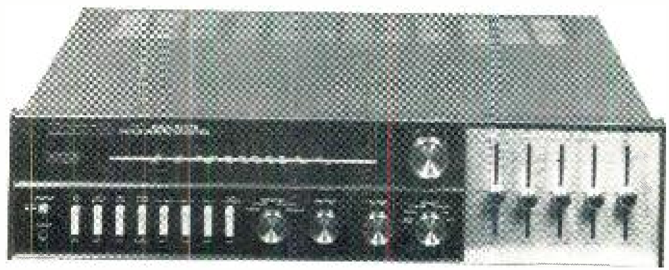
The company also has three lower priced receivers. The AR-13a, rated at 20 watts per channel (*versus* 50 watts for the AR-15) has a more conventional design and sells for $190 (kit form only). The AR-14 (FM only) is rated at 10 watts per channel, and the AR-17 at 5 watts per channel. They are priced at $115 and $70, respectively, in kit form.

JVC Nivico 5003

This new arrival on the local high-fidelity scene is a product of the *Japanese Victor Company* and is sold here under the *Nivico* brand-name. It is a large receiver, quite complete in its control functions, and lacking only a center-channel output. Its tone controls are unique and unquestionably among the best we have ever used.

Instead of the usual bass and treble tone controls, the *JVC* 5003 has five slider controls, operating vertically. Each controls the response centered at a different frequency—60 Hz, 250 Hz, 1000 Hz, 5000 Hz, and 15,000 Hz. When the knobs are centered, the response is flat. The response at any frequency can be varied up or down by about 10 dB, independent of the other control settings. On our test sample, we measured a "cut" of only 5 dB, but still found that the "Sound Effect Amplifier," as *JVC* calls it, was superior to ordinary tone controls when correcting for record, loudspeaker, or room response characteristics.

The *JVC* 5003 has an FET FM front-end and an imposing array of rocker switches for the various filters, a.f.c., muting, etc. One switch bypasses the tone-control circuits entirely.



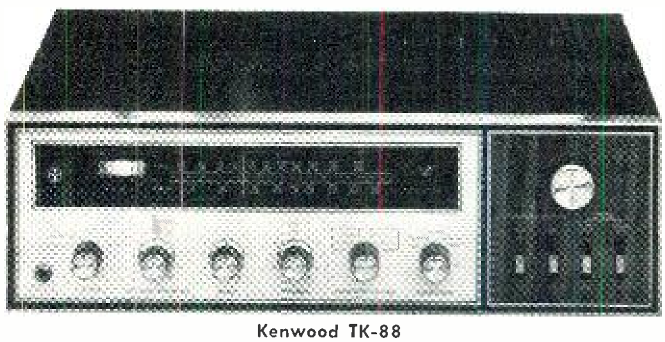
JVC Nivico 5003

We found the RIAA equalization and FM tuner frequency response to be somewhat less flat than the other receivers tested, although the flexibility of the amplifier tone controls allowed effective compensation of both response curves.

Kenwood TK-88

The TK-88 is the medium-priced unit of the *Kenwood* receiver line. It has a full complement of operating controls and features, a husky audio amplifier, and a sensitive FM tuner in a handsomely styled package which includes a simulated walnut metal cabinet.

The more expensive TK-140 ($340) is similar except for a more powerful amplifier and an extra crystal phono cartridge input. The $240 TK-66 has about two-thirds the power output of the TK-88, with similar FM and AM tuner



Kenwood TK-88

performance. The Model TK-55, at $200, is identical to the TK-66 except for the omission of the AM tuner.

Lafayette LR-1500T

The *Lafayette* LR-1500T offers impressively high performance and complete operating flexibility at a modest price. Its FM muting circuit has a continuously adjustable front-panel threshold control and a front-panel tape-output jack allows easy connection to an external tape recorder.

The FM tuner has two FET's and four IC's. The "Computor-Matic" overload protection for the output transistors is instantaneous in its operation and resets automatically when the short circuit or overload is removed, unlike some receivers which must be shut off for a few seconds to reset the protective circuits.

The LR-1500T has three phono sensitivity settings, to

Lafayette LR-1500T

accommodate the full range of outputs available from modern cartridges without risk of overdriving the phono preamplifier on loud passages. It also has exceptionally low FM distortion and excellent FM stereo separation.

The LT-1500T is the top model of the *Lafayette* line. The LT-1000T, at $240, is similar but has about one-third less power output. The $180 LR-500T has about half the power output of the LR-1000T, and lacks the "Computor-Matic" protection circuit and FM muting. Cabinets are included in the prices of the receivers.

Pioneer SX-1500T

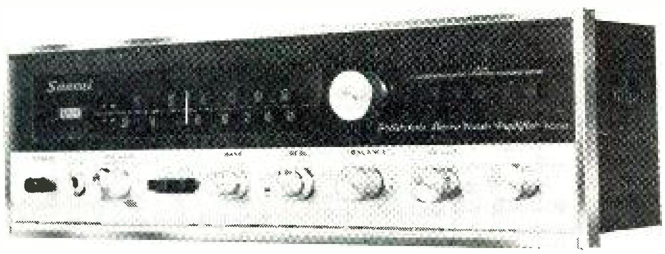
The *Pioneer* SX-1500T was among the most sensitive FM tuners of the receivers tested this year. Its high audio power, extremely low audio distortion, and complete array

Pioneer SX-1500T

of controls and features (only center-channel output was lacking) are noteworthy. The FM tuner employs FET's in the front-end and IC's in the i.f. amplifier. The FM muting circuit is highly effective and free from transient thumps. The output transistors are electronically protected against shorts and overloads. Walnut side panels and a walnut-finished metal cabinet are included in the price.

Sansui 2000

One of the most attractive and distinctively styled receivers in this group, the *Sansui* 2000 has a dial which is



Sansui 2000

invisible behind an opaque glass window except when the tuner is in use. On other modes, colored illuminated words appear against a black background to indicate the input.

Many of the controls are push-button operated. Only a center-channel output is lacking among the tabulated features. At middle frequencies, the FM channel separation was exceptionally good.

The other model in the current *Sansui* line is the $450 MD5000, with nearly twice the power.

Scott 341

The *Scott* 341 is a recent low-cost addition to the comprehensive line of stereo receivers from this manufacturer. It combines a moderately low-powered amplifier section with a very good FM-stereo tuner. Although not shown on our table, it has a very low limiting sensitivity, which means that even fairly weak signals are fully limited.

Although the low price of the 341 has meant the omission of such features as filters, FM muting, and center-channel output, it does have tape-monitoring facilities, switches for two pair of speakers, and loudness compensation.

The Scott 341 features several advanced design techniques, including an FET front-end, IC's in the i.f. amplifier, and phono preamplifiers using IC's.

The continuous power rating into 8 ohms (single channel) is 15 watts, which it exceeded comfortably.

Scott has available the FM tuner portion of the receiver listed in our table as the 315B at $213. Also, the amplifier portion of the receiver with slightly higher power output is available separately as the 299F at $200. Prices do not include cabinets.

Other receivers in the *Scott* line include the 342B, with slightly better FM sensitivity and an 18-watt-per-channel power rating, the 344C with still higher sensitivity and 30 watts per channel, and the 348B with a sensitivity rating of 1.7 μV and a power output of 40 watts per channel. The last three receivers also have equivalent models with the addition of AM tuning facilities, the 382B, 384, and 388B.

Sherwood S-8800a

The *Sherwood* S-8800 receiver has been with us for some time, but has undergone a series of design improvements and refinements which most manufacturers would have used as a basis for a new model designation. *Sherwood* has chosen merely to add the suffix "a" to the current model.

The audio amplifier of the S-8800a maintains extremely low distortion up to just below the clipping level, which is over 40 watts per channel. The hum and noise level of the S-8800a, on all inputs, are among the lowest we have tested. Phono equalization and FM tuner frequency response are also among the best of the group.

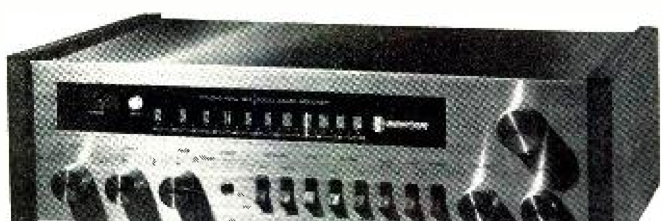
The FM tuner uses FET's in the front-end and IC's in the i.f. amplifier. The output transistors are electronically protected, but the receiver must be shut off for a few seconds to reset the circuits after they have been tripped.

Sherwood also has a Model 7800 receiver at $420. This is similar to the model listed in our table except for the addition of AM. In addition, the FM-only tuner portion of the receiver is available separately as the S-3300 at $198; the AM-FM tuner portion is available separately as the S-2300 at $225; and the amplifier portion is available separately as the S-9900a at $230. All prices are without cabinet.

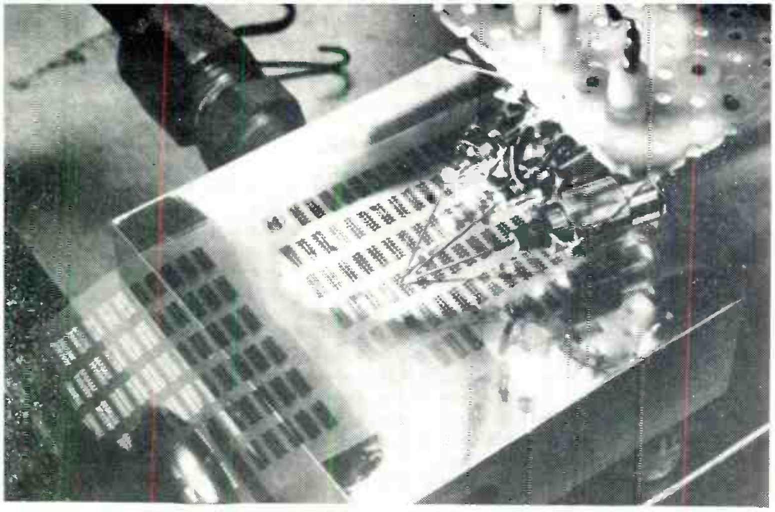
University Studio Pro 120A

The Studio Pro 120A is *University's* first (and thus far, only) FM-stereo receiver. It has an FM tuner with FET front-end and an IC i.f. amplifier. The receiver has a very good power-bandwidth characteristic. The Studio Pro 120A has all the operating flexibility and features of any of the receivers tested, and is distinctively styled with a brushed gold-colored panel and knobs, and optional walnut side panels.

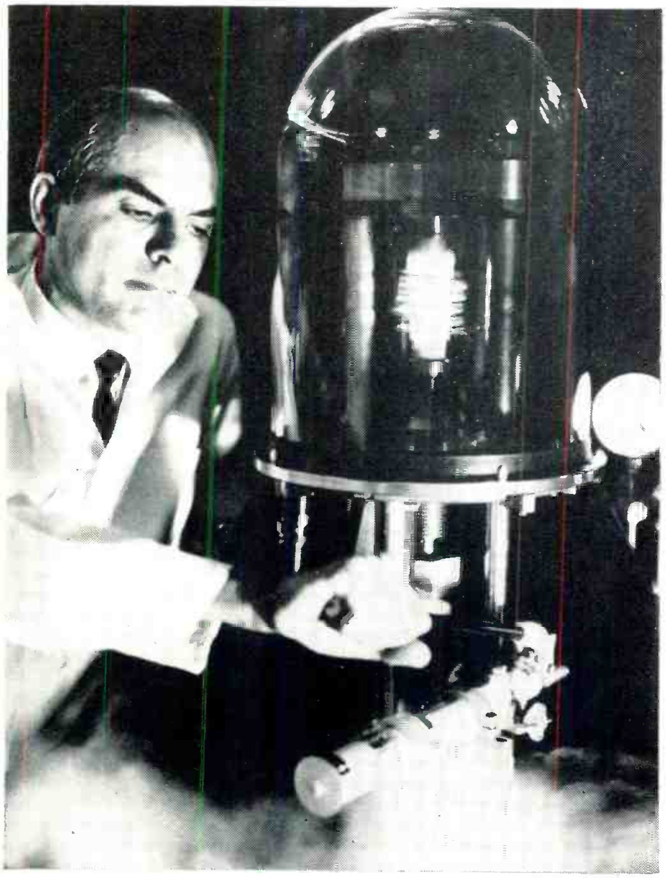
The receiver is basically similar to the Model 120 we tested last year except for some small design improvements and an "on-off" speaker switch. ▲



University 120A

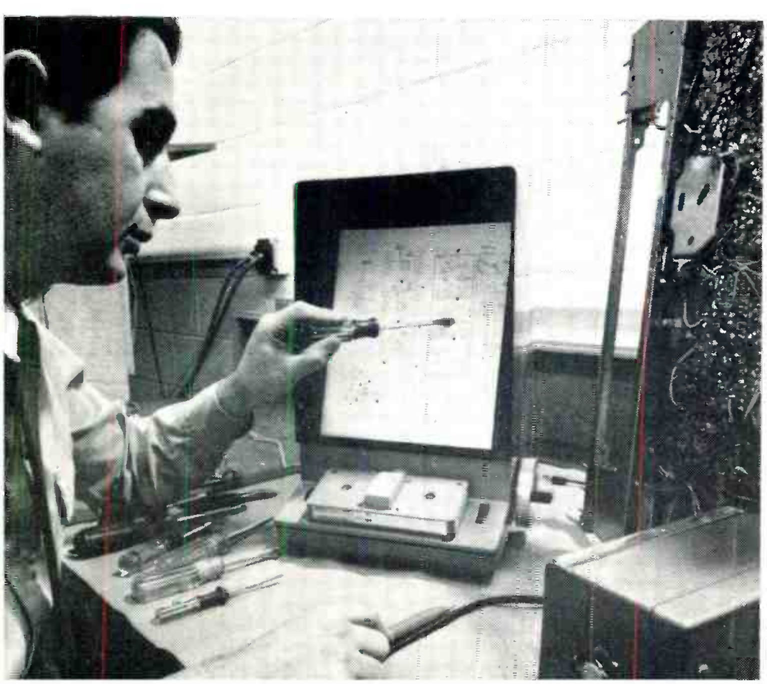


RECENT DEVELOPMENTS IN ELECTRONICS



Paper-Based Transistors. (Top left) Transistors are now being made on a wide variety of flexible bases, such as Mylar tape, cellulose acetate film, anodized metal foil, and even rough-textured paper. These thin-film flexible transistors have worked with good stability at frequencies up to 60 MHz. By using inexpensive bases, the cost of transistors may be even further reduced so that toys, novelties, hobby kits, and teaching aids may employ them. Another advantage of using a flexible substrate is that the thin-film transistors may be mass-produced in continuous rolls or strips. In addition, thin-film passive components, such as capacitors, resistors, and interconnections may be deposited at the same time. In the photo, test probes are contacting three terminals of a flexible transistor to permit a display of its characteristic curve. No less than 658 tellurium transistors are printed simultaneously on the Mylar tape substrate shown here before the tape is moved to the next position. These transistors were fabricated at the Westinghouse Research Labs.

World's Most Powerful Transistor. (Center) New, experimental high-power transistor, using a laminated construction, is shown here being fabricated under intense pressure and heat in a vacuum chamber. This technique has enabled RCA to build experimental transistors whose power output rivals that of large electron tubes for the first time. One of the transistors, operating at 1000 kHz, has already produced an output power of 800 watts. The new units are formed on two separate silicon wafers, the emitter-base wafer and the base-collector wafer. The two wafers are then fused or laminated under heat and pressure into a single monolithic structure. The active regions of the laminated transistor are located in the center plane of the semiconductor pellet in contrast to conventional devices where the active regions are essentially at the surface. The pellet also provides an emitter contact area that has a solid and continuous surface that is suitable for heat sinking in addition to the collector contact area on the opposite side.



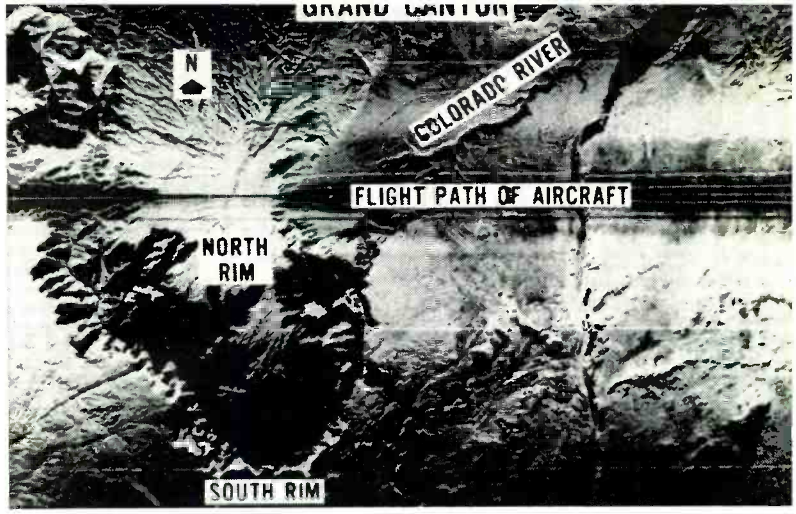
Microfilmed TV Service Data. (Left) The service industry's first microfilm system which instantly locates and displays technical and service information on home entertainment products has been placed in operation. The service is being leased to distributors, dealers, and servicing contractors by Sylvania. The unit consists of two reel-to-reel microfilm cartridges and a desk-top reader which projects the material on an 8 by 10½ inch screen. The cartridges contain 20 years of service data on the company's radios, phonographs, and television receivers. The microfilm library is expected to be updated periodically at no additional charge to subscribers of the service.

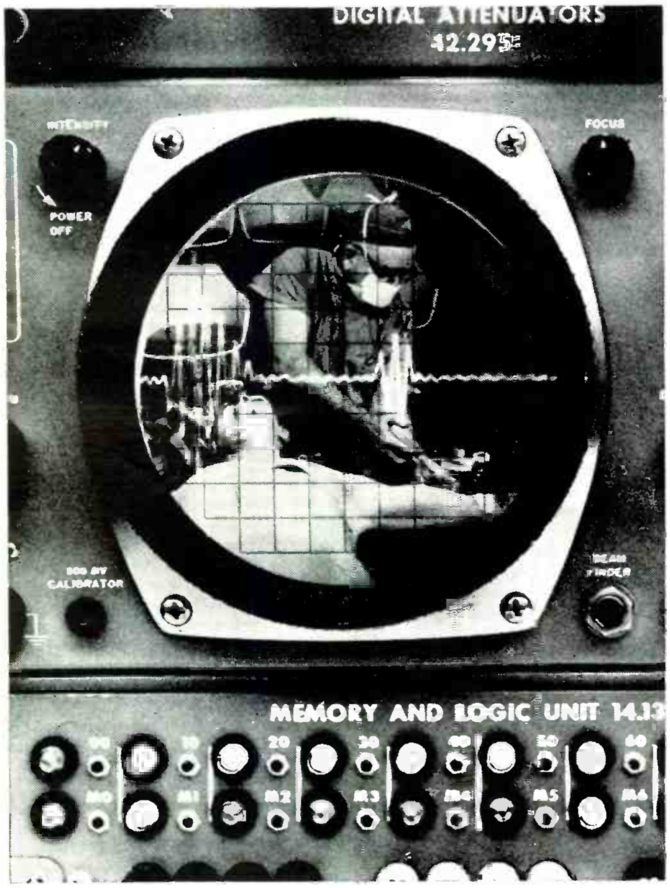
High-Resolution Radar Display. (Top right) Many tourists have taken many different pictures of the Grand Canyon, but this one is unusual in that it shows the entire Canyon and the surrounding area all in one picture. The picture is actually a high-resolution radar display made by a special airborne system developed by Motorola. The plane was flying at an altitude of about two miles. The radar system, which is one of several designed by various manufacturers for the government, would appear to be ideal for geological and for geodetic surveys.

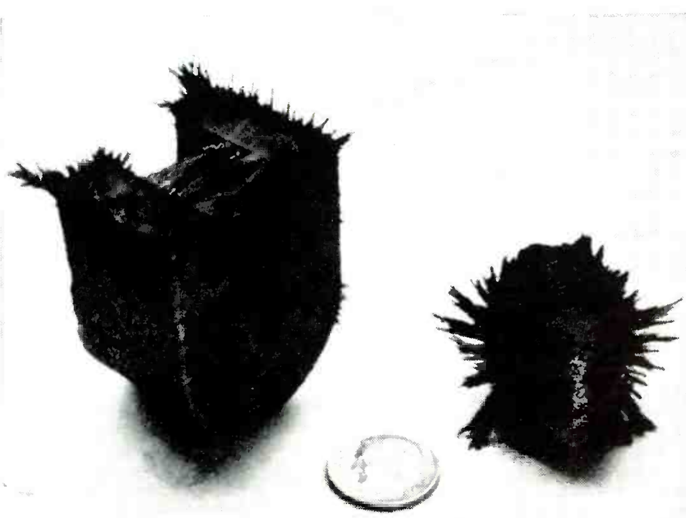
Computer-Controlled Patient Simulator. (Center) Resident physicians are being trained in anesthesiology with the use of a patient simulator. Known as Sim One, this complex medical teaching tool consists of a manikin with a hinged jaw inside of which are all the structures to be found in the human patient. Sim One has a heart beat, pulse beats, and blood pressure; "muscles" of the chest and diaphragm simulate the action of breathing; the eyes open and close and the pupils dilate and constrict. Computer-controlled electronic systems drive these mechanical actions of the manikin to simulate the responses produced during an operation. Further, the system may be programmed to provide responses to the injection of varying amounts of four drugs, as well as oxygen and nitrous oxide. Conceived by the University of Southern California's School of Medicine, computer design was done by Aerojet-General Corp.

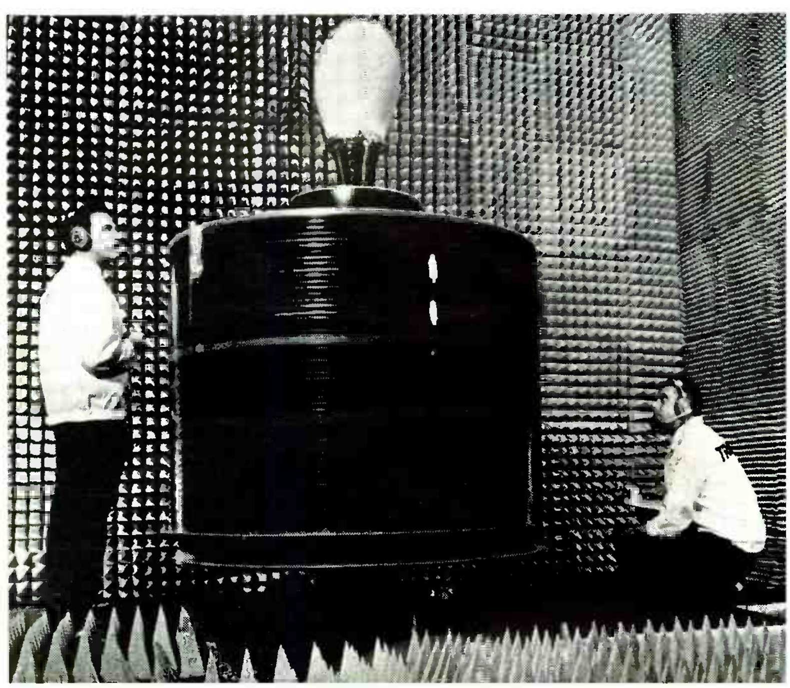
New Permanent-Magnet Material. (Below left) The disc-shaped magnet to the right is one of the most powerful small magnets ever made. Fabricated at Bell Telephone Laboratories, the magnetic material contains the rare earths samarium or cerium, a metal commonly used in flint for cigarette lighters. The new material has the highest intrinsic coercive force, or resistance to demagnetization, of any known material of comparable magnetic properties. Other constituents of the new magnet material include solid cobalt, copper, as well as iron.

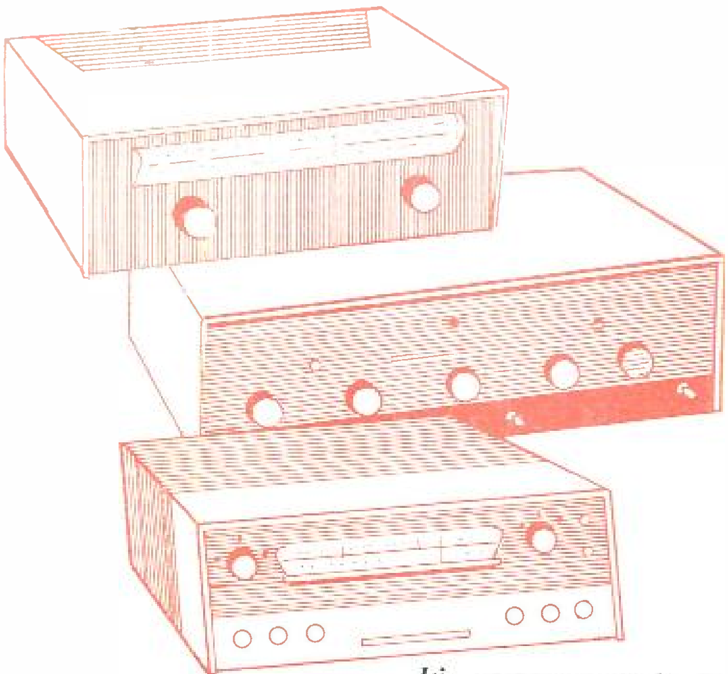
First Intelsat III Being Tested. (Below right) Engineers from TRW Inc. and Comsat are shown here in an anechoic room testing the first Intelsat III communications satellite. The body of the satellite is spinning at 90 r/min while the horn antenna at the top is spinning at the same speed but in the opposite direction. This keeps the antenna always pointed in one direction. In space, this direction will be toward the earth below. Although the first launch of Intelsat III was not successful, future launches are expected to put into synchronous orbits a number of these satellites to provide world-wide communications.











BIAS-FREE POWER AMPLIFIER

By DAVID CAMPBELL/ Fairchild Semiconductor

It's unnecessary to match device characteristics when transistors are operated without bias in a complementary power amplifier. In addition to running cooler, fewer components are needed for good performance.

IN low-power complementary power amplifiers, thermal stabilization of the output stage is a major problem where heat dissipation, due to both bias and signal conditions, is significant. The stability problem is acute because the junction's thermal resistance is high at ambient temperatures. Since the junction temperature is high during normal operation, it leaves little margin for abnormal conditions. One method of minimizing the total dissipation in the output stage is to operate without bias at zero signal conditions. Several benefits can be derived from this mode of operation: 1. The output transistors will operate at lower junction temperatures; 2. With a fixed supply voltage, more power can be obtained; 3. Quiescent supply current will be lowest; and 4. Bias stability is eliminated as a problem. There is, however, one obvious problem, notch distortion. This dead zone is caused by a lack of bias and must be minimized. The problem has been solved with a circuit configuration which uses feedback to reduce distortion at low levels while operating the output device without bias.

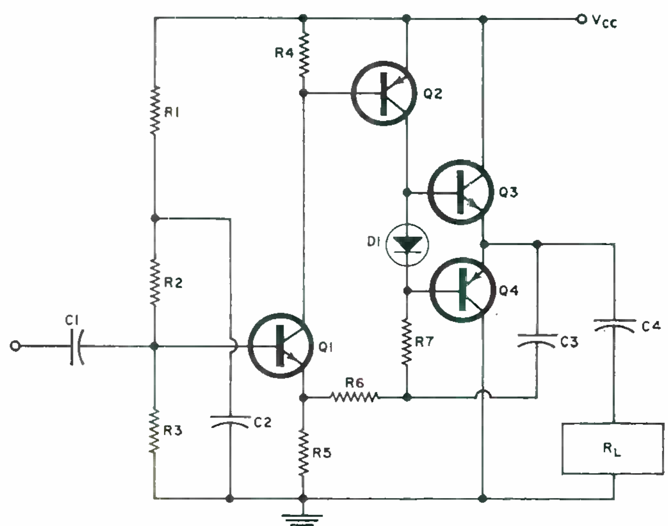
The objectives of a system design are determined by performance levels, manufacturing ease, total quantities involved, etc. The following list is a typical set of goals for the design of a low-power amplifier. Manufacturing objectives include: low component count, low component cost, simple component mounting, and simple test procedures. Design objectives are: no setup adjustments, no direct current in load, d.c. output should track power supply, low temperature coefficient on d.c. output, low power dissipation in output stage, wide tolerance on active device parameters, and no matching requirements on output transistors. Finally, performance objectives are: maximize power output, optimize input impedance and load impedance, high input sensitivity, low hum and noise output, wide operating temperature range, and low harmonic distortion.

The circuit is shown in Fig. 1. The amplifier can be analyzed by separating the voltage gain stages, $Q1$ and $Q2$, from the current gain stages, $Q3$ and $Q4$. $Q1$ and $Q2$ are common-emitter amplifiers with both d.c. and a.c. negative feedback. $Q3$ and $Q4$ comprise the familiar complementary current amplifier stage. This circuit differs from a conventional amplifier in the following ways. First, the d.c. feedback signal to the emitter of $Q1$ is obtained from the collector of $Q2$. (This eliminates d.c. current in the output transistors.) Second, the open loop gain of the amplifier is large enough to provide sufficient feedback to operate the output transistors without bias.

$Q2$ is operated as a bootstrapped common-emitter stage. The bootstrap capacitor, $C3$, supplies current for the feedback resistors $R5$ and $R6$ and maintains the current at the base of $Q4$ essentially constant. The base-emitter of $Q2$ is terminated by $R4$ to provide a current path for the I_{CBO} of $Q2$ to insure thermal stability of the stage. It is sufficient that $I_{CBO}\,R4$ is less than $V_{BE(on)}$ of $Q2$ at its highest junction temperature. For epoxy transistors such as the 2N3638 and 2N4354, a value of 22,000 ohms or less will insure thermal stability to their maximum junction rating of 125°C. In some amplifiers, a heat sink is required to keep the junction temperature below 125°C.

$Q1$ is also a common-emitter amplifier. The SE4021 is a high-gain, low-level amplifier with a minimum h_{FE} of 600 at 0.01 mA. The input base current is very small so that the

Fig. 1. This complementary transistor power amplifier circuit has two voltage (Q1, Q2) and two current (Q3, Q4) gain stages.



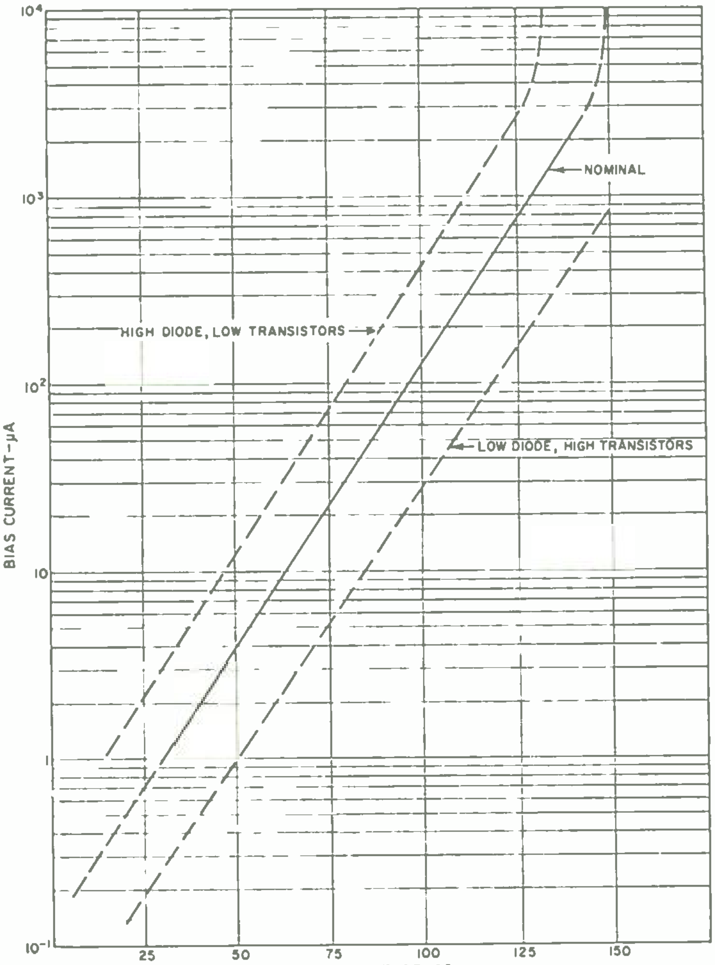


Fig. 2. Quiescent current vs temperature for typical output stage.

bias circuit for $Q1$ does not require bootstrapping to have a high impedance. This eliminates the cost of an input bootstrap capacitor and simplifies the circuit. Also, capacitor $C2$ which filters the power supply hum from the input, can be a low-cost disc capacitor instead of an electrolytic.

The a.c. feedback is driven from the output *via* $C3$ so that the total emitter circuit impedance of $Q1$ is much less than in a conventional circuit. This gives $Q1$ typically 20 dB more gain than in a conventional connection. Since the closed loop gain is fixed, this additional gain adds to the feedback in the amplifier. This feedback compensates for the dead zone in the open loop transfer characteristic as well as for non-linearities due to large signals. Linearity in the amplifier at both low power and high power is improved.

Output Stage

The bases of the output transistors are separated with a high conductance FDH694 diode, which minimizes the dead zone in the transfer characteristic and gives a low impedance between the transistor bases. It also eliminates the variation in base voltage that would occur due to resistor tolerances, power supply variations, etc.; and it extends the ambient range for stable bias by partially compensating the $V_{BE} - I_C$ characteristic of the output stage.

The quiescent current in the output transistors is less than 1 μA at room temperature. Fig. 2 is a graph of quiescent current as a function of temperature for a typical output stage with a 28-volt supply. With no signal, the output circuit is thermally stable at temperatures greater than 125°C ambient. With worst-case power dissipation in the transistors, the 28-volt circuit is thermally stable to above 70°C ambient.

Since there is a large amount of negative feedback in the

PART	12 V, 4 OHMS	18 V, 8 OHMS	28 V, 16 OHMS
R1	2.2 megohms	4.7 megohms	5.6 megohms
R2	2.7 megohms	4.7 megohms	10 megohms
R3	1.2 megohms	1.2 megohms	1 megohm
R4	22,000 ohms	22,000 ohms	22,000 ohms
R5	100 ohms	47 ohms	56 ohms
R6	180 ohms	180 ohms	470 ohms
R7	120 ohms	120 ohms	150 ohms
C1, C2	0.01 μF	0.01 μF	0.01 μF
C3	50 μF, 6 V	25 μF, 6 V	25 μF, 6 V
C4	500 μF, 10 V	500 μF, 15 V	250 μF, 20 V
D1	FDH694	FDH694	FDH694
Q1	SE4021	SE4021	SE4021
Q2	2N4249	2N3638	2N3638
Q3	SE8040	SE8040	SE8041
Q4	SE8540	SE8540	SE8541

Table 1. Components for various values of V_{cc} and common loads.

amplifier, the output stage parameters are relatively constant. Of particular importance is the fact that only a minimum h_{FE} is required for the output transistors and no h_{FE} matching is necessary to achieve good performance. This simplifies specification of the devices and reduces purchasing and handling costs.

Since the circuit is thermally stable, no emitter degeneration resistors are required. Thus, the available power output from a given power supply is increased. This is particularly important in low-voltage applications where emitter resistors account for a large part of the voltage swing.

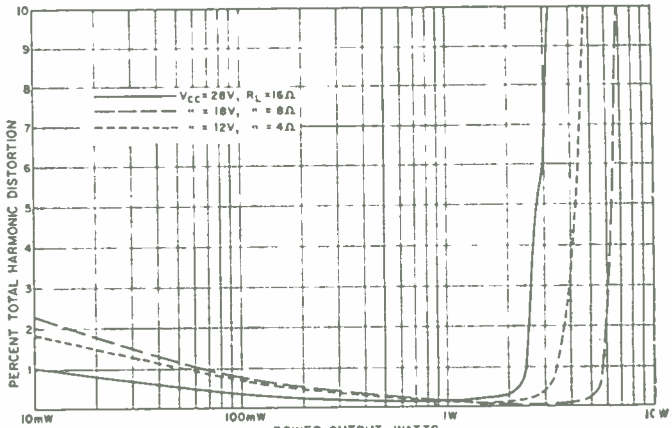
Three circuits utilizing the SE8040, SE8540, SE8041, and SE8541 transistors are shown. See Table 1 for parts values. These devices were developed for use in low-power applications. They feature high h_{FE} at 1 A and 1.3 V (min. 30), BV_{CEO} of 30 V, and a large safe area. Typical circuit values for amplifiers with 4-, 8-, and 16-ohm loads and performance characteristics of each are given. The circuits are designed to have an input impedance of 1 megohm so that they will operate directly from crystal phonograph pickups.

Heat sink requirements for the circuits are:

$V_{cc} = 12$ V, $R_L = 4$ ohms
$Q3, Q4$ R_{S-A} 40°C/W
$V_{cc} = 18$ V, $R_L = 8$ ohms
$Q3, Q4$ R_{S-A} 30°C/W
$V_{cc} = 28$ V, $R_L = 16$ ohms
$Q2$ R_{S-A} 40°C/W
$Q3, Q4$ R_{S-A} 30°C/W

If an increase in distortion at 10 mW output can be accepted, diode $D1$ can be removed and the bases of $Q3$ and $Q4$ connected together. High power output distortion and other performance characteristics are not significantly affected. See the graph of Fig. 3. ▲

Fig. 3. Harmonic distortion for 4, 8, and 16 ohm loads.



IC frequency dividers & counters

By DONALD L. STEINBACH / Research Engineer
Lockheed Missiles and Space Co.

Part 1. Advantages of logic-element approach to frequency division, techniques of dividing and counting using IC's, and characteristics of typical, inexpensive integrated-circuit flip-flops, gates, and buffers.

Editor's Note: This is the first part of a two-part article designed to acquaint the reader with the use of the basic integrated-circuit logic elements (flip-flops, gates, and buffers) in frequency dividing and counting applications. The article, while not a complete course in counter-divider design, will provide an understanding of the circuitry and the problems involved, an exposure to some inexpensive (and typical) IC's, along with a variety of complete divider-counter circuits.

COUNTERS made up of logic elements offer superior performance as frequency dividers. Anyone who has tried to use regenerative dividers, synchronized multivibrators, or synchronized relaxation oscillators as frequency dividers can readily appreciate the features and advantages of logic-element frequency dividers. These include:

No *LC* or *RC* frequency determining networks are used.

They are not designed around a particular input or output frequency and therefore will divide any frequency within the operating frequency range of the logic element used.

They may be designed to divide by any whole number and the division ratio *will not change* unless the manner in which the logic elements are interconnected is changed.

The input signal may be random or regular and periodic.

Short- and long-term stability is excellent.

No adjustments are required.

They will function as counters when suitable decoding circuits are added.

The logic elements used in the frequency dividers described in this article are available as low-cost integrated circuits (IC's). Using IC's instead of discrete components results in a significant reduction in both cost and construction time.

A frequency *divider* is customarily designed to provide one output cycle for every *n* input cycles (where *n* is any integer). A *counter* is a divider designed in such a way that at any instant the number of events that have occurred at its input may be readily ascertained. In this article the words "divider" and "counter" are interchangeable although "counter" is intended to identify those circuits that provide a visual display of the events counted.

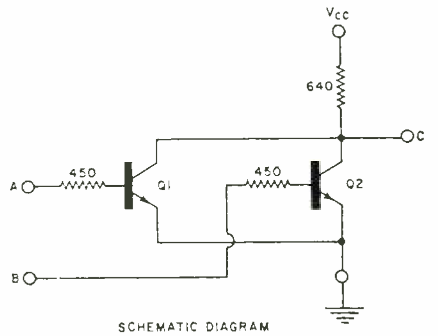
The literature supplies an abundance of asynchronous divider/counter circuits; synchronous circuits are emphasized in this article. Each of the frequency divider circuits to be described has been built and tested by the author and will operate at input frequencies in excess of 2 MHz.

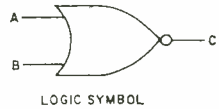
The three IC logic elements (flip-flops, gates, and buffers) used in these frequency dividers are members of a large family of logic elements widely used in industry. All three of the devices are electronic circuits that accept one or more input signals and deliver one or more related output signals. The relationship of the input signals to the output signals depends upon the particular device.

Gates take on many forms, depending on the relationship desired between the inputs and outputs. They usually have two or more independent input terminals and at least one output terminal. The gate is basically a "decision-making" device and its output is typically used to allow some function to occur (or prevent its occurrence) when a particular set of conditions exists at its inputs.

Buffers are current amplifiers. They may be either inverting (polarity reversing) or non-inverting. Buffers are used to amplify the output of a logic element when it is insufficient to drive other logic elements, or to provide isolation.

The bistable multivibrator or flip-flop (FF) is primarily a memory element. It has two stable states and will remain in one of them until forced to transfer to the other by some change in the input signal. The transition from one state to the other is regenerative and when initiated will continue to





A	B	C
0	0	1
1	0	0
0	1	0
1	1	0

TRUTH TABLE

Fig. 1. Here is a typical two-input "nand/nor" logic gate.

completion. Once the FF is in its new state it will remain there even though the input signal that caused it to change to that state is removed.

In normal operation, the input and output voltages of logic elements lie in one or the other of two "allowable" regions. The exact voltage levels are not important, only their relative magnitudes. The higher of the two voltage levels (the one having the greater magnitude) is usually called the "1-level" or simply "1". The lower of the two levels (the one having the smaller magnitude) is usually called the "0-level" or simply "0" (zero). For logic elements of the type described in this article, 0 typically represents a voltage level from 0.0 V d.c. to 0.5 V d.c. and 1 typically represents a voltage level from 1.0 V d.c. to 3.6 V d.c. (the supply voltage). It must be emphasized that these values are only typical and are subject to fairly wide variations.

The input/output relationship of a logic element can be expressed in the form of a general (Boolean) equation or tabulated in a "truth table." Unless you're a logic expert, the truth table approach is the most meaningful and will be used throughout this article. The truth table is nothing more than a list of all possible input combinations and the output resulting from each combination of inputs. The input and output levels are expressed in terms of ones and zeros.

A typical gate having two input terminals (A and B) and one output terminal (C) might be described by the truth table shown in Fig. 1.

The truth table makes four statements:

1. When A and B are both 0, C is 1.
2. When A is 1 and B is 0, C is 0.
3. When A is 0 and B is 1, C is 0.
4. When A is 1 and B is 1, C is 0.

Four statements are necessary (and sufficient) to completely describe this particular gate since there are two inputs and two possible states for each input (2 × 2=4). If the gate had three inputs, then eight statements would be required (2 × 2 × 2=8).

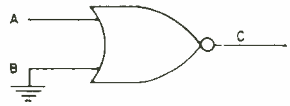
The schematic diagrams of certain logic elements may be quite complex and a complete system (such as a frequency divider) may contain many such logic elements. For this reason, it is convenient to represent logic elements by their logic symbols rather than by their schematic diagrams.

Gates and Buffers

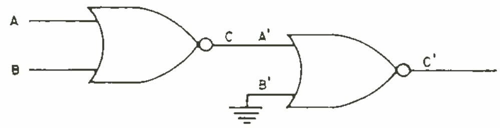
A typical gate, its logic symbol, and its truth table are shown in Fig. 1. A and B are inputs; C is the output.

The correctness of the truth table can be verified from the schematic diagram: C will be at its 0 level whenever $Q1$ or $Q2$ are turned on (A *or* B at the 1 level); C will be at its 1 level only if $Q1$ and $Q2$ are both off (A *and* B at the 0 level). Note that the 0 level of output C can never be less than $V_{CE(sat)}$ of $Q1$ or $Q2$. The 1 level of output C can never be greater than V_{cc} and will be less if C is connected to an external load.

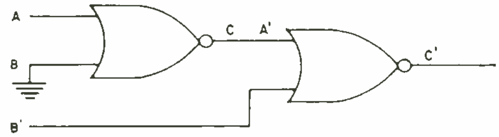
This gate is called a *nand/nor* gate. Fig. 2 shows several ways that one or two of these gates may be connected to produce other logic functions.



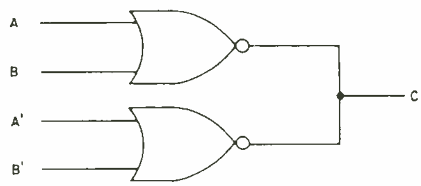
A	C
0	1
1	0



A	B	C'
0	0	0
1	0	1
0	1	1
1	1	1



A	B'	C'
0	0	0
1	0	1
0	1	0
1	1	0



A	B	A'	B'	C
0	0	0	0	1
1	0	0	0	0
0	1	0	0	0
1	1	0	0	0
0	0	1	0	0
1	0	1	0	0
0	1	1	0	0
1	1	1	0	0
0	0	0	1	0
1	0	0	1	0
0	1	0	1	0
1	1	0	1	0
0	0	1	1	0
1	0	1	1	0
0	1	1	1	0
1	1	1	1	0

Fig. 2. Several ways of connecting "nand/nor" gates in order to produce a number of other logic gating functions.

A typical inverting buffer, its logic symbol, and its truth table are shown in Fig. 3. Terminal A is the input and terminal C is the output. Terminal B is not normally used, but may be connected to the supply voltage for some applications such as differentiation of pulses.

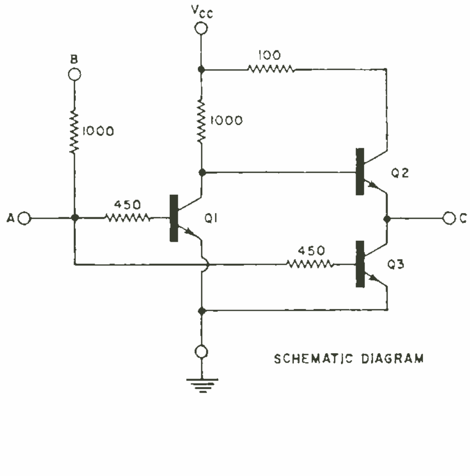
When A is at the 1 level, $Q1$ and $Q3$ are on and $Q2$ is off; C will be at its 0 level. When A is at the 0 level, $Q1$ and $Q3$ are off and $Q2$ is on; C will be at its 1 level.

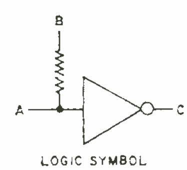
RS Flip-Flops

A simple FF made from two *nand/nor* gates is shown in Fig. 4. This FF is called an RS flip-flop. The inputs are R and S and the outputs are Q and $\overline{Q}$ (Q is read as "not Q"). Like all other FF's, it has two stable states. The FF is said to be in the 1 state when output Q is at the 1 level and in the 0 state when output Q is at the 0 level.

Transistors $Q2$ and $Q4$ form the RS FF's "memory" and $Q1$ and $Q3$ switch the FF between its two states. The FF

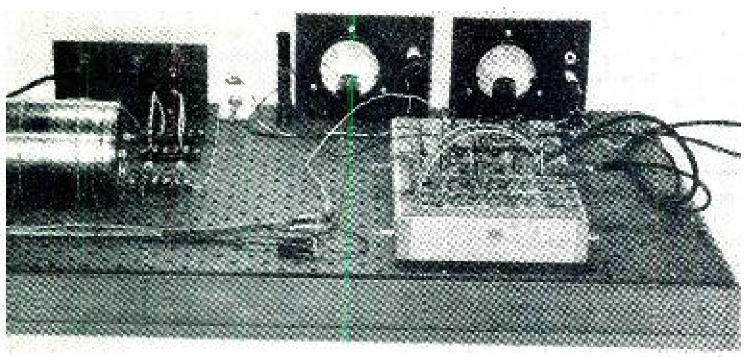
Fig. 3. An inverting buffer. The buffer is a current amplifier that is used for amplification or isolation.





A	C
0	1
1	0

TRUTH TABLE



Breadboard test setup used by author. Power supply is at left; meters monitor voltage and current. Various IC's are mounted on a perforated board atop wood subchassis base in foreground.

is switched to the 1 state by applying a 1-level signal to input S and to the 0 state by applying a 1-level signal to input R.

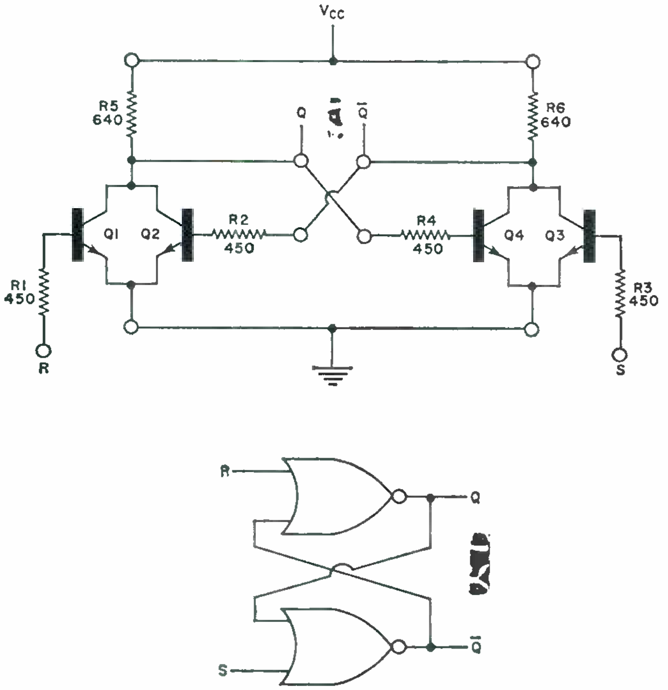
In the 1 state, Q4 is held on by the base current supplied from output Q through R4. Since output $\bar{Q}$ is at the 0 level, Q2 will remain off because it receives no base current. The FF will remain in this state even after the 1-level signal is removed from S, provided a 1-level signal is not applied to R.

In the 0 state, Q2 is held on by the base current applied from output $\bar{Q}$ through R2. Since output Q is at the 0 level, Q4 will remain off because it receives no base current. The FF will remain in this state even after the 1-level signal is removed from R, providing a 1-level signal is not applied to S.

The two outputs are always at opposite levels except when R and S are both 1. When R and S are both 1, Q1 and Q3 are both on and Q and $\bar{Q}$ are both 0.

The logic symbol and truth table for the RS flip-flop are shown in Fig. 5. The truth table R and S columns list all possible combinations of inputs that can be applied to the FF. It is assumed that the signals are applied to (or removed from) the R and S inputs simultaneously. The Q^{n+1} column shows the state of the FF (or the level of output Q) that exists *after* the particular R and S input signals are applied. The term Q^n represents the FF state

Fig. 4. An RS flip-flop made from two gates of Fig. 1.



that existed prior to the application of the R and S input signals. The term * represents the condition mentioned earlier where both Q and $\bar{Q}$ are 0.

The four statements in the truth table can be expressed as:

1. If simultaneous signals are applied to R and S such that R is 0 and S is 0, then the FF will remain in the state it was in prior to the application of the signals.
2. If simultaneous signals are applied to R and S such that R is 0 and S is 1, then the FF will switch to the 1 state.
3. If simultaneous signals are applied to R and S such that R is 1 and S is 0, then the FF will switch to the 0 state.
4. If simultaneous signals are applied to R and S such that R is 1 and S is 1, then the FF state is not defined since both outputs will be at the 0 level. Note that in the first three cases the FF state will not change if the input signals are disconnected or returned to the 0 level.

The RS flip-flop is not used in any of the frequency dividers in this article. It is the simplest of all logic-element FF's and is described here so that the operation and function of FF's in general may be better understood.

JK Flip-Flops

Fig. 6 is a schematic diagram of a typical JK flip-flop. Its associated logic symbol and truth table appear in Fig. 7. The JK flip-flop is the basic building block for logic-element counters and frequency dividers.

The JK FF has two output terminals, Q and $\bar{Q}$. Unlike the RS FF, the two outputs will *always* be at opposite levels; when Q is at 1, $\bar{Q}$ is at 0 and when Q is at 0, $\bar{Q}$ is at 1. It has four input terminals, labeled Preset, S, C, and T.

When a 1-level signal is applied to the Preset terminal, output Q is forced to the 0 level. Since the two outputs are always at opposite levels, $\bar{Q}$ will then be at the 1 level. Thus, the Preset input is used to preset the FF to the 0 state.

S and C are control inputs. The levels applied to S and C determine what the state of the FF will be *after* an appropriate input signal is received at T. Merely changing the levels applied to S and C will not change the state of the FF—an input to T is also required.

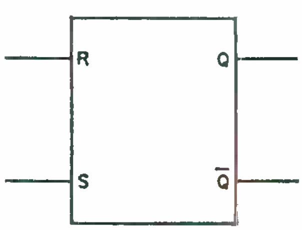
T is the signal input. The FF is incapable of responding to any signal applied to T except a 1-to-0 step such as the trailing edge of a square pulse. The fall-time of this pulse must be fairly small; on the order of 100 nanoseconds or less. Any pulse meeting these requirements is called a *clock pulse* (CP).

It should be emphasized that the FF will *not* respond to a positive-going pulse (0-to-1) applied to T. Further, it will not respond to a negative-going pulse (1-to-0) unless the fall-time is sufficiently small. Steady-state levels (1 or 0) at T are likewise ignored.

Transistors Q1 and Q2 form the basic FF "memory" exactly the same as Q2 and Q4 in the RS FF of Fig. 4. The sole function of Q15 is to switch the FF to the 0 state independent of any inputs to S, C, and T.

Q7, Q9, and Q11 form a 3-input *nand/nor* gate whose inputs are S, $\bar{Q}$, and T. When all three of these inputs are 0, the charge stored in the base-collector junction of Q3 will be transferred into the base of Q1 at the arrival of a

Fig. 5. Logic symbol and truth table for the RS flip-flop.



R	S	Q^{n+1}
0	0	Q^n
0	1	1
1	0	0
1	1	*

* Q AND $\bar{Q}$ BOTH 0

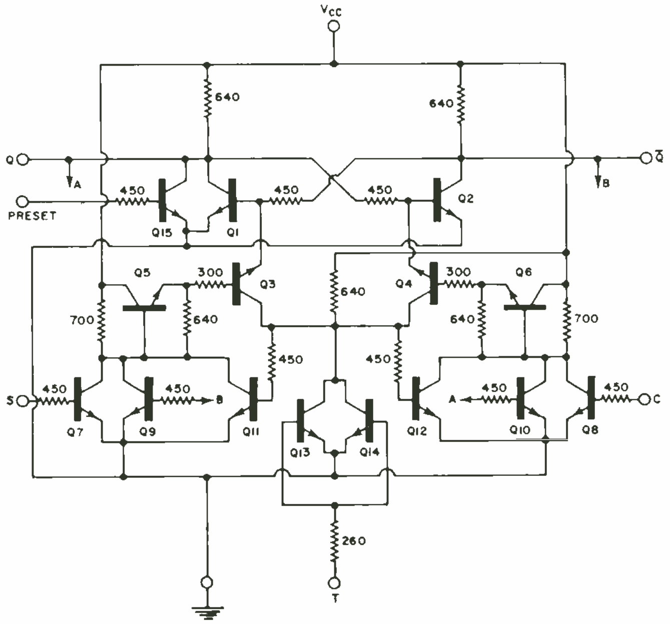
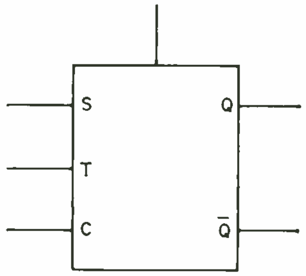


Fig. 6. Schematic diagram of typical JK flip-flop circuit. This complex circuit is readily fabricated on an IC chip.



S	C	Q^{n+1}
1	1	Q^n
1	0	1
0	1	0
0	0	$\overline{Q^n}$

Fig. 7. Logic symbol and truth table for the JK flip-flop.

CP, turning Q1 on and switching the FF to the 0 state.

Q8, Q10, and Q12 form a 3-input *nand/nor* gate whose inputs are C, Q, and T. When all three of these gate inputs are 0, the charge stored in the base-collector junction of Q4 will be transferred into the base of Q2 at the arrival of a CP, turning transistor Q2 on and switching the FF to the 1 state.

Whether or not the FF changes state at the instant the CP arrives depend on (*a*) the state of the FF just prior to the arrival of the CP, (*b*) the level of input S just prior to the arrival of the CP, and (*c*) the level of input C just prior to the arrival of the CP. The S and C columns of the truth table in Fig. 7 list all possible combinations of levels that might be present on S and C just *prior* to the arrival of the CP. The Q^{n+1} column shows the corresponding FF states that will exist *after* the arrival of the CP. The term Q^n represents the FF state that existed prior to the arrival of the CP. The term $\overline{Q^n}$ represents the FF state that is the opposite of that which existed prior to the arrival of the CP.

The data contained in the truth table can be completely summarized in four statements about S and C:

1. If S and C are both 0 prior to the arrival of the CP, then the FF will change state coincident with the arrival of the CP.
2. If S and C are both 1 prior to the arrival of the CP, then the FF will not change state. The state of the FF after the arrival of the CP will be exactly the same as it was prior to the arrival of the CP.
3. If S is 1 and C is 0 prior to the arrival of the CP, then the FF will change to the 1 state coincident with the arrival of the CP (or remain in the 1 state).
4. If S and 0 and C is 1 prior to the arrival of the CP, then the FF will change to the 0 state coincident with the arrival of the CP (or remain in the 0 state).

It is apparent, then, that the state of the FF after the arrival of a CP is completely specified by the levels applied to S and C when the CP arrives. It is this property of the JK flip-flop that makes it ideally suited for counting.

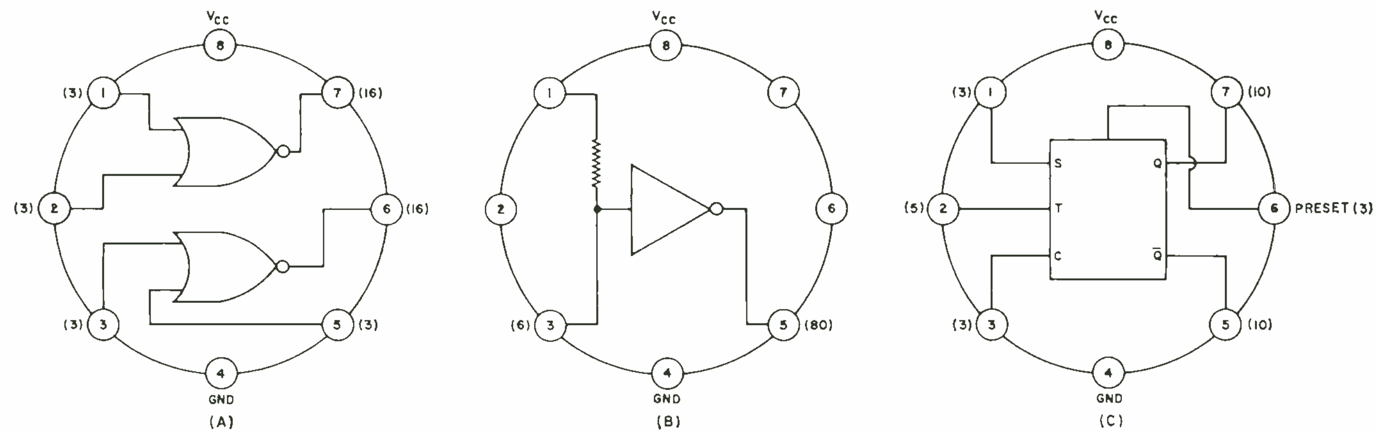
Integrated-Circuit Logic Elements

The gate of Fig. 1, the buffer of Fig. 3, and the JK flip-flop of Figs. 6 and 7 are readily available commercial integrated circuits. The devices used by the author are members of the *Fairchild* Industrial Resistor-Transistor Micrologic integrated circuit family. These three devices are available in economy epoxy-encapsulated packages. The *Fairchild* part numbers and prices (for quantities of 1 to 99) in effect at the time of this writing are: 9914 medium-power dual two-input gate, part number U8A991428, $0.80 each; 9900 medium-power buffer, part number U8A990028, $0.80 each; 9923 medium-power JK flip-flop, part number U8A992328, $1.50 each. Comparable units available in the *Motorola Semiconductor Products Inc.* MC700P series line are: MC724P quad two-input gate, MC799P dual buffer, and MC723P JK flip-flop or MC790P dual JK flip-flop.

The 9914 contains two gates like the one in Fig. 1. The package pin connections are shown in Fig. 8A. The 9900 contains one buffer like the one in Fig. 3. The package pin connections are shown in Fig. 8B. The 9923 contains one flip-flop like the one in Figs. 6 and 7. The package pin connections are shown in Fig. 8C. The FF will operate to at least 2 MHz.

The package pin connections in Fig. 8 are arranged as they appear looking at the top of the package. Pin 8 is adjacent to flat spot on outer circumference of package. Numbers in parentheses (*Continued on page* 69)

Fig. 8. (A) Pin connections for the U8A991428 two-input gate containing two of the gates shown in Fig. 1. (B) Pin connections for the U8A990028 buffer shown in Fig. 3. (C) Pin connections for the U8A992328 JK flip-flop shown in Fig. 6.



Laser Diodes

The performance of this gallium arsenide injection laser is improved by using an industrial diamond as a heat sink. The laser is the rectangular piece between the triangular diamond and the ball contact. Metal spring is an electrical connection.

By DAVID L. HEISERMAN

Injection lasers (laser diodes) are playing an increasingly important role in laser technology. They are efficient coherent light emitters.

WITHIN the past ten years, the laser has grown from a theoretical possibility into an integral part of modern science and industry. During its brief history, the most popular sources of laser energy have been certain crystals such as the artificial ruby, and inert gases such as helium and neon. Lately, however, a third laser source—the laser diode or injection laser—has begun to play an increasingly important role in laser technology. (See "Lasers: Multi-Million Dollar Market", ELECTRONICS WORLD, March, 1968.) Injection lasers have limited power output. They are small, rugged, and simple in structure and, since they require little external circuitry, they are relatively inexpensive to use. All of these advantages combine to make possible a portable, low-cost laser communications and ranging device.

All forms of light (other than laser light) are made up of a jumble of many different wavelengths and phase angles. On the other hand, laser light is composed of an extremely narrow band of wavelengths, all of which are nearly in phase with one another. In optical terminology, laser light is both monochromatic and coherent (Fig. 1). Because laser light is coherent, it's possible to treat it as an ultra-ultra short wavelength radio wave, that is, the light can be concentrated into a thread-like beam, amplified, attenuated, modulated with thousands of signals, demodulated, transmitted, reflected, received, and heterodyned to produce optical "i.f." frequencies.

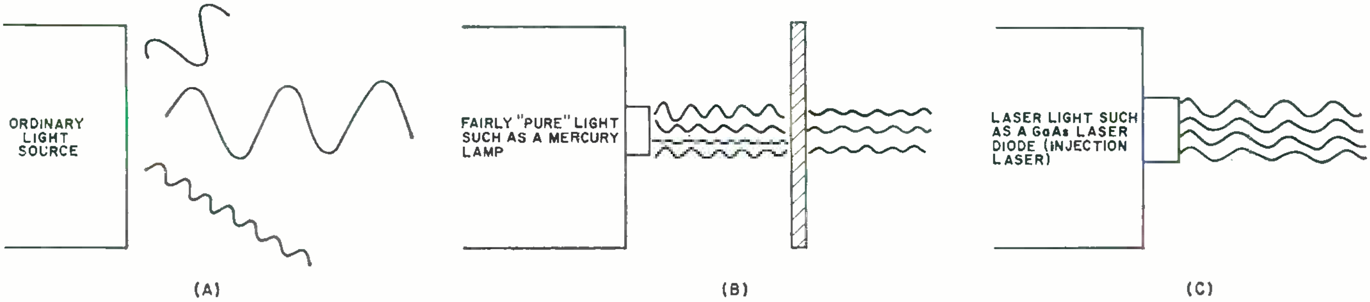
Theory of Light-Emitting "P-N" Junctions

Laser diodes produce coherent light energy when their *p-n* junctions are forward-biased with sufficient current.

In a forward-biased diode, electrons escape from the *n*-material and enter a high-energy electron band inside the *p*-material. The electrons occupy this special high-energy state a very short time before they spontaneously drop across the *p*-material forbidden gap to combine with a hole in the valence band. A continuous series of such electron-hole recombinations sustain current flow through the *p-n* junction.

At the instant of the electron-hole recombination, the electron emits a discrete amount of energy, ΔE, that almost equals the difference in energy between the high-energy electron band and the hole conduction band (Fig. 2). It is the form in which ΔE is dissipated that distinguishes an ordinary rectifier diode from a light-emitting junction device. In the case of silicon or germanium rectifiers, ΔE

Fig. 1. (A) illustrates the jumbled nature of ordinary light waves. (B) shows that when the light is passed through high-quality filters, it becomes monochromatic but not coherent. The light in (C) is monochromatic and coherent.



is dissipated as non-radiant "lattice vibrations" and heat energy. With the newer light-emitting semiconductor materials such as gallium arsenide, as many as 80% of the electron-hole recombinations result in the dissipation of ΔE as a photon or quantum of light energy.

The wavelength of the light emitted from a *p-n* junction is inversely proportional to the dissipated energy, ΔE. This can be shown by the equation: $\lambda = hc/\Delta E$, where λ is the wavelength of emitted light energy, h is Planck's constant, and c is the speed of light in a vacuum. As an example, zinc-doped gallium arsenide has a characteristic ΔE of 1.37 electron-volts at room temperature. Using the appropriate constants or the chart in Fig. 3, the wavelength of output light energy at the instant of an electron-hole recombination will be about 9050 angstroms which is within the infrared portion of the light spectrum.

Thus far we've discussed the operation of the simplest commercially available light-emitting semiconductor, the light-emitting diode (see "Light-Emitting Diodes", ELECTRONICS WORLD, January, 1968). It's important to note that the high-energy electrons injected into the *p*-material of a simple LED fall across the forbidden gap in a spontaneous or random fashion and that the photons emerge from the junction in sporadic, low-level bursts. Thus, under such random emission conditions, it is unlikely that any two photons will ever be in phase with one another. Therefore, the light output of an LED is incoherent.

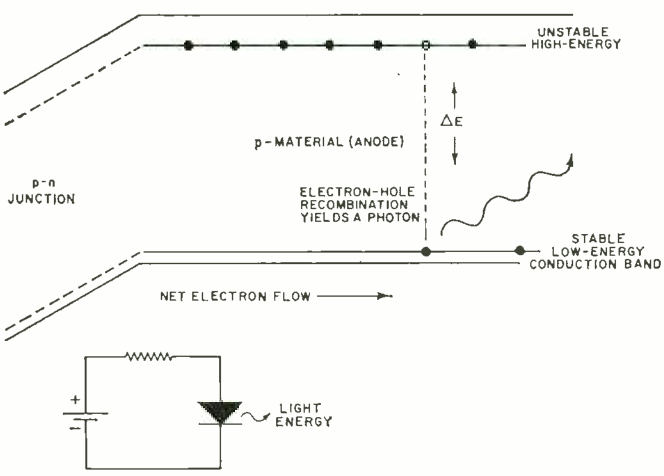
The forbidden gap in any light-emitting semiconductor also has slight imperfections due to certain chemical elements remaining in the substrate after refinement. Because of these imperfections, a diode may have several different values of ΔE grouped around the characteristic energy gap width. With several different ΔE paths available to each high-energy electron, the light from a simple LED will be a mixture of several different wavelengths. In other words, output of an LED is neither monochromatic nor coherent.

Laser Diode Theory

Fig. 4 is a drawing of a laser diode. Note that laser light emerges from the two polished end surfaces. As polished surfaces, the ends of the diode act as partially reflective mirrors which reflect a small percentage of the photons back into the *p-n* junction while allowing the remaining energy to emerge as useful laser light. The polished end surfaces are the mechanism which makes it possible for a light-emitting *p-n* junction to function in the laser mode.

In a simple LED, high-energy electrons injected into the *p*-material remain over the forbidden gap for an undetermined short interval of time before falling across the gap and emitting a photon. It is possible, however, to

Fig. 2. Electrons injected into the p-material from n-side of a diode occupy a high-energy state. As they fall across forbidden gap, their excess energy is emitted as a photon.



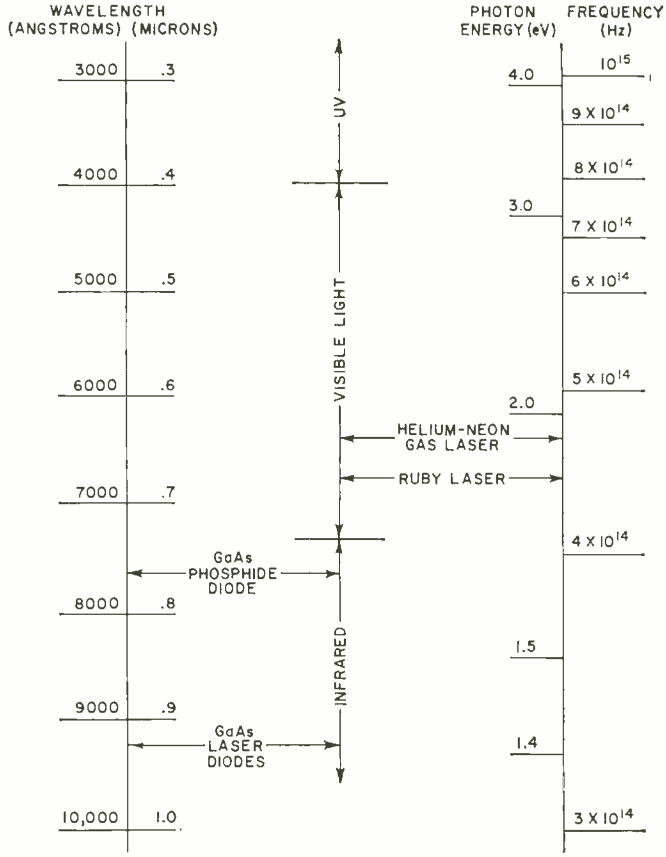


Fig. 3. Chart showing the laser spectrum.

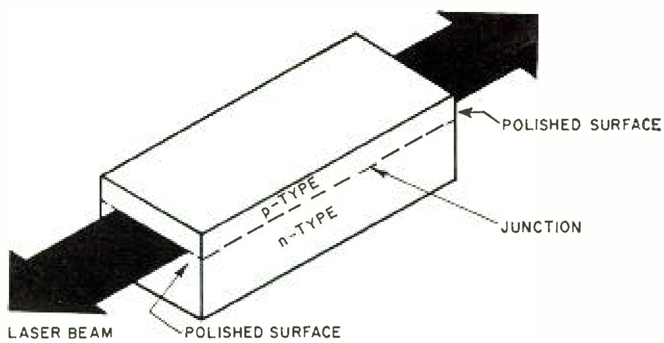


Fig. 4. Light energy from a laser diode radiates from either end of the p-n junction. The end surfaces act as reflective mirrors.

determine the precise instant the high-energy electron makes its transit by stimulating it with an energetic photon emitted by a previous electron-hole recombination. At the instant of the stimulated reaction, another photon is released to speed along the *p-n* junction with the original one. Under ideal conditions, each of these photons will stimulate the emission of another photon, and the system will contain four energetic photons.

Therefore, what begins as a single, random electron-hole recombination turns into an avalanche that produces a traveling wavefront of light energy. Once this wavefront reaches the reflective end surfaces of a diode, a portion of the energy bounces back and sweeps the junction again, stimulating high-energy electrons freshly injected into the *p*-material. The photons not reflected by the polished surface emerge from the diode as a narrow, powerful wavefront of light energy. •

If this sweeping wavefront is maintained by injecting electrons into the *p*-material at a very high rate, standing waves of light energy build up and the laser diode behaves as a source of coherent, monochromatic light energy. ▲

troubleshooting FET circuits

By LARRY ALLEN & THOMAS R. HASKETT

New test equipment as well as TV's and stereo sets will contain FET amplifiers. Technicians should know how FET's work before troubleshooting new circuits.

IN voltmeters, in audio preamps, in FM and TV front ends, the field-effect transistor (FET) has become a popular solid-state device. Before long, technicians will have to troubleshoot equipment that contains FET's. If they understand ordinary transistors and vacuum tubes, they'll find FET's easy to work with.

The FET fills a long-standing need. It combines certain advantages of a vacuum tube with the size, efficiency, and geometry of a transistor. The FET has a high input impedance—in the megohms—and it's voltage-controlled (input voltage controls transistor current). It exhibits the high power gain of a tube, but has less noise than either a tube or a transistor. The FET has a higher frequency response than most transistors and, as a front-end mixer in FM or TV sets, the FET produces less cross-modulation than either a tube or a conventional transistor.

How the FET Works

There are two basic types of FET's, by structure—the junction type (JFET), and the metal-oxide-semiconductor type (MOSFET). The JFET will be considered first.

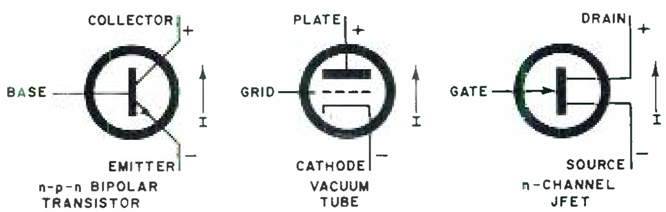
One way to explain the operation of an FET is by comparing it with the conventional transistors and the vacuum tube. Fig. 1 shows the symbols for all three devices, with elements labeled and the basic current flow indicated. In the *n-p-n* transistor, current flows from emitter to collector, with the base controlling the amount of current flow (common-emitter mode). In the tube, current flows from cathode to plate, and the grid is the control element (common-cathode mode). In the *n*-channel JFET, current flows from the *source* (source of current) to the *drain* (point of current drain). The control element is the *gate*, and the FET is shown connected in the common-source mode.

You may have noticed that in Fig. 1 the *n-p-n* transistor is called *bipolar*. The term is used to distinguish a conventional transistor from an FET, which is a *unipolar* device. In a conventional transistor, both electrons and holes are used as current carriers. Electrons are the majority carriers, and holes are the minority carriers. Because both are used, the transistor is called bipolar.

Note the symbol used for the *n*-channel JFET in Fig. 1. The long vertical bar represents an *n*-type semiconductor material through which electrons move easily. In the middle of the bar, two junctions of *p*-type material are diffused. Connected in parallel, these junctions become the gate, which forms a *p-n* diode at the bar or the channel. The gate regulates current by controlling the number of electrons that flow through the channel. The holes in the *n*-material contribute nothing to current flow, so the device is said to be unipolar.

Like bipolars, FET's are made with two sexes. The sec-

Fig. 1. Here, the transistor, tube, and JFET symbols are compared. Arrows indicate direction of electron flow.



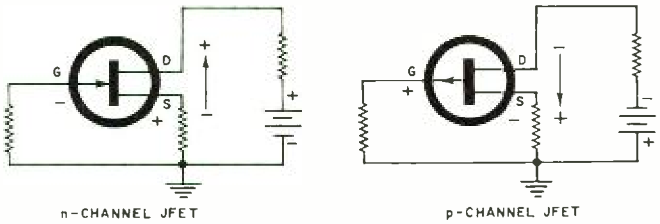


Fig. 2. "N" and "p" channel FET's connected in common-source mode.

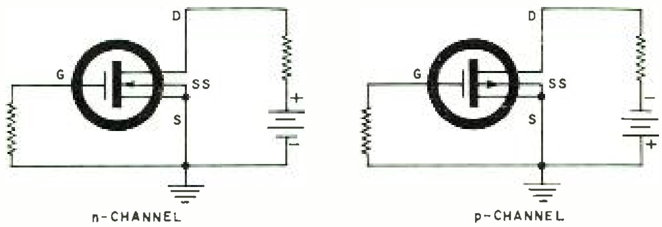


Fig. 4. "N" and "p" MOSFET's tied in common-source mode.

ond type is a *p*-type material into which *n*-type junctions have been diffused. Fig. 2 shows both types, connected in the common-source mode.

Consider the *n*-channel JFET again. The drain is made positive with respect to the source. If the gate is left floating, current flows from source to drain. Only if the gate is made *negative* with respect to the source, as shown in Fig. 2, can source-to-drain current be cut down. Does this sound familiar? Of course it does—the JFET acts like a vacuum tube. Both are normally on; channel (or plate) current must be limited or cut off by reverse bias between the control element and the source of current. Both devices are voltage-controlled and both are unipolar.

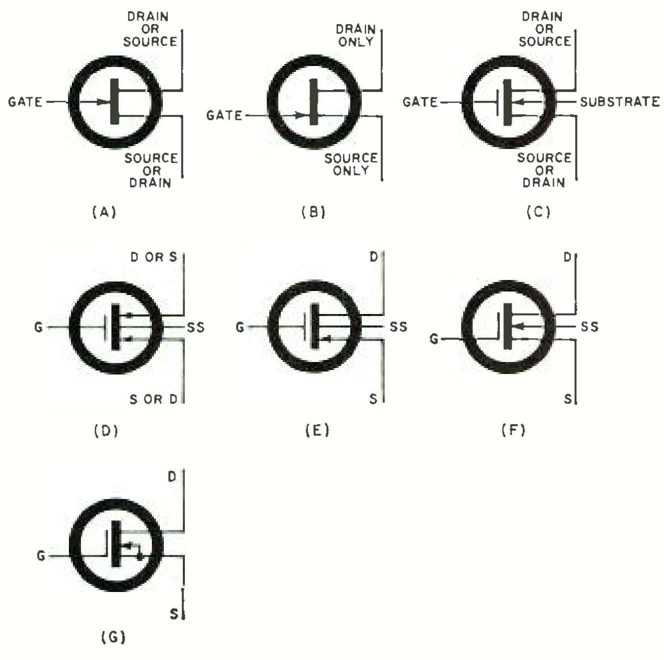
If you examine the direction of each gate arrowhead in Fig. 2, and the indicated gate-to-source bias, you'll see that each gate junction is reverse-biased. And, as you may recall, the impedance of any reverse-biased diode is high. That's why the JFET has a high input impedance. Normally, there's very little gate current in a JFET (typically a few nanoamps), and thus—for all practical purposes—input voltage alone controls output current.

Another thing JFET's have in common with tubes is biasing methods. While external gate bias is sometimes used, a common technique (shown in Fig. 2) utilizes the voltage drop across a source resistor. When voltage gain is important, the source resistor is usually bypassed. If left unbypassed, the source resistor develops current feedback.

One term you'll see used a lot with FET's is *pinch-off*. It means the same as cut-off does in a vacuum tube, that is, sufficient gate bias to reduce source-to-drain current virtually to zero.

Many JFET's are made with symmetrical geometry; construction is such that either end of the conducting channel may be used as drain or source. But some manufacturers make nonsymmetrical JFET's. The symmetrical JFET symbol is shown in Fig. 3A; that for the nonsymmetrical JFET in which drain and source terminals cannot be interchanged, is shown in Fig. 3B.

Fig. 3. Accepted symbols for JFET's and MOSFET's: (A) symmetrical JFET; (B) nonsymmetrical JFET; (C) and (D) common MOSFET symbols; (E), (F), (G) nonsymmetrical MOSFET's in (G) substrate is tied internally to the source.



The MOSFET is Different

In a JFET, the *p-n* gate junction constitutes a direct electrical (ohmic) connection. Input signals must not be allowed to drive the JFET into forward bias, or the gate will draw current. When this happens, input impedance decreases and signal-clipping occurs. Of course, you would expect this—the JFET is, in operation, practically a solid-state tube.

The MOSFET, however, avoids this difficulty by using an insulated, capacitor-like gate. Figs. 3C and 3D show two symbols often used for one type of MOSFET. The gate does not connect directly to the conducting channel. The symbol represents MOSFET construction which, in turn, gives it the name. The gate is *metal* (M), below which is a thin insulating film *oxide* (O). Below the oxide is the bar or channel of *semiconductor* (S). The combination is known, then, as a metal-oxide-semiconductor field-effect transistor, or MOSFET. Some manufacturers use such terms as IGFET (for insulated-gate FET) and MOST (for metal-oxide-semiconductor transistor).

The extra terminal in Figs. 3C and 3D is called the *substrate*. (It is also called the *base*, *body*, or *bulk* by some manufacturers.) The substrate is the foundation for the MOSFET. In an *n*-channel MOSFET, for example, the substrate is a bar of *p*-type material, with *n*-type junctions diffused into both ends. These *n*-type junctions are the drain and source. (That's why both symbols are equally valid. From the substrate's point of view, there's only one diode—between the substrate and either the drain or the source. But the drain and source each see a separate diode to the substrate.)

The symbols of Figs. 3C and 3D are for symmetrical MOSFET's. Nonsymmetrical MOSFET symbols are shown in Figs. 3E, 3F, and 3G. Note that in Fig. 3G, the substrate is connected to the source internally. If not internally connected, the substrate is usually tied externally to either ground or source.

MOSFET's also come in two sexes, and Fig. 4 shows both *n*- and *p*-channel devices connected in the common-source mode. Both are *depletion/enhancement* devices. To understand what this means, go back to the JFET, which is a depletion-type device. Normally on when there is bias, the JFET is turned off or controlled by reversing the gate bias. This reverse bias depletes the channel, or makes it smaller, restricting source-to-drain current flow.

The *n*-channel MOSFET shown in Fig. 4 works the same as a JFET. Reverse bias (or a negative-going input signal) depletes the channel, and reduces source-to-drain current flow. But the MOSFET gate is insulated from the channel and should the gate of an *n*-channel MOSFET be driven positive, it will not draw current (as the JFET gate does). As a matter of fact, in the depletion/enhancement MOSFET, when the gate goes positive (with respect to the source) the channel is *enhanced*, or made larger, and more current can flow.

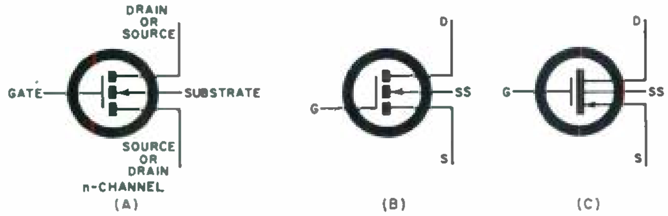


Fig. 5. (A) is the symbol for an enhancement-type MOSFET. (B) and (C) are symbols for nonsymmetrical version of the device.

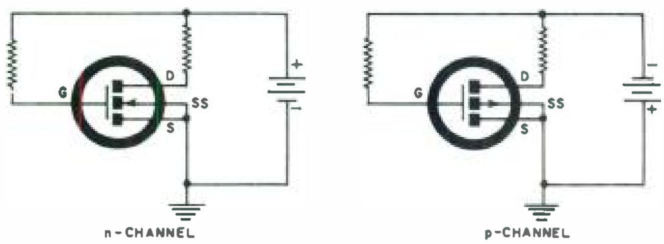


Fig. 6. These MOSFET's are operating in common-source mode.

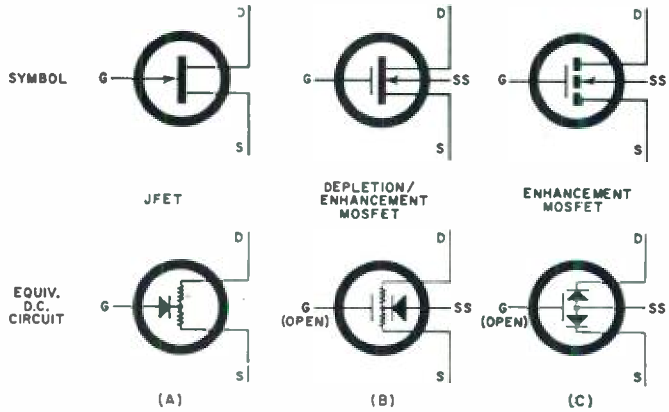


Fig. 7. FET's and MOSFET's and their equivalent circuits.

Since the gate can go either positive or negative without ill effect, depletion/enhancement MOSFET's are often operated with zero bias; therefore, no self-biasing source resistor is required. There is no voltage drop across the gate resistor because the gate doesn't draw current.

Still another kind of FET is the enhancement-type MOSFET. (A few depletion-only MOSFET's have been made, but they are seldom used. They operate almost exactly like JFET's.) Fig. 5A shows the symbol for the symmetrical version and Figs. 5B and 5C for nonsymmetrical versions.

This type of MOSFET also has an insulated gate and very high input impedance (as much as thousands of megohms). But it operates like a bipolar transistor—current doesn't flow continuously, it must be turned on by a forward gate bias. As you can guess from the symbol, there is no conducting channel between source and drain until the gate *enhances*, or turns on, the channel.

In Fig. 6 you see the typical common-source connection for both *n*- and *p*-channel enhancement-type MOSFET's. Because this device must have forward gate bias (just like a bipolar transistor), the gate resistor is often returned through a resistor to the drain supply. Sometimes a stabilizing resistor is connected from gate to source (ground).

There is no such thing as pinch-off voltage in an enhancement-type MOSFET, for the device is normally off until turned on. *Threshold voltage* is the term used to denote how much forward gate bias is necessary to start source-to-drain current flowing.

General FET Troubleshooting

The FET—irrespective of its internal construction—is still just another amplifier, oscillator, phase splitter, or other working stage. With one exception, forget about FET's as such when you first troubleshoot equipment using them. Analyze the gear in terms of stages, be they amplifiers or oscillators, mixers or inverters. Use signal injection and tracing to isolate the defective section and stage.

Almost all FET gear today is hybrid—using both FET's and bipolars. And that brings up the exception mentioned above. FET's are high-impedance devices, and you cannot test them with instruments that have low-impedance inputs (or outputs). Actually, most modern electronic voltmeters, scopes, and generators can work into FET circuits without loading them down much.

If you used an ohmmeter on various FET types, you'd find that they "look" like Fig. 7. The JFET symbol is shown on top in Fig. 7A, with its equivalent circuit below. The drain-to-source channel is effectively a simple resistance; the value depends on the particular FET, but usually runs from about 100 to 10,000 ohms if the device is good. The gate-to-channel diode measures about 1000 ohms in one direction and open in the other.

Fig. 7B shows the symbols and equivalent circuit for a depletion/enhancement MOSFET. Again, the drain-to-source channel appears as a resistance of 100 to 10,000 ohms. Since the gate is insulated from the channel, it reads open irrespective of ohmmeter polarity. The drain and source each show a diode connection to the substrate, each measuring about 1000 ohms in one direction and open in the other.

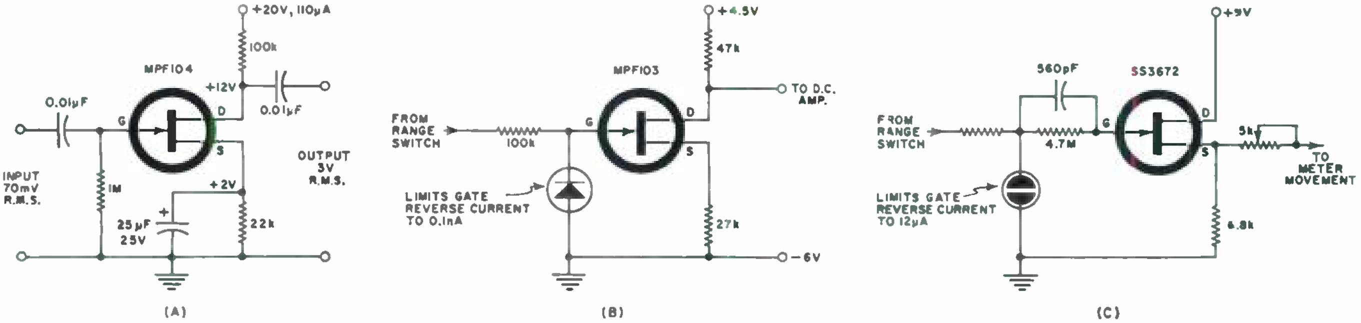
The enhancement-type MOSFET, shown in Fig. 7C, exhibits an open circuit between drain and source. As mentioned earlier, the drain and source are *p-n* junctions diffused into the substrate. Resembling back-to-back diodes, they measure an open circuit. But when measuring from drain to substrate, you'll find a single diode with 1000 ohms resistance in one direction and open in the other. The same is true when measuring from source to substrate. The gate, of course, is open between itself and all elements.

All the FET's in Fig. 7 are *n*-channel types. Diode polarities are reversed in *p*-channel devices.

What Goes Wrong with an FET?

In terms of failure, the FET isn't much different from an

Fig. 8. (A) These components in an FET audio amplifier are equivalent to those of a vacuum-tube circuit. The circuit of (B) is as used in a millivoltmeter. Another maker uses FET meter circuit shown in (C).



ordinary bipolar silicon transistor. Overvoltage, high temperature, shock, and moisture can all be bad news to an FET.

Other than manufacturing defects (which are few), the most common cause of FET failure is circuit overvoltage. The manufacturer specifies a breakdown voltage, from element to element. If this voltage is exceeded, the FET may be permanently damaged.

Excessive drain-to-source voltage usually causes too much current to flow, and the power rating is exceeded. The result is usually an open circuit from drain to source; this damage is permanent.

Excessive gate-to-channel voltage in a JFET causes diode breakdown, resulting in excessive gate current. If the power rating is not exceeded, the JFET won't be permanently damaged, and will work okay once the overvoltage is removed. If the heat (power) is too much, the gate will either short to the channel or open. Both faults are permanent. Remember that the JFET gate-to-channel junction is a diode and is subject to all the troubles of an ordinary rectifier or detector diode.

Gate overvoltage in a MOSFET is usually fatal to the device, because the insulating film is punctured. The usual result is a gate-to-substrate short, although the channel is sometimes included in the shorted region.

MOSFET Handling Precautions

MOSFET's are extremely sensitive to voltage between gate and channel. The gate-to-channel capacitance in a typical MOSFET is quite small—only a few picofarads—and even ordinary handling during replacement may ruin the device.

As you may have observed, when you comb your hair or walk across a dry rug, your body builds up a potential of static electricity. Such a static voltage can easily damage a MOSFET. Because of the high gate impedance, this voltage can—and will—puncture the insulating film between gate and channel, causing a permanent short that ruins the MOSFET.

MOSFET's are normally supplied with all leads shorted together (called "zot-proofing" them), and they should be kept this way until installed in equipment. The safest way to install a MOSFET is as follows: Slide a shorting ring up the leads to the case, and then spread the leads apart. Ground your body, perhaps by placing a grounded metal sheet on your bench and resting your elbows on it. Ground the tip of your soldering gun or iron with a jumper. Power to the equipment in which you are installing the MOSFET must, of course, be off. Install and solder each MOSFET lead, using heat-sink pliers so you don't overheat the device. When all leads have been soldered in place (or inserted in the transistor socket), clip the shortening ring off.

Common Circuits

In Fig. 8A the circuit of a simple FET audio amplifier is shown. The component values are similar to those of a vacuum-tube-type circuit. Because of the high FET impedances, resistors are higher in value than they would be in bipolar circuits and, because the FET is a solid-state device, the supply voltage is low. So are the drain current and gate-to-source bias voltage.

If the input capacitor in Fig 8A were to short, the supply voltage from the preceding stage would be applied to the gate of the MPF104. The gate would be driven positive on alternate half-cycles by the input signal. However, the FET probably would not be destroyed, because the drain resistor would limit drain heating to a safe value; but, just like a vacuum tube, the FET would saturate on positive half-cycles and clip the signal, producing distortion.

One of the first places you're going to find an FET used—although you may not have to troubleshoot it right away—is in a voltmeter. You recall the traditional difference between a v.o.m. and a v.t.v.m.; the v.o.m. is portable but is low-impedance and loads down a high-Z circuit. The v.t.v.m., on the other hand, is high-impedance, but usually is not portable. Bipolar transistors are ill-suited to high-impedance voltmeter use, and any such transistor voltmeters had to be designed around complex bootstrap circuits. The FET solves that problem, having both high impedance and low voltage. A voltmeter designed around an FET is portable and can be battery-operated.

Fig. 8B shows part of the circuit of the *Amphenol* 870 "Millivolt Commander" FET voltohmmeter. The FET input amplifier is fed from the range switch and allows a 10-meg-ohm input impedance. Supply voltage is low and the instrument is battery operated. *(Continued on page 60)*

THE DUAL-GATE OR TETRODE FET

MULTI-GRID vacuum tubes were developed because of the need for mixing two signals; they use two independent grids to control the electron stream. The FET is well suited to such construction, for two gates can be easily diffused into the conducting channel. A number of tetrode FET's are available.

The symbols for dual-gate JFET's are shown in Fig. 1A, the first two being symmetrical and the last non-symmetrical. Dual-gate MOSFET's are shown in Fig. 1B, both of which are nonsymmetrical and have the substrate connected internally to the source.

Dual-gate FET's are ideal as mixers, as color-TV and stereo-FM demodulators, and as a.g.c.-driven i.f. amplifiers. The typical v.h.f. mixer shown in Fig. 2 uses an RCA developmental type TA7151. The two independent gates provide good isolation between r.f. amplifier and oscillator, which contributes to stable oscillator operation. And, of course, the dual-gate MOSFET has a low cross-modulation figure.

Fig. 1. Symbols for dual-gate JFET's and MOSFET's.

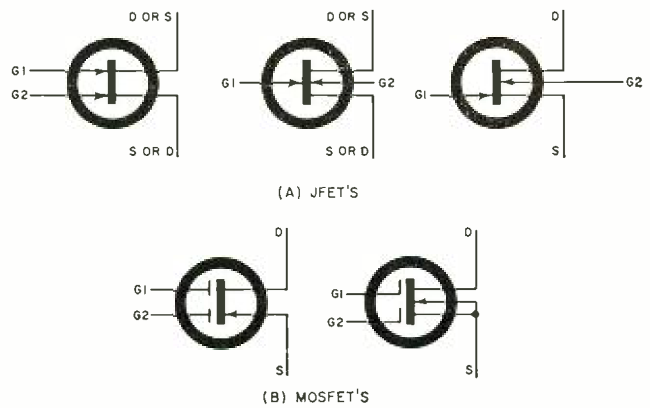
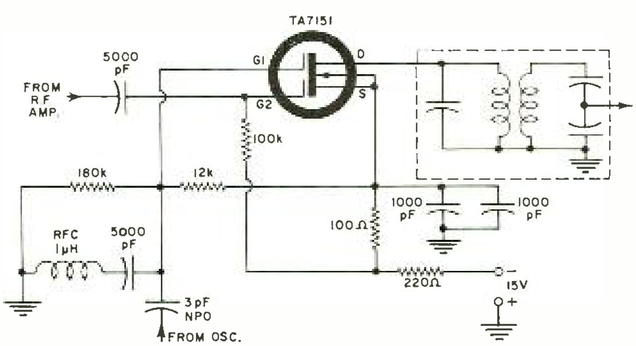


Fig. 2. Typical v.h.f. mixer using an RCA TA7151 unit.



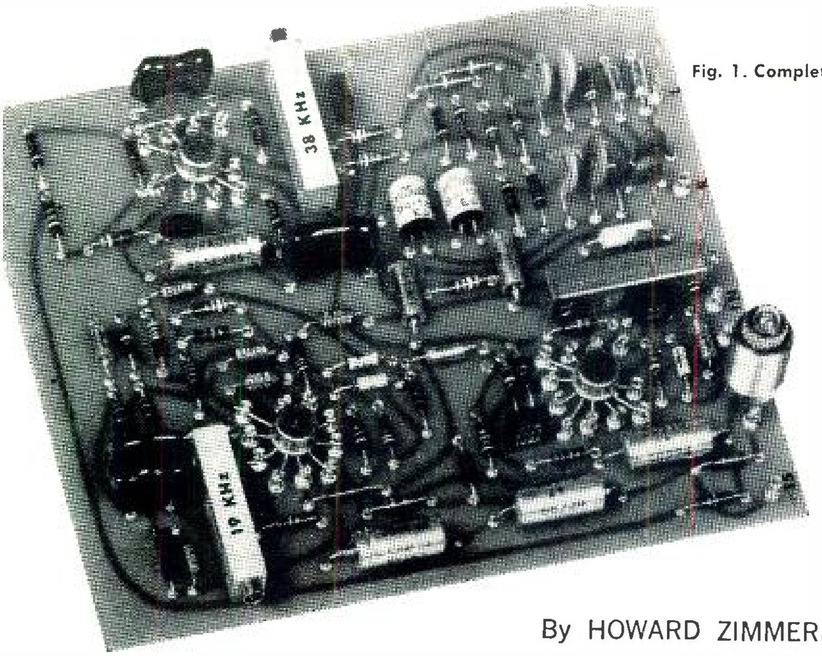


Fig. 1. Complete IC demodulator mounted on 4½" x 5" board.

IC STEREO MULTIPLEX DEMODULATOR

By HOWARD ZIMMERMAN

Low-cost, off-the-shelf IC circuits make possible design of FM multiplex demodulator which beats many discrete types.

THE availability of low-cost, high-performance, integrated circuits, particularly the *RCA* CA3000 series of monolithic chips, provides an opportunity to design fairly complex and sophisticated systems with a minimum of space and total parts count. The FM multiplex demodulator to be described has three integrated circuits and performs as well as or better than many of the discrete-component units now on the market. The measured separation is 30 decibels at 1 kilohertz and maximum sensitivity is 5 millivolts (r.m.s.) in the 19-kHz pilot channel. Subsidiary Communications Authorization (SCA) rejection is 36 dB when the unit is driven from a source impedance of 1000 ohms or less. Input and output impedances are 30,000 and 50,000 ohms, respectively, and the power requirement is 15 volts ±0.5 V at 55 mA.

Fig. 1 shows one of several units that have been built from the basic design. This particular model uses *Bourns* Type RH Trimpots and two *Aladdin* pulse transformers for *T*1 (in the schematic of Fig. 2). Since these parts are relatively expensive, other types may be substituted with no degradation in performance.

Operation of the demodulator follows conventional practice; for example, there is a 19-kHz narrow-band amplifier, a doubler to 38 kHz, and a 38-kHz locked oscillator and time-sharing detector. These functions are obtained without the use of tuned *LC* circuits and with a minimum of adjustments. Since this circuit is not critical, the SCA filter is fixed tuned.

Circuit Description

The complete schematic is shown in Fig. 2 (except for the internal circuitry of the three IC's). The CA3018, which is packaged in a 12-lead TO-5 can, has a gain-bandwidth product of 400 MHz. It can be used as a 100-MHz cascode amplifier, a video amplifier, a 15-MHz tuned radio-frequency amplifier, or as a final intermediate-frequency amplifier and second detector. The demodulator's second stage is a CA3035, which is an ultra-high-gain wide-band amplifier array whose three amplifier sections have half-power points of 500 kHz and 2.5 MHz (sections 2 and 3). The third stage is a CA3001, a wide-band video amplifier whose useful frequency range is from d.c. to 30 MHz.

A composite signal from the FM detector is fed to one section (there are two two-transistor amplifiers in this IC) of the CA3018, which is connected as an emitter-follower to provide a relatively high input impedance for the SCA filter and a low-impedance drive to detector diodes *D*7, *D*8, *D*9, and *D*10. The output from the emitter-follower is fed directly to transformer *T*1. The signals from threshold control *R*12 are fed to the 19-kHz filter amplifier through *C*10 and *R*13.

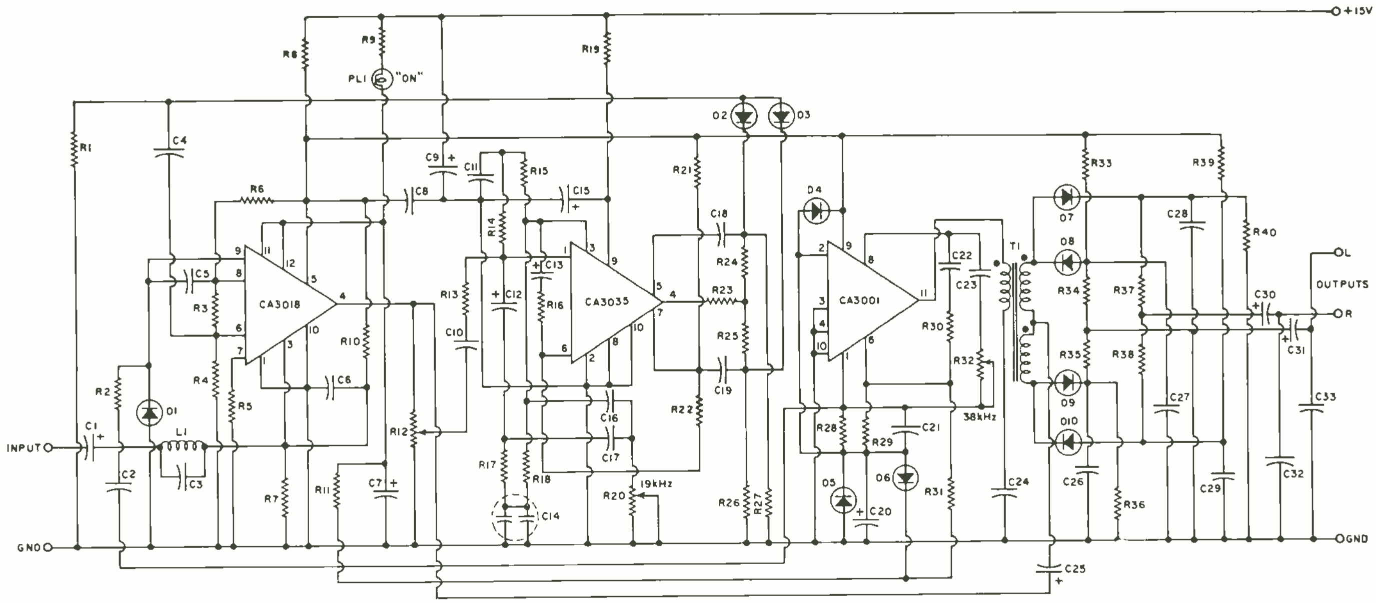
The three sections of the CA3035 comprise the complete 19-kHz pilot channel. Amplifier #1 is connected as a feedback amplifier with the feedback path formed by a twin-T filter consisting of *R*17-*R*18-*R*20 and *C*14-*C*16-*C*17. *R*13 isolates the drive source from the amplifier input and feedback is developed across this resistor. *R*20 and *C*14 are used to tune the filter to 19 kHz. The typical amplifier gain is 44 dB ($A_v = 160$). The circuit "*Q*" of a twin-T amplifier is $A_v/4$ or 40. By making the circuit slightly regenerative at 19 kHz, the "*Q*" can be increased to something greater than 100 before oscillations occur. Typically, "*Q*'s" of 140 were obtained in several pilot models.

Amplifier #3 is used as a buffer to prevent loading the filter-amplifier by the doubler diodes. Since the input impedance of amplifier #3 is about 270 ohms, the load on the filter-amplifier consists almost entirely of resistor *R*16 and is nearly independent of variations in amplifier #3.

Amplifier #2 is connected as a feedback inverter similar to the operational inverter. True operational amplifier operation is not needed because of the amplifier's relatively low input impedance.

The output from terminals 5 and 7 of the CA3035 consists of a push-pull 19-kHz signal which is fed to the doubler diodes *D*2 and *D*3. These diodes rectify the 19-kHz output and produce a series of pulses at a 38-kHz rate.

The output from the doubler is fed back to the CA3018's second stage and amplified by the previously unused transistor in this section. The collector signal of this transistor is a limited 38-kHz pulse train similar to a 38-kHz square wave. This pulse train, in turn, is coupled to a Darlington-connected transistor pair (in the CA3018) and used to drive a stereo indicator lamp and oscillator gate. The Darlington amplifier is normally non-conducting since its base has no bias voltage. When pulses are applied to the base, a d.c. bias is developed by rectification in the base-emitter junc-



R1, R17, R18—5600 ohm, ½ W res.
R2—39,000 ohm, ½ W res.
R3—51,000 ohm, ½ W res.
R4—47,000 ohm, ½ W res.
R5—160 ohm, ½ W res.
R6—12,000 ohm, ½ W res.
R7—160,000 ohm, ½ W res.
R8—110 ohm, ½ W res.
R9—270 ohm, ½ W res.
R10—120,000 ohm, ½ W res.
R11—20,000 ohm, ½ W res.
R12, R32—2000 ohm pot (Bourns Type 3068)
R13—43,000 ohm, ½ W res.
R14, R23—33,000 ohm ½ W res.
R15, R34, R35, R37, R38—150,000 ohm, ½ W res.
R16—10,000 ohm, ½ W res.
R19—1300 ohm, ½ W res.
R20—5000 ohm pot (Bourns Type 3068)
R21—5100 ohm, ½ W res.
R22—82,000 ohm, ½ W res.
R24, R33, R36, R39, R40—39,000 ohm, ½ W res.
R25—27,000 ohm, ½ W res.
R26, R27, R31—24,000 ohm, ½ W res.
R28, R29—1100 ohm, ½ W res.
R30—3900 ohm, ½ W res.
Note: All res. should be ±5% units.
C1, C30, C31—0.1 μF capacitor
C2—24 pF capacitor
C3—560 pF capacitor
C4—0.33 μF capacitor
C5, C32, C33—1000 pF capacitor
C6—390 pF capacitor
C7, C9, C15, C20—10 μF, 50 V elec. capacitor
C8, C25—2.2 μF capacitor
C10, C11, C18, C19, C22—0.01 μF capacitor
C12, C13, C24—0.56 μF capacitor
C14—2700+ pF capacitor (see text)
C16, C17—1500 pF capacitor ±5%
C21, C23—3900 pF capacitor ±5%
C26, C27, C28, C29—2000 pF capacitor
PL1—10 V, 15 mA Type 344 pilot light
L1—10 mH choke (Nytronics SWD 10000)
T1—600:1500(both c.t.) transformer, pri. & sec. reversed (UTC-SSO-20)
D1, D2, D3—Germanium diode (1N277)
D4—6 V zener diode (1N762)
D5—5.1 V zener diode (1N751)
D6, D7, D8, D9, D10—Silicon diode (1N914)

Fig. 2. Complete schematic of demodulator shown in Fig. 1. Note low parts count made possible by using three monolithic chips.

tions. If the amplitude of the pulses is high enough, conduction occurs. Diode *D*1 clamps the base to approximately −0.2 volt so that the base sees only positive pulses. Conduction begins when the pulse peaks are approximately 1.5 volts and saturation occurs when pulse amplitude equals 2 volts.

Usually pulses above 1.7 volts amplitude will provide enough current to light the stereo "on" lamp, *PL*1. Full indicator brightness occurs at saturation.

The Darlington's collector voltage swing is used as the gating voltage for the 38-kHz oscillator. This voltage, coupled through *R*11 and *R*31 to terminal #6 of the CA3001 38-kHz oscillator, unbalances the differential amplifier in the CA3001 and reduces the differential gain for as long as the Darlington collector voltage remains high. When the gating voltage drops to approximately 13 volts, the CA3001 approaches a balanced condition and oscillations build up. As the Darlington saturates, diode *D*6 clamps the junction of *R*11 and *R*31 to 4.7 volts to prevent gating the oscillator off in the reverse direction.

The 38-kHz oscillator is a Wien bridge type with *R*28, *R*32, *C*21, and *C*23 forming the frequency selective portion of the bridge. Amplitude limiting is controlled by applying negative feedback to one side of the differential amplifier through *R*30. *R*32 adjusts the frequency and phase of the oscillator to its proper relationship with the 19-kHz pilot. Sync for the oscillator is provided by feeding the amplified doubler output from terminal 9 of the CA3018 through *C*2 and *R*2.

The output from the 38-kHz oscillator is coupled to the detector diodes by *T*1. This transformer switches the diode detectors when demodulating a stereo signal. In the absence of the 38-kHz signal, the diodes are all forward biased and a monophonic output results.

Either a stereo station or a 19-kHz generator can be used as an alignment tool. We recommend that preliminary adjustments be made using an oscillator and final adjustment be done with an off-the-air signal. The 19-kHz oscillator must have an accuracy of ±100 Hz to correctly align the pilot channel.

This is how the alignment procedure goes. Apply a 19-kHz signal to the input and tie an oscilloscope to terminal 7 of the CA3035. (A very low capacitance probe should be used to minimize the effect on the tuning of the twin-T.) Adjust the threshold control and input signal level so that a 1-volt peak-to-peak signal appears at terminal 7. (Note: This voltage should be maintained by varying the input level as the tuning operation progresses.)

Adjusting *R*20 should peak the output signal at terminal 7; the sharpness of which will depend upon the exact value of *C*14. It should be possible, by adjusting *R*20, to cause the amplifier to oscillate. To check this, remove the input and look for an output at terminal 7. When *R*20 is correctly adjusted, its resistance will be slightly higher than that at which oscillations occur. *C*14 should be padded and *R*20 adjusted alternately until the (*Continued on page 74*)

Fig. 3. When CA3035 is properly tuned, output waveforms at pins 5 and 7 will look like those at left. At right, the output to Darlington amplifier and doubler diode outputs are shown.

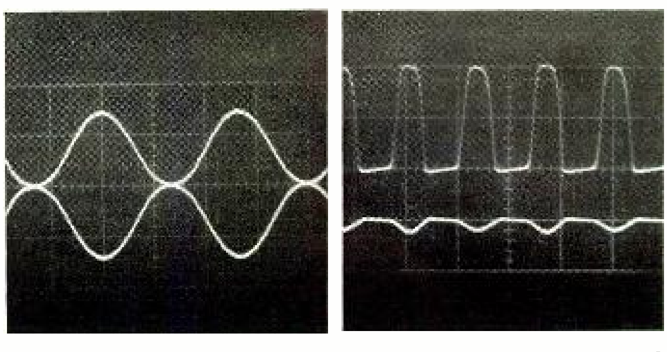


Fig. 1. View of the high-voltage tester being used in the daily testing of high-voltage power supplies for IBM's TV-like CRT display stations. The reason for the large size of the tester is the large size of some of the h-v components used.

HIGH-VOLTAGE PRODUCTION TESTER FOR COMPUTER DISPLAYS

By GEORGE A. BOLD / Sr. Associate Manufacturing Engineer, IBM Systems Manufacturing Division

Description and design of a high-resolution tester that checks 35-kV power supplies for cathode-ray tube displays used in computer systems.

THE use of cathode-ray tube displays in commercial and scientific computer systems has created a number of specialized manufacturing and testing problems. For example, the graphic display stations used with *IBM* System 360 computers require an extremely precise high-voltage source for the CRT's used. These units employ up to 30,000 volts at currents below one milliampere and they must be tested to a resolution of 0.005 percent. In other words, voltage changes as small as 1½ volts must be measurable.

This requirement has made it difficult to test the display's power-supply units because high-voltage measuring equipment with this degree of resolution was not readily available. Also, available testing devices did not take into account all of the potential safety hazards faced by the test operator.

A testing device, which not only provides the required resolution and accuracy but also takes into account the safety of the operator, has been developed. The device, or more exactly, the testing system, is now being used in the production testing of power supplies for cathode-ray-tube displays by manufacturing engineers at *IBM's* Systems Manufacturing Division plant in Kingston, N. Y. Members of this group designed and built the high-voltage tester, which uses a precision high-voltage reference supply in conjunction with the "null" principle of electrical measurement, to measure the output voltage of the power supply that is being tested.

Tester Design

The tester, 10-feet long, 8-feet wide, and 6-feet high, is "U" shaped (Fig. 1). The size of the unit was dictated by the large size of many of the high-voltage components used.

A Formica-covered table top is located to the left of the "U". Half of this top is fitted with a movable safety cover that can completely enclose the power supply being tested (Fig. 2).

The tester is housed in a special room which has its own air-conditioning unit containing dust filters and a dehumidifier. This controlled environment protects the tester against contamination by dust and other airborne matter as well as guards against subsequent high-voltage leakage. The room in which the tester is located also has lights that can be controlled from the tester and turned off for visible corona (leakage) checks.

Many problems were encountered during the design stage of this project. One of the knottiest was the approach that should be used in the measuring equipment to provide high resolution (at least 0.005 percent) at load currents in the microamp range.

Electrostatic voltmeters, inherently low-resolution devices, were found to be useful only as rough indicators. Voltage dividers were also considered. But, like the voltmeters, they were rejected as not being practical because of voltage gradient problems, physical size, and high cost. (To test a power supply with an output of 27,000 volts at 50 microamperes, with a total resolution of 0.005 percent, would have required a voltage divider in the range of 540 megohms plus a second divider to provide load-changing capability.)

Because of the difficulties involved, it was decided to use the "buck-boost" (or null) method to directly null-out the high voltage. Following this course, however, gave rise to additional problems in technique which were reflected in the physical design of the tester's components. These will be described later.

Another difficulty encountered during the design stage involved the ripple voltage and how it could be measured. This problem was solved by coupling the ripple voltage directly to an oscilloscope through a high-voltage capacitor. Using a 3900-pF, 40-kV capacitor resulted in ripple measurement to an accuracy of 5 percent or better, depending on the frequency.

The possibility that leakage, in the form of corona, and arcing in the high-voltage lines, would occur was also considered during the design stage. It was found that both leakage and arcing had to be eliminated because of the low output current of the power supplies being tested.

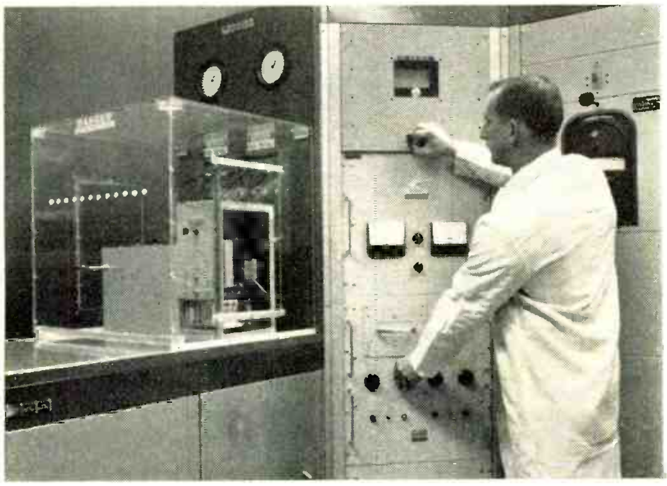


Fig. 2. The operator is shown here testing for a "null." The power supply being tested is at the left, completely enclosed in a movable, transparent plastic safety cover.

One of the power supplies tested has a full-load output current of 10 microamperes at 15,000 volts. It was found that at least 10 microamperes of corona will result if extreme caution is not taken when wiring the tester's circuits. The presence of this corona can cause a reduction in the tester's measurement accuracy unless high-voltage wires are carefully placed.

Operator Safety

Operator safety, one of the most important considerations in the design of this tester, was emphasized by the extensive use of safety covers and interlock circuits. Compact relays (rated at 8000 volts in air) were immersed in liquid Freon so that the operator could switch the high potentials from a central control panel (Figs. 3 and 4). This technique eliminated corona in the switching circuit during the test while at the same time boosted the useful operating voltage of the relays to 35,000 volts.

The 8000-volt relays were selected over manual switches or vacuum-type relays because they are compact, economical, and provide a high degree of operator safety.

Interlock circuits were also used in the testing device so that high voltages are removed and test-unit outputs bled to a safe level if a door or safety cover is opened.

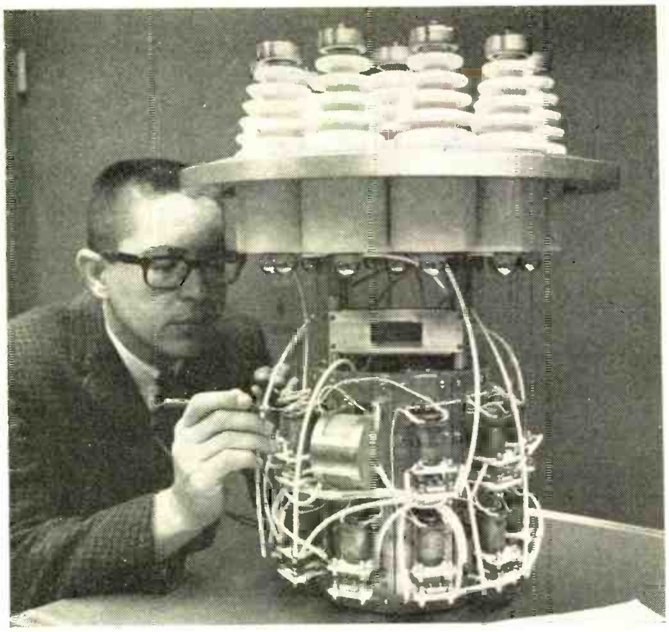


Fig. 3. Assembly of 8000-V relays which is to be immersed in tank of Freon liquid. The liquid, high in dielectric strength, eliminates corona and raises the operating voltage of the relays. When repairs are necessary, the relay assembly dries clean in air within 5 seconds after removal from tank. Load tubes and resistors form part of assembly.

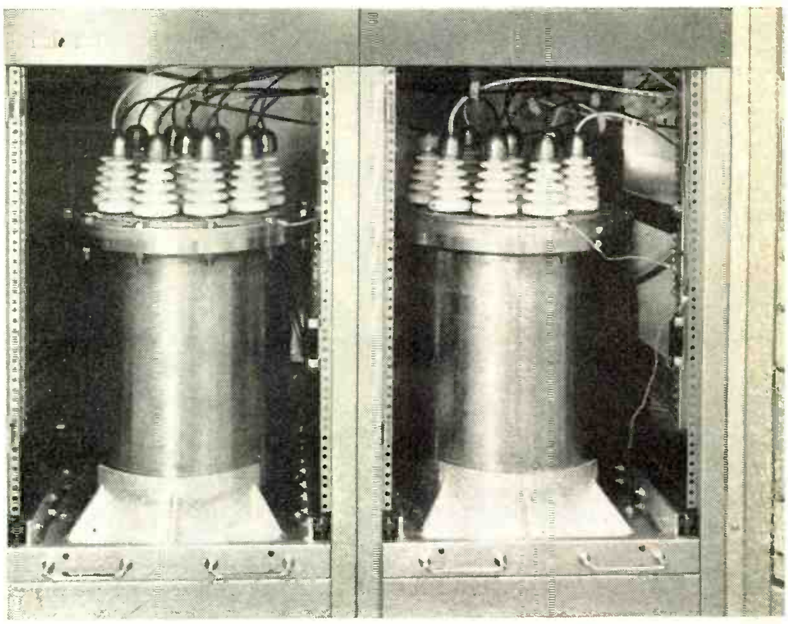
The tester uses 50/60-Hz, 230-V, three-phase power. Variable transformers provide adjustable a.c. power to the power supply being tested. Two sources of 0-60 volts at 5 amps and two sources of 0-300 volts at 5 amps are available for power-supply units which require d.c. input. Several d.c. sources were also employed for tester control voltages that are required.

Six Simultaneous Loads

The tester is capable of testing power supplies with up to six simultaneous output sources. These are divided into two groups: three "low" voltage outputs and three "high" voltage outputs.

The low-voltage section covers voltages up to 5000 volts. Loading is accomplished by using three variable-resistance voltage dividers. Each load divider consists of two high-

Fig. 4. The tester's two relay tanks are mounted on slides inside two 42-in cabinets located at the far left of the "U"-shaped unit. Top surface of cabinets serves as work area.



voltage decade resistance boxes, one ganged to the other. Fig. 5A shows a simplified diagram of the circuit.

This arrangement permits the load resistance to be varied while at the same time maintaining a constant 1000:1 voltage-divider ratio. Voltage readout is taken with a digital voltmeter on the output of the voltage dividers.

The high-voltage section covers three separate outputs, ranging from 5000 to 35,000 volts. The load elements in this case are 6BK4 triodes. The load current is controlled by varying the bias on the grid of these tubes. Load current is read on a microammeter in the cathode circuit (Fig. 5B).

Output voltages from the power supply undergoing test are applied to the loads *via* the Freon-immersed relays.

Measurement Technique Used

The buck-boost method of high-voltage measurement used in the tester is believed to be unique for voltages in the 5000-35,000-volt range. Although this method is used extensively at low voltages, direct high-voltage measurements have been restricted to electrostatic meters with inherent low resolution. It was selected over divider methods because (1) high-voltage dividers at currents below one milliampere are cumbersome, difficult to construct, and costly; and (2) housing these devices in a production tester is impractical because they are large (3 to 4 feet high and 18 inches or more in diameter) and have exposed high voltage.

The reference sources were *Fluke* high-voltage power supplies. A Model 410B covers the range of 0 to 10,000 volts while a modified 430A covers the 10,000- to 35,000-volt range. These power supplies have a calibration accuracy of 0.25 percent, a resolution of 5 mV and 100 mV respectively (with stability of 0.005 percent per hour), and a regulation of 0.01 percent or better.

With the reference sources selected, the next major problem in the design project was to devise a null detector. The null detector uses an ordinary center-zero microammeter inside a metal box. One terminal of the meter is electrically connected to the box. This box, in turn, is mounted on long ceramic stand-offs inside another metal box which is grounded. Openings are provided in both boxes so that the meter can be read conveniently.

High-voltage inputs through the grounded box were carefully insulated to prevent leakage. Connecting the inside box to one side of the circuit permitted the box and microammeter to float at the potential being measured, which can be up to 35,000 volts (Fig. 5C).

Resolution of the null detectors is 100 mV. A sensitivity network allows the null detector to indicate up to 50,000 volts full-scale on lowest sensitivity, although for test measurement purposes all readings were taken on null. In an effort to reduce the size and cost of the tester, two of the output levels shared the 430A reference source and one null detector.

An electrostatic voltmeter was used for rough measurements where resolution was not considered to be critical. An electrometer voltmeter, with an input impedance of 10^{12} ohms, was also used to check "bleed-down" characteristics of the tested power supplies.

Switching and Controls

Another important part of the project was the switching of high voltages. The 8000-volt compact relays mentioned previously were immersed in two tanks of Freon liquid. The Freon, high in dielectric strength, eliminated corona and raised the operating voltage of the relays. It was preferred over oil because it will squeeze out from between closed relay contacts. When repairs are necessary, the relay assembly dries clean in air within 15 seconds after being removed from the Freon solution. Small high-voltage circuit components like relays, load tubes, null detector sensitivity resistors, and bleed-down resistors were placed in this liquid solution.

Although a good solvent, the Freon did create some problems when used in connection with organic compounds. These problems were overcome, however, by coating all questionable materials with epoxy. In cases where it was necessary to build non-metallic structures, Teflon was used instead of phenolic materials. (Care was taken to remove all solder flux from electrical connections before high voltage was applied to the Freon-immersed assembly. If this is not done, a fungus-like growth begins to appear at the site of the flux.)

High-voltage connections are made into the tanks of liquid Freon through special high-voltage feed-through connectors with 1.5-inch corona balls surrounding the actual connection point. The relay tanks are mounted on slides inside two 42-inch cabinets, the top surfaces of which serves as the work area for the tester.

Molded high-voltage connectors are used between the tester and the power-supply unit undergoing test. High-voltage wires rated at 40 kV bridge the gap between these connectors and the various components in the tester. Because these connectors preclude the use of shielded cable, sufficient space had to be allowed between wires inside the tester and between these wires and the tester's frame. Care was taken to keep all wires three inches from any conducting material, by using special Plexiglas separators.

It was found in testing various production power supplies with outputs of 30,000 volts or more that care must be taken when wiring the supply unit in order to prevent any possibility of arcing.

Development of a high-voltage tester for these power supplies has enabled *IBM* to significantly increase the accuracy of its cathode-ray-tube displays while eliminating any potential safety hazards that might be encountered by the operator during the testing process. ▲

Fig. 5. (A) Resistive load divider used for voltages up to 5000 V. (B) Vacuum tubes are used as load for voltages ranging from 5000 to 35,000 V. (C) Microammeter is mounted on box within a box so it can "float" at potential being checked.

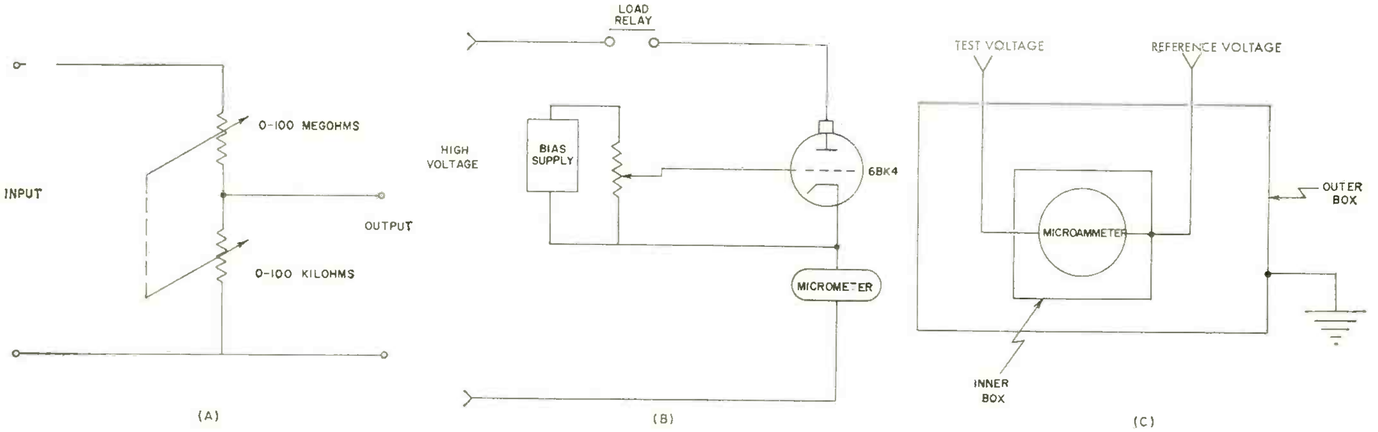
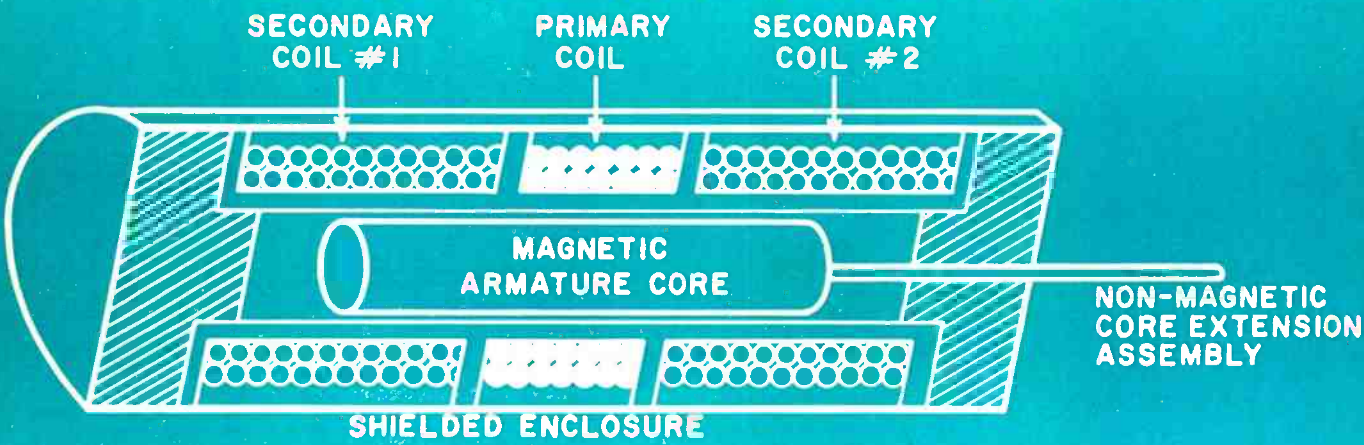


Fig. 1. Cutaway view of a typical differential transformer.

DIFFERENTIAL TRANSFORMERS



By SIDNEY L. SILVER

Operating principles of a high-precision electromechanical transducer that is used in industrial instrumentation, telemetering, and inertial guidance.

IN an increasing number of applications, electromechanical measuring devices are employed as high-precision transducers in automatic control systems and processes. One of the most widely used electromechanical transducers for converting physical quantities into electrical values is the *differential transformer*. Such a device produces an electrical output which is proportional to the mechanical displacement of a linear moving element. As a primary sensing element, it is incorporated in many industrial instruments to accurately measure, control, and record such variables as temperature, humidity, vibration, pressure, flow, radiation, strain, and many other process functions which are susceptible to change.

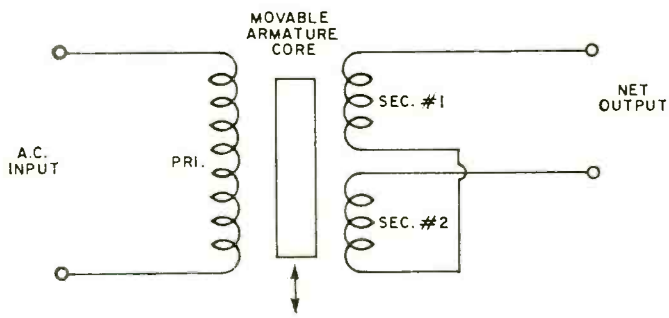
Differential transformers are particularly adaptable to the telemetering of electrical signals in which the measured variables are transmitted to remote points. In inertial guidance systems, they are commonly used as sensors to measure linear velocities and accelerations, in order to control the flight path of missiles and other unmanned space vehicles. Generally, differential transformers are found wherever it is necessary to translate relatively small linear motions into highly stable a.c. output signals.

Theory of Operation

Basically, a differential transformer is a mutual-induction unit consisting of a primary coil and two secondary coils mounted on a hollow non-magnetic form. A magnetic armature core is passed through the form to develop a variable magnetic coupling between the primary and the secondary windings. As shown in Fig. 2, the primary coil is energized by an a.c. source to provide a continuous magnetic field, and the two secondary coils are connected in series-opposition so that their induced voltages are 180 degrees out-of-phase. The position of the movable core within the coil assembly determines the relative flux distribution and hence the mutual coupling between the primary and each of the secondary windings.

When the armature core is positioned so that each secondary coil receives an equal amount of flux, the induced voltages will be equal. At this point, the induced voltages effec-

Fig. 2. Schematic representation of differential transformer.



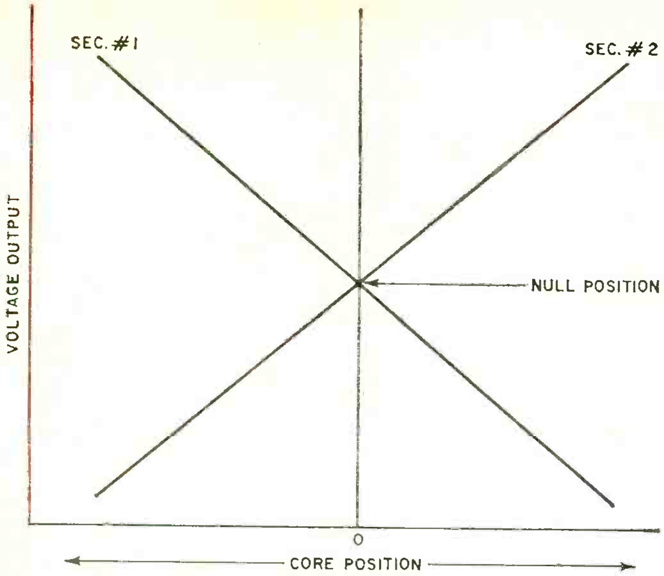


Fig. 3. Voltage curves for linear range of core displacement.

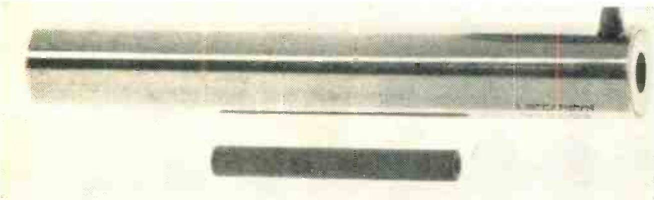


Fig. 4. Commercially available differential transformer which features complete separation between core and coil assembly.

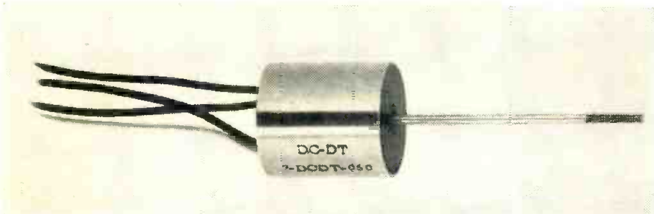


Fig. 5. Miniature displacement transducer of the differential type which employs self-contained carrier system as described.

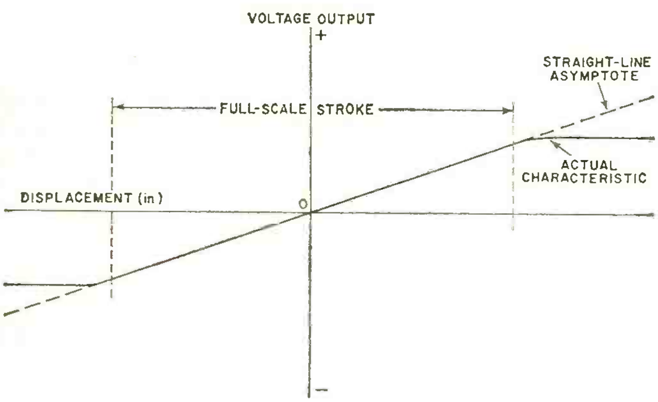
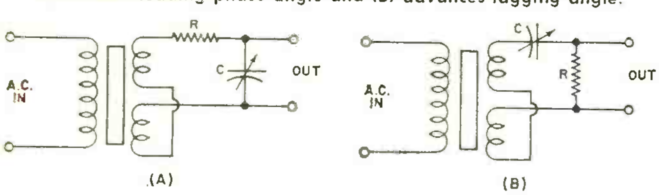


Fig. 6. Linearity characteristics of differential transformer.

Fig. 7. Circuits for adjusting phase angle to zero. RC network (A) retards leading phase angle and (B) advances lagging angle.



tively cancel each other so that the net output voltage is theoretically zero. This condition denotes the electrical center of the device, referred to as the *null position* or *balance point*.

If the armature is displaced by an actuating force to either side of the null position, the voltage induced in the secondary toward which the core is moved increases, whereas the voltage induced in the other secondary decreases. Similarly, motion of the core in the opposite direction produces a corresponding voltage of opposite phase. The difference between each secondary coil voltage results in an a.c. output signal whose magnitude is proportional to the axial displacement of the core from the null position. For every possible position of the armature core within the designed displacement range, the output voltage is either 90 degrees or 270 degrees out-of-phase with the primary excitation voltage, depending on which side of the balance point the core has been moved. Fig. 3 shows the voltage curve of the secondary windings as the armature core is moved through its linear range of displacement.

Construction Features

In the most common arrangement, the primary and secondary coils are wound in close proximity on a tubular bobbin fabricated of a suitable non-metallic material. A laminated plastic, such as epoxy, is generally used because of its dimensional stability and ruggedness, as well as its low coefficient of thermal expansion. As illustrated in Fig. 1, the primary winding occupies the center portion of the bobbin and the secondaries are spaced equidistant from the primary, along the end sections of the form. To provide high resistance to environmental humidity, shock, and vibration, the entire coil assembly is encapsulated in a potting compound such as epoxy resin.

Many differential transformers incorporate shielding to reduce disturbances caused by surrounding metallic masses which may distort the normal symmetrical pattern of the displacement *vs* output-voltage curve. Any metallic mass located at the ends of the transducer will have the most pronounced effect since the flux concentration is highest in this region. In applications involving displacement measurements in high alternating-current fields such as those associated with motors, the coil assembly is hermetically sealed in a special magnetic steel jacket. This arrangement minimizes the effects of stray electrostatic and electromagnetic coupling.

The armature core is made of a high-permeability ferromagnetic alloy which is free to move axially within the bore of the cylinder without actually making mechanical contact. Since each core must be accurately matched to a particular transformer, the device must be precisely machined in order to obtain a linear magnetic characteristic. To further improve the magnetic properties, the core is heat-treated during the fabrication process to relieve mechanical stresses. The core extension assembly consists of a non-magnetic plunger which is threaded into the end of the core and bonded with cement. According to application, the plunger may be spring-loaded to help eliminate radial forces which can contribute to measurement error. Where dynamic displacements are too rapid to be accurately followed by a spring-loaded plunger, the transducer is provided with a separate armature core and plunger assembly for direct attachment to the moving object to be measured.

Fig. 4 shows a commercial differential transformer which may be used to measure any physicial variable capable of conversion to a relative displacement as small as one-millionth of an inch between core and coil assembly. Units of this type are especially adaptable to displacement measurements involving liquid level, fluid flow, and pressure. The complete separation of the armature and coil assembly remains external to the fluid. In Fig. 5, a miniature differential transformer which contains a built-in carrier system is shown.

This type of transducer requires a d.c. excitation which is modulated in the primary circuit. The secondary voltage is demodulated and filtered to provide a direct-current output.

Electrical Characteristics

In defining the quality of performance of a differential transformer, an important consideration is the functional relationship between the voltage output and the armature displacement on either side of the null position, where the curve begins to deviate from a straight line (Fig. 6). This relationship, referred to as the linearity characteristic, is usually taken as the best straight line drawn through the zero position to the maximum rated output points, and is expressed as a percentage of full-scale output voltage.

A linearity of ±0.05% of total stroke range of the armature core can be expected from commercial units. Linear range, or the excursion of core travel for which a particular transformer is designed, may vary from ±0.005″ for miniature transducers to ±10″ or more for larger units. To achieve good linearity, the geometric tolerances of the magnetic armature assembly must be closely controlled, so that the relative mutual coupling between primary and secondary coils changes as a linear function of armature displacement.

Of equal importance in establishing specific performance requirements is the nominal phase shift of the output voltage with respect to the input voltage. This parameter is expressed in degrees which may be leading, lagging, or zero, depending on the excitation frequency and the ambient temperature. Although differential transformers are capable of operating over a wide range of energizing frequencies (60 Hz to 20 kHz), each unit exhibits a phase shift of zero degrees between the primary input and secondary output voltages at a specific frequency. The output of the transformer is reasonably constant at this frequency over a wide range of ambient temperatures and throughout an excitation frequency range of ±5% of the zero phase frequency.

If the phase-angle shift caused by variations in ambient temperature is intolerable, it is possible to compensate for these changes by inserting a phase-correction network in the output circuit. To retard a leading phase angle, the *RC* combination shown in Fig. 7A is used to load the secondary, while the network in Fig. 7B is used to advance a lagging phase angle. In both cases, capacitor *C* is adjusted until a zero phase shift is achieved.

Another useful criterion for evaluating the operating characteristics of a differential transformer is the sensitivity, or output voltage rating of the device. This is based on the nominal output at one mil (0.001″) displacement of the armature, with one volt excitation on the primary coil at a specific frequency. Sensitivity is influenced by excitation level and can vary substantially at different load conditions.

The most significant factor limiting the maximum excitation voltage at a given frequency is the maximum allowable primary current which can be used to excite the transformer without overheating. The allowable input current increases as the ambient temperature decreases and *vice versa*. Generally, it is desirable to operate with no more excitation voltage than is necessary to obtain the desired output voltage. The maximum excitation voltage at room temperature may be calculated at a given frequency by multiplying the allowable input voltage by the primary input impedance at that frequency. Excitation voltage varies from 1 to 30 volts for standard units.

At low frequencies, the sensitivity is a function of the resistive component of the primary coil impedance. Any change in ambient temperature alters the primary resistance so that the resulting input current variation causes the magnetic flux and hence the output sensitivity to change. At the higher frequencies, an increase in input impedance due to high reactive components causes a reduction in the output voltage. Since the reactive values dominate the impedance,

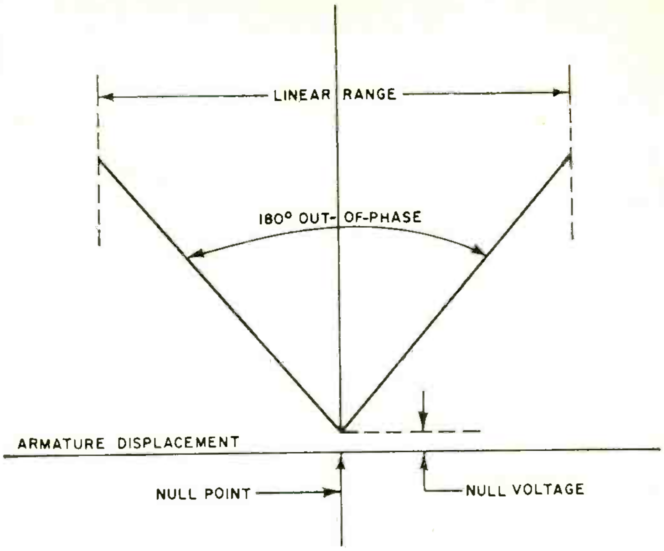


Fig. 8. Net output curve showing null voltage at balance.

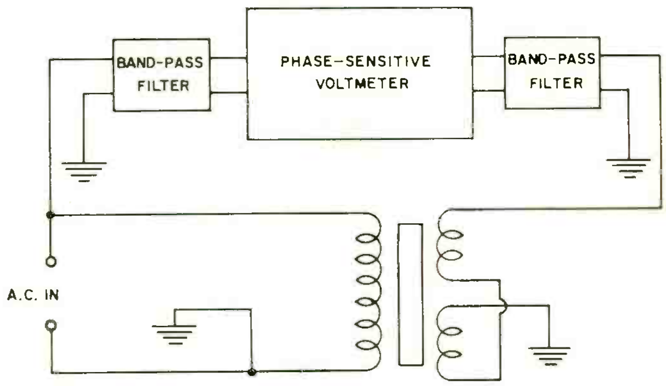


Fig. 9. Setup for testing null characteristics. Matched band-pass filters are used for large amount of harmonics and hum.

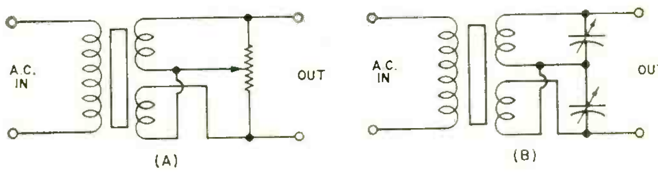


Fig. 10. Quadrature-rejection circuits. Upon adjusting the quadrature voltage to zero, the pot in (A) and trimming capacitors in (B) may be replaced by fixed components.

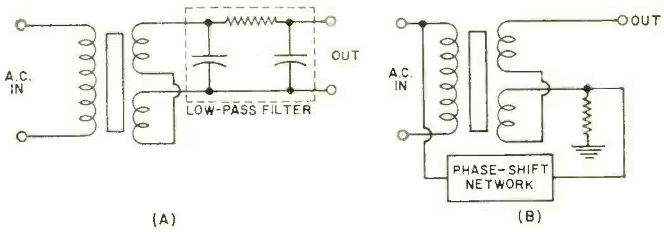
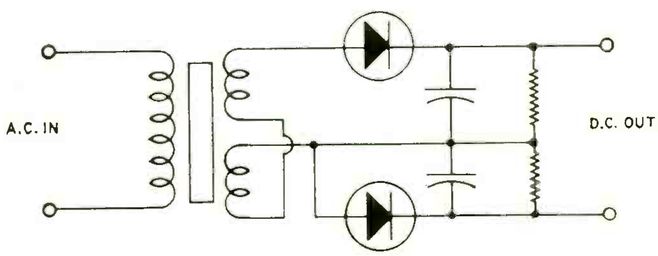


Fig. 11. Methods of suppressing harmonics at the null position include (A) low-pass filter and (B) phase-shift network.

Fig. 12. Simple readout producing a d.c. demodulated output.



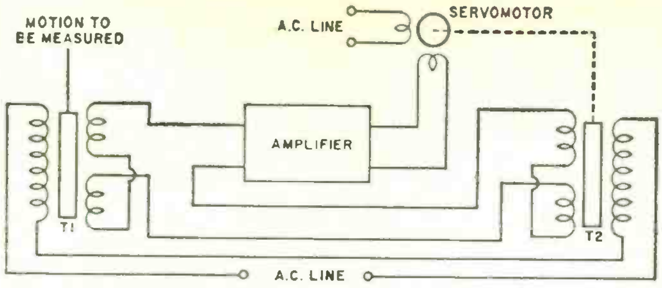


Fig. 13. Matched pair of differential transformers that are employed in a null-balance servo system described in text.

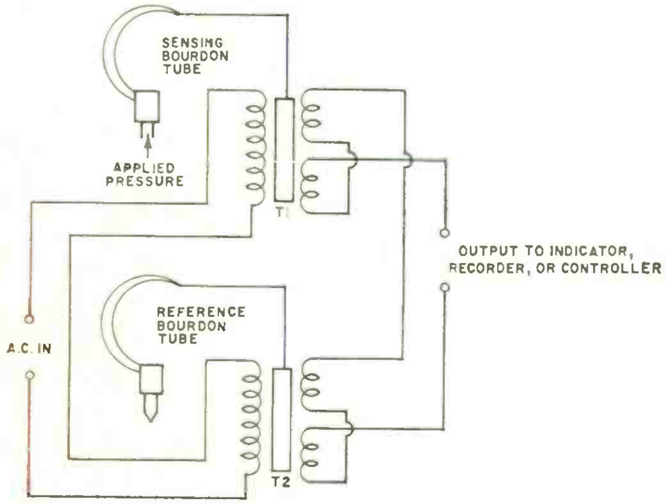


Fig. 14. System used to measure absolute fluid pressure.

any change in primary coil resistance due to a variation in ambient temperature has a negligible effect on sensitivity.

The optimum excitation frequency is that which causes the output voltage to reach a maximum, beyond which point the sensitivity starts to decrease. It is desirable to operate the transformer at this frequency (zero phase), since any losses in the primary circuit due to an increase in ambient temperature are balanced out by an equivalent reduction of eddy current and hysteresis losses in the magnetic core assembly.

Null-Voltage Components

Due to the presence of residual voltages at the null point, the output of a differential transformer is not exactly zero but approaches a minimum. Since residual voltages tend to reduce sensitivity in deplacement-measuring systems with a consequent loss of accuracy, it is desirable to maintain as low a null signal as possible. Some of the basic factors which contribute to undesirable residual effects are non-symmetry in the geometric dimensions of the armature core, non-linearity of the magnetic properties of the core due to impurities, and poor winding distribution. These residual elements can be effectively minimized by careful engineering and close manufacturing control. Fig. 8 shows the net output curve of a typical transformer in which the null voltage consists of a very small percentage of the full-range output at the standard frequency.

The null-voltage components of a differential transformer are composed of three elements of the fundamental (excitation) frequency: an in-phase component, a quadrature component, and harmonics. Noise and stray pick up also influence the magnitude of the null voltage to some extent, depending upon the voltage levels employed, operating frequency, and the effectiveness of the shielding components.

To determine the null characteristics of a differential transformer, a phase-sensitive voltmeter is connected across the output, as indicated in Fig. 9, to provide direct readings of the phase relationships among the complex signal components at the null position. Any in-phase residual voltages appearing at the balance point may be cancelled out by shifting the zero position of the armature to correct for slight unbalances in the symmetry of the magnetic core assembly. Quadrature, however, cannot be cancelled out by zero shifting the core, but requires simple network trimming procedures.

Quadrature voltage consists primarily of an unwanted component of the fundamental frequency remaining at the null which is 90 degrees out-of-phase with the predominant phase of the output signal. This error voltage is caused by small differences in phase angle which exist between the voltage output of each secondary coil. Fig. 10A shows a common method of quadrature rejection in which a high resistance potentiometer is placed across the output in such a way as to provide a different load across each secondary. By adjusting the pot setting, a point can be found where the quadrature error will be close to zero. In Fig. 10B, similar results may be obtained by using small capacitors.

Harmonics of the fundamental frequency may be generated at the null point due to non-linearity of the magnetic material of the armature, distributed capacitance between the coil and the magnetic core, and distortion of the excitation frequency. Since the presence of harmonics obscures the true null position of the fundamental frequency, they must be kept within tolerable limits by employing high-permeability cores operating at low flux densities.

If harmonics are still objectionable, the output signal may be passed through a low-pass filter, as shown in Fig. 11A, which is adjusted to pass only the fundamental frequency. Care must be taken in the design of the harmonic suppressor, however, to avoid the introduction of time delays which may cause a lag in the fundamental frequency and adversely affect the stability of the measuring system. Where third harmonic distortion is predominant, the input voltage may be fed through a phase-shift network as in Fig. 11B, into the secondary circuit. The reversed phase voltage cancels out the fundamental existing at the third-harmonic null position.

Readout Circuitry

One of the simplest measuring systems to provide an indication of mechanical displacement is the demodulator circuit illustrated in Fig. 12, in which the output of each secondary is rectified and appears as a linear d.c. output voltage across the resistors. The polarity of the output signal corresponds to the direction of displacement from the null position. To obtain a readout, the transducer is initially balanced to give a minimum output at the energizing frequency, and measurements are taken from either side of the balance point. Even the slightest variation in core position has a measurable effect on the output voltage. It is desirable to hold the excitation frequency to at least ten times the highest mechanical modulation frequency, in order to avoid errors due to filtering and to maintain the desired sensitivity.

A more sophisticated approach which combines greater accuracy with maximum sensitivity is the null-balance circuit shown in Fig. 13. In this system, two matched differential transformers are employed in a bridge circuit to form a null-seeking device. The differential voltage output is fed through an amplifier to one phase of a servomotor while the other phase is continuously energized by the line. When both differential transformers produce equal out-of-phase voltages, there is no output to the amplifier and the system is at rest. If an unabalance occurs due to a mechanical displacement of the sensing transformer *T1*, a restoring signal excites the motor in the proper direction. Since the core of the balancing transformer *T2* is mechanically linked to the motor shaft, the system is returned to a balanced condition.

Since the primary windings of both differential transformers are connected in series- (*Continued on page* 66)

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Because every manufacturer *claims* to have the "guts" to make the best sound. But, if you had the opportunity to "tear apart" most of the tape recorders on the market, you'd find a lot of surprises inside.

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Like stamped sheet metal and lots of other not-so-solid stuff that gets by but who knows how long? And all kinds of tiny springs and gadgets designed to do one thing or another. (If you didn't know better, you'd swear you were looking at the inside of a toy.)

Like heads that are only adequate. Heads that might work fine at first, but wear out sooner and diminish the quality of sound reproduction as they wear.

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Exclusive Ampex rigid block head suspension. Most accurate head and tape guidance system ever devised. Solid.

Exclusive Ampex deep gap heads. Far superior to any other heads on the market. Last as much as 10 times longer. There's simply no comparison.

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Pick the Ampex 755 for example. (This is the one for "professional" nitpickers.) Sound-on-sound, sound-with-sound, echo, pause control, tape monitor. Three separate Ampex deep gap heads.

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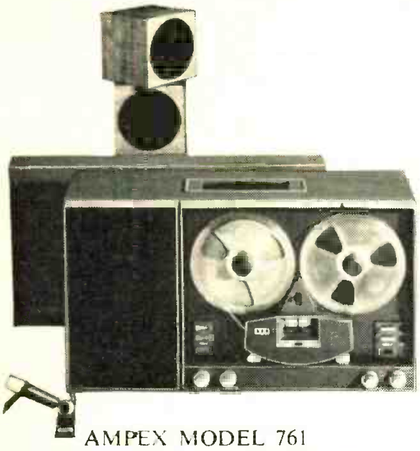
Model 755

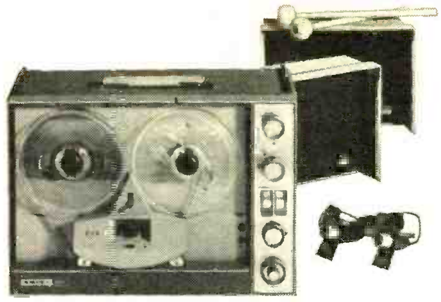
Model 1455

A deck for nitpickers.

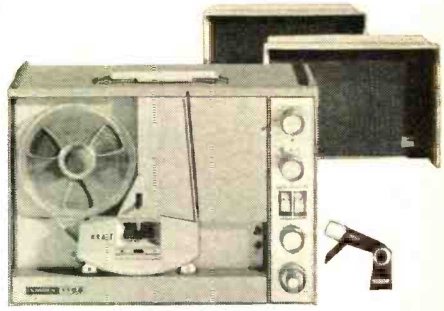
And a deck for lazy nitpickers.



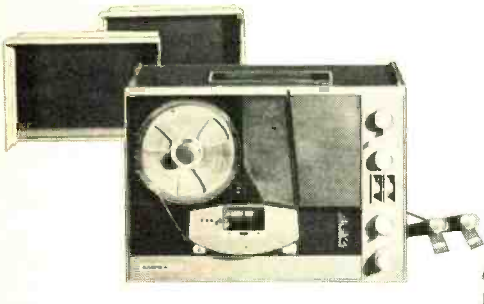
AMPEX MODEL 761
Three-head stereo portable tape recorder. With monitor, echo, sound-on-sound, sound-with-sound.



AMPEX MODEL 861
Two-head stereo portable tape recorder. With slide-on speakers.

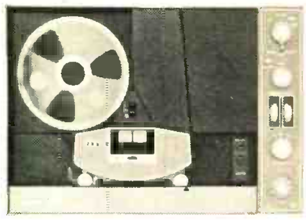


AMPEX MODEL 1161
Three-head stereo portable tape recorder. With automatic threading and reverse, slide-on speakers.

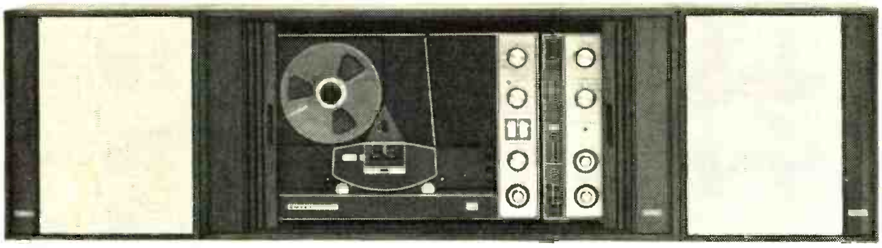


AMPEX MODEL 2161
Four-head stereo portable tape recorder. With automatic threading and reverse, bi-directional recording, and mixer.

AMPEX MODEL 1461
Four-head stereo portable tape recorder. With automatic threading and reverse, monitor, sound-with-sound.



AMPEX MODEL 2150
Four-head stereo tape deck. With automatic threading and reverse, bi-directional recording, and mixer.



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Three-head stereo music center. With automatic threading and reverse, built-in FM stereo, FM/AM receiver, and two dynamic microphones.

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CIRCLE NO. 124 ON READER SERVICE CARD

JOHN FRYE

Electronics is the handmaiden of the art of surveillance but technicians must use their "know how" for the common good.

ELECTRONICS AND SPYING

HEY, Mac, did anyone ever try to enlist your electronic know-how in spying or in similar hanky-panky?" Barney asked his employer working at the service bench beside him. "What on earth makes you ask that?" Mac exclaimed.

"Oh, I dunno. I've just been reading about various modern methods of surveillance and the electronic gadgets used. I mean everything from crude wire taps to sophisticated, hush-hush satellites employed in international spying. All at once it came to me that a mossy old electronics technician such as you are must have been approached in this regard somewhere along the line."

"Knock off that 'mossy' bit," Mac ordered with some asperity, "but it happens you're right. Let me see now. Oh yes! The first incident I recall happened several years ago when a kind of mousey little guy, straight out of a Damon Runyan short story, sidled up to me here at the store and wanted to know if I could make him a miniature transmitter and receiver to be used in playing a joke on a friend. Cost, he said, was no object. That should have made me suspicious right there, but it didn't. He said the apparatus was going to be used in a phony mind-reading act he was putting on to fool a friend.

"Actually, I was intrigued by the problem. You've got to remember this was long before transistors, and trying to miniaturize equipment was a real challenge, but I bought some of those flat little miniature hearing-aid tubes and started experimenting. The receiver was no problem. I simply installed a self-quenched superregenerative detector inside an old hearing-aid and used the aid's amplifier for the audio. The transmitter was something else. Frequency stability was a problem, and so was putting out enough signal with the available small batteries—especially since he kept stretching out the required working distance.

"Finally he admitted that what he really wanted to do was to beat the ticker tape race returns at the local horse parlor. He had it figured out that an accomplice listening to a track-side telephone report of the race could flash the information a block or so to him inside the betting parlor in time to get a bet down on the winner before the start of the race on the slow ticker tape could officially cut off the betting. I was too ignorant of the whole business to know if he was dreaming or not, but as soon as I learned what he was trying to do I dropped the whole project as though it were a red-hot rectifier tube. I could just see myself being hauled into court as an accomplice."

"You said that was the first incident. Were there others?"

"Yes. Not long ago a fellow came to the house one night and wanted me to equip his miniature battery-operated tape recorder with VOX circuitry so that it would operate only when sound was striking the microphone. What he had in mind was to plant the recorder in his own house to collect proof his wife was cheating on him! You can bet I didn't touch that one either."

"I get the idea you don't think an electronics technician should concern himself with the construction of snooping equipment of any sort."

"Not at all. I simply believe the technician should be doggone careful about who is going to use the equipment he builds and how it is to be used. I know many electronics technicians are doing excellent, needed work designing and building electronic equipment for use by law officials, the military, and our counter-espionage people. My point is that *any* technology is amoral. The same acetylene torch that welds a broken piece of farm machinery or frees a man trapped in a wrecked car will also obligingly burn a hole in a safe for a burglar. Electronics is no exception. We've both read newspaper accounts of bank robbers using hand-held transceivers and of illegal wire-tapping performed by criminals or even overly competitive businessmen."

"I understand what you're driving at," Barney offered. "When anyone says to me, 'Can you—?' I want to show him I can. I'm proud of what I can do with electronics, and it would be very easy for me to become so engrossed in working out an electronic problem I'd never think about the long-range results of the solution. Still, you must admit electronics has been a powerful tool for law-enforcement people. Think of the two-way radio, radar speed measuring equipment, and the sophisticated wire taps law-enforcement officials can use under certain circumstances."

"Of course you're right. Electronics is too powerful a weapon to be left in the hands of criminals or subversive elements of our society. And we both know not all technicians are good guys any more than are all pipe smokers or dog lovers. Some clever unscrupulous joker will always sell his knowledge to criminals. But you said you had been reading about surveillance equipment. How about telling me a little about it?"

"Thought you'd never ask!" Barney said with a sigh of relief. "Let's start with something recent and easy to understand. The *CBS Laboratories* in Stamford, Connecticut, very recently received a $69,476 contract from the State of Connecticut to develop a 'noise-pollution' trap. This is basically an instrument that will measure the noise level produced by a car or motorcycle and will tie the measurements to an offending vehicle so this relationship will stand up in court."

"Now that's what I call fulfilling a need!" Mac exclaimed. "We could certainly use something like that on our street. Young knotheads with souped-up hotrods use our street for a dragstrip all night long, and the police always seem to be somewhere else—which may not be a coincidence, since I'm told the gang keeps tab on the squad cars in the vicinity and knocks off their racing and tire squealing when the police approach. How is this gadget going to work?"

"The thing is portable, is about the size of a suitcase, and can be remotely actuated by the police when they think permissible levels are being exceeded. Noise from a passing vehicle is picked up by a microphone and recorded both on a chart and on magnetic tape. At the same time a split-screen camera photographs the chart and the vehicle."

"Sounds like a winner to me," Mac commented, "especially when you remember a noisy vehicle quite often indicates a defective or inoperative muffler that may be leaking dangerous carbon monoxide gas into the car. And that inspires me to dream up a companion unit for the one you just described. Mine will be an 'air-pollution' trap. It will measure the pollution exuded by a passing vehicle, will photograph same, and then correlate the two. As we clamp down tighter and tighter on air pollution—and we must for survival—something of this nature will become mandatory. Only electronics can provide omnipresence to our scanty police forces if checking for noise and air pollution is added to their already heavy work load. But tell me something about snooping gadgets on a more sophisticated level."

"Okay, let's talk about the snooping satellites used by both this country and Russia. Space spying is tacitly accepted by both sides but admitted by neither. There are basically two types of spy satellites: the ones that photograph the earth below, and those that listen for all types of radio signals and record them. The latter are called 'ferret' satellites.

"Anyway, the Russians have orbited a reported seventeen spy satellites from January through August of this year, which have managed to keep watch on the United States for 100 days. The U.S., with only eleven snooper satellites, has inspected the Soviet Union and Red China for 142 days during this same period, according to reports."

"I'd think not much could be learned from photographs taken from such a high altitude."

"There's where you're wrong. The layman was really astonished when he saw what could be learned from crude earth photographs taken by the Gemini astronauts. Even though no attempt was being made to get fine details in these photographs, the Gemini pictures of Love Field Airport, Dallas, permitted identification of airplanes sitting on the runways. It's reported space cameras are now good enough to pick out newspaper headlines from 100-mile altitudes or identify the types of guns carried by soldiers."

"How is the film returned to earth?"

"The Russian capsules are recovered on the ground. According to reports, the U.S. is still using its Discoverer series with Thor-Agena boosters to orbit camera payloads that are jettisoned on command. C-130 aircraft make mid-air grabs of these payloads; or, if necessary, can snatch them from the surface of the ocean. The lifetime of this Discoverer capsule has been boosted up to a month. Since the initial orbit is as low as 100 miles perigee, that means the Agena is most likely restarted sometime during the mission to boost the capsule back up before it decays in the atmosphere. We also are said to be using a larger reconnaissance vehicle put into orbit by a Titan 3B-Agena D combination that can carry a spy payload which may weigh up to three tons."

"What do these spy satellites look for?"

"Mostly for strategic targets: new missiles, ships and submarines, and new radar sites. Both countries are working hard to get as close as possible to real-time satellite surveillance, probably by means of on-board photo developing and scanning for relay to ground stations. Video relay can't yet approach the high resolution of photographs."

"Well, we must conclude some of the very best electronic brains both here and in the U.S.S.R. are devoting full time to the international snooping business," Mac concluded; "and as long as the cold war lasts, this will continue to be true. This may seem a sad waste of electronic know-how, but actually it is not. Techniques developed for snooping are already being readied for the constructive use of mankind, as in the proposed Earth Resources Satellite that will soon be surveying the earth to map the moisture content of various areas, to identify crops, to reveal warm areas of the sea where fish are feeding, to identify sources of stream pollution, and even to spot beginning forest fires. When the time comes for the sword to be hammered into a plowshare, very little effort will be needed to change the malevolent *Spy in the Sky* into a benevolent *Eye in the Sky*."

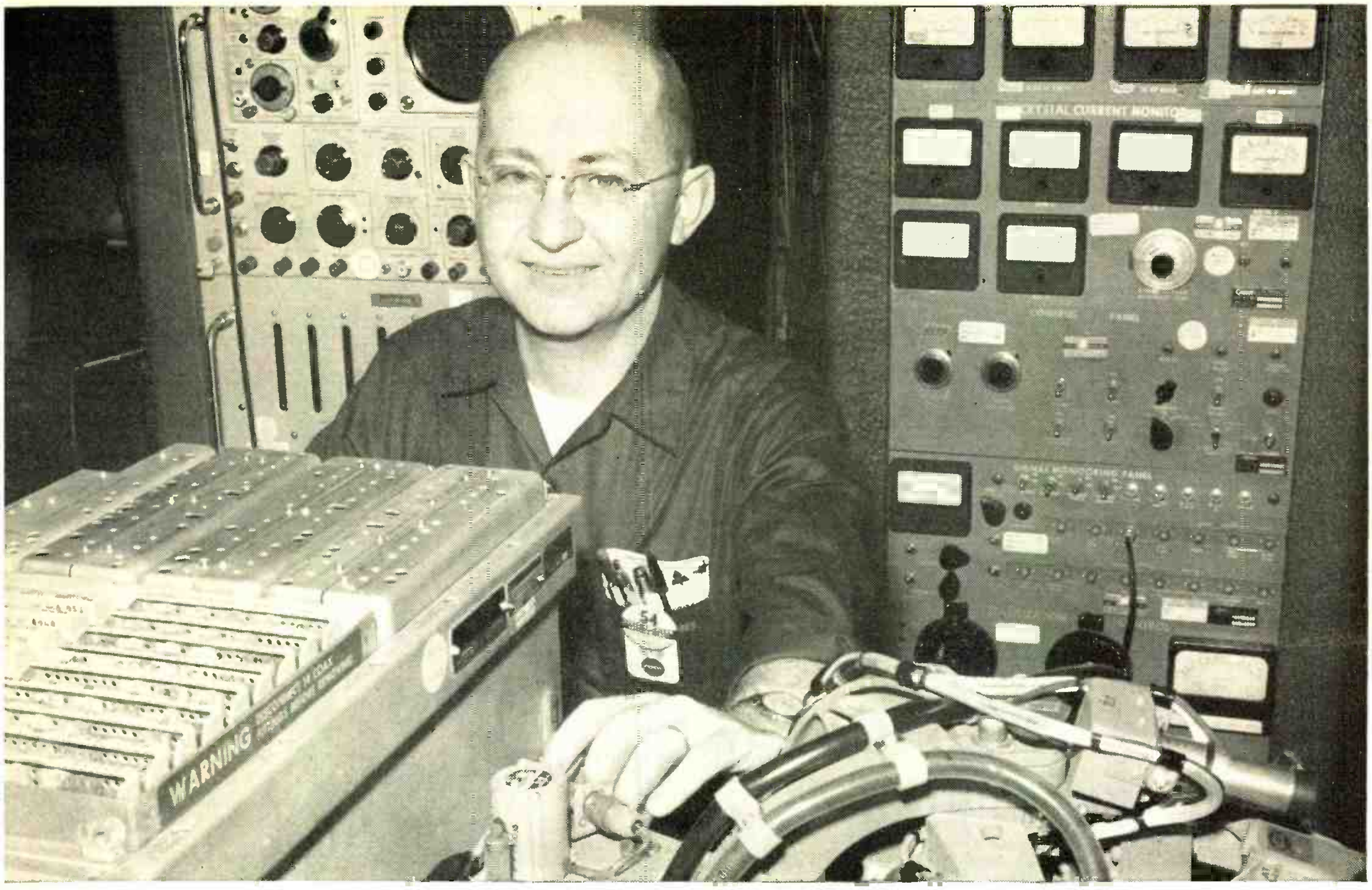
"I'll drink to that," Barney said as he headed for the water cooler. ▲

"FISHTALK" DROWNS ECHOES

Many times during World War II, Navy commanders reported a submarine destroyed only to find out later that their deep-diving submersible was, in reality, a whale. Not only did the sonar beams bouncing off whale bodies confuse the sonar-men, but squeals, buzzes, creaks, taps, and clicks emitted by the whales and other mammals cluttered up passive listening devices. In many instances, subs were able to hide and escape by following a pod of killer whales or a school of dolphins.

Since the end of the war, the Navy has conducted a number of studies whose purpose was the classification and cataloguing of underwater sounds. In this way, Navy marine biologists hope to learn more of the habits and movements of certain species of fish.

More important are the benefits which the Navy's anti-submarine forces derive. Although many new submarines are shaped like fish, sonar echoes from whales and subs have a different quality. Tapes of underwater sounds are used in ASW schools as training aids for fledgling sonar-men. And the experiences of naval oceanographers in tracking the mammals are used to teach the sonar-men what to expect when they "ping" on a pod of the big fish. ▲



replacing components. You need to really know the fundamentals.

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

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

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

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

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CIRCLE NO. 120 ON READER SERVICE CARD

Troubleshooting FET Circuits

(*Continued from page 41*)

Never has there lived a technician who didn't overload his voltmeter (or ohmmeter). Zapping a 50-μA meter movement used to be part of the initiation to the electronics fraternity. (The fee was the cost of buying a new meter.) This embarrassing procedure is on its way out. As Fig. 8B illustrates, the input stage is protected by a diode which limits gate reverse current to the harmless value of 0.1 nA. Neither the FET nor the succeeding bipolar transistors (nor the meter movement) can be seriously damaged by input overvoltage.

A similar technique is used by *Sencore* in the FE-14 field-effect meter (actually an amplified v.o.m.), as Fig. 8C shows. The input gate is protected by a neon lamp which limits gate reverse current to 12 μA, which is well below the manufacturer's limit for the FET used.

The input stage (shown) is a source-follower (analogous to a cathode- or emitter-follower). The complete circuit is almost identical to the classic v.t.v.m. circuit, where the meter movement is connected between the cathodes of a pair of triode vacuum tubes in a differential-amplifier configuration.

The chief virtue of the MOSFET so far is its superior performance as an r.f. amplifier and mixer at v.h.f., where it exhibits less cross-modulation than even nuvistor vacuum tubes. One circuit, from an FM-set front end, is shown in Fig. 9. It is typical of FET r.f. amplifier design. The FET, an *RCA* 40468, is a low-noise v.h.f. type operated in the depletion mode. Gate-to-source bias is developed across a source resistor (200k). Coil *L2* furnishes the drain load. Note that the power supply is a positive-ground type, because of the bipolar transistors used in the rest of the circuit.

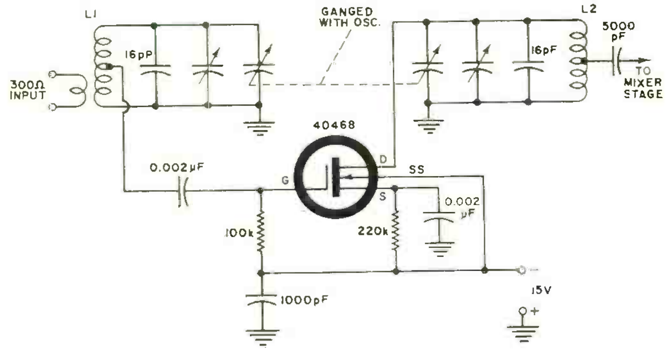
In the circuit of Fig. 9, theoretically, nothing can go wrong, because the FET is not fed by a preceding stage. However, there is always the possibility of a static discharge through the antenna to ground, during a thunderstorm. Such a potential could overload the gate of the FET and destroy it. The trouble would reveal itself as weak (or no) r.f. amplification, and probably by excessive current flow from the supply through the shorted FET to ground.

Summary

The FET is, functionally, a hybrid between the bipolar transistor and the vacuum tube; it has, generally, the best features of both. Unfortunately, the FET has even worse breakdown disadvantages than the bipolar, and thus must be handled with care.

FET circuits are much like vacuum-tube circuits, in terms of impedance and the manner in which bias works. Supply voltages are lower, more like those in bipolar circuits. When you troubleshoot an FET circuit, merely think of the device as a solid-state tube. ▲

Fig. 9. This FET circuit is used in front end of an FM tuner.



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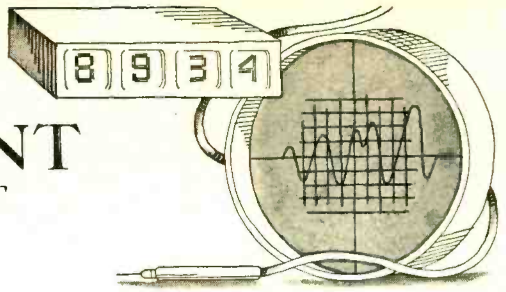

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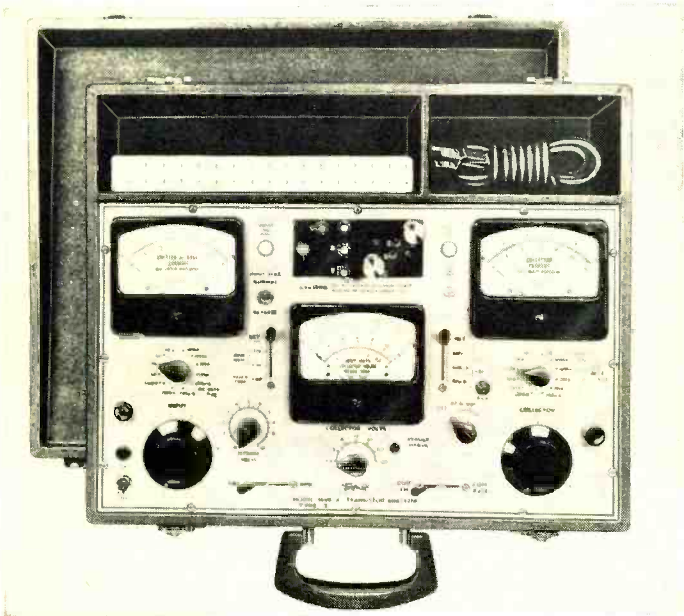
For copy of manufacturer's brochure, circle No. 23 on Reader Service Card.



A NEW and improved transistor analyzer has been introduced by *Triplett* as the Model 3490-A, Type 2. The instrument provides a true small-signal a.c. *beta* test; makes *h* parameter, high-current, high-voltage, a.c. and d.c. *beta* measurements; and reads leakage current in the nanoampere region. It tests both small-signal and power transistors, diodes, rectifiers, zener diodes, SCR's, and the latest FET's in the collector current range of 100 μA to 30 amperes.

The Model 3490-A permits the plotting of complete transistor characteristic curves or taking single readings plus setting up any type of transistor test. It is designed for use in electronic laboratories, research and development departments, in quality control sampling, evaluation engineering, and technical training schools.

Continuous current and voltage controls are a built-in feature of the analyzer. Three large and separate 4½" meters are used to read static and dynamic values of current and voltage. The instrument handles over 100 d.c. volt-amperes of collector power. Collector voltage range is 0 to 120 volts. A tetrode control is provided on the analyzer for use with double-base or tetrode transistors.

In the top center section of the analyzer's panel are mounted two transistor testing sockets. One is for the in-line types and the second for types where the leads are grouped in a circle or square on the bottom of the transistor. A socket for one of the most commonly used types of power transistors, the JEDEC outline TO-3, is built into a solid copper bar heat sink. Binding posts are also available in the heat sink for other transistor types.

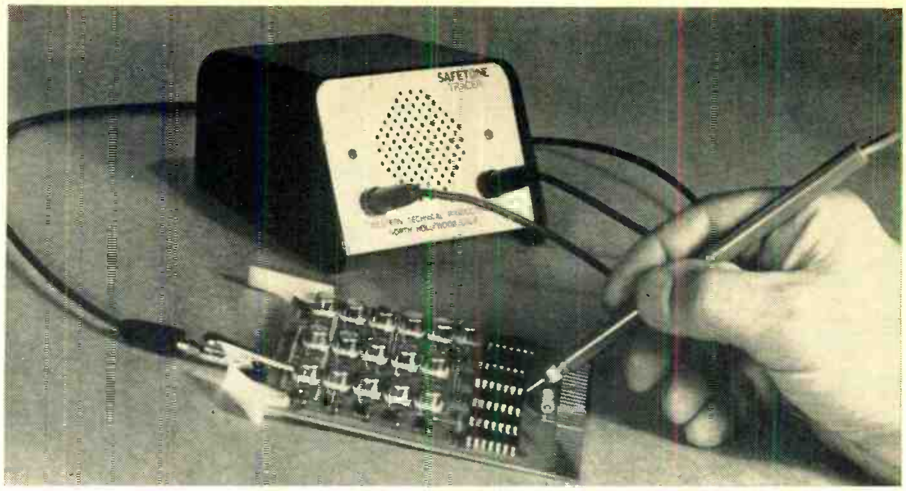
The *Triplett* Model 3490-A, Type 2 transistor analyzer has a gray leatherette covered case measuring $18\frac{13}{16}''$ x $15\frac{7}{16}''$ x 8" with removable cover. User net price is $441.00. ▲

Western Technical Products "Safetone Tracer"

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

A NEW approach to "goof-proofing" continuity testing is taken with the "Safetone Tracer" (pat. pend.) developed by *Western Technical Products.* This small and inexpensive limited current continuity tester assures safety in circuit testing and will not damage semiconductors.

The tracer emits a pleasant tone when low-resistance continuity exists.



Since there are no meters or lights to watch, the technician has new eye freedom to assure greater accuracy in circuit probing.

The tester is unique in two respects: it injects a maximum current of 1 mA into the circuit being tested, making it suitable for integrated circuits and other sensitive applications; and the frequency of the audible tone is a function of the circuit resistance seen by the tracer, rising with higher resistance. The technician can quickly determine good continuity or the range of the circuit resistance by the pitch of the tone.

The device has many uses in the assembly area, in the laboratory, or in inspection functions. It is particularly valuable in the hands of personnel with limited training where a test device with heavier currents may destroy valuable components. Polarity or current flow direction of semiconductor devices may easily be determined.

The unit is a specially modified cascaded complementary amplifier with two transistors. The power supply consists of two 1½-volt "D" cells. When no test circuit is connected to the tester, no current flows except for a few microamps of leakage current. When the test probes are connected to an external load, the circuit is completed and the transistors oscillate at a frequency dependent on the resistance between the test prods.

The "Safetone Tracer" is priced at $19.95 with leads, less batteries. ▲

Sencore PS148 Oscilloscope

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

MOST new oscilloscopes designed for color-TV servicing incorporate a special switching or terminal arrangement for a vectorscope display. This shows the output of the color set's detectors in a vector presentation, with (R-Y) producing vertical deflection on the CRT and (B-Y) producing horizontal deflection.

The vectorscope incorporated in the new *Sencore* PS148 oscilloscope provides a quick and easy method of determining the phase angle and relative amplitude of the (R-Y) and (B-Y) signals. By using a standard 10-bar generator and the vectorscope, the demodulator phase can be adjusted by observing the control's effect on the display, and the band-pass amplifier can be adjusted for the correct shape of the petals of the vector display.

Fig. 1 shows an ideal vector pattern for a 90° color-demodulator system. In actual practice the pattern will not look quite this good; the petals will be rounded rather than flat. Also, the difference in the amplitudes of the signals on the red and blue control grids and the fact that the CRT in the vectorscope has a higher sensitivity on the vertical plates than it does on the horizontal plates will cause the pattern to be slightly compressed in the horizontal direction.

For demodulation angles other than 90°, the angle between the (R-Y) maximum, or the third bar, and the (B-Y) maximum, or sixth bar, will vary. For systems that demodulate at 105°, this angle will be 105° and for 116° systems, the angle will 116°. The graph screen on the PS148 is calibrated in 30° increments, so the 105° angle would fall halfway between the sixth and seventh mark and the 116° angle would fall almost on the seventh mark.

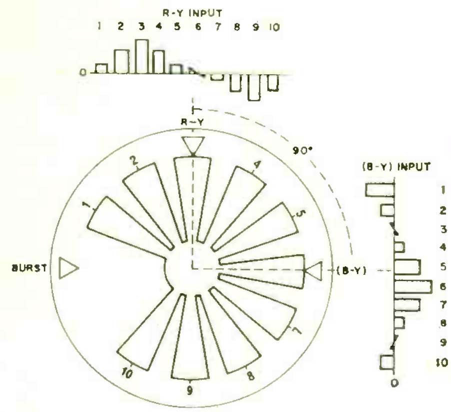
Most troubles that can occur in the chroma circuit produce definite indications on the vectorscope. A complete loss of (B-Y) signal will be indicated by a vertical line on the vectorscope, a complete loss of (R-Y) signal will be indicated by a horizontal line on the vectorscope. A complete loss of color will be indicated by a dot in the center of the screen with just the blanking pulse present. The vectorscope will indicate the general area of the problem, but will not pinpoint the exact location of the trouble. To actually isolate the defect to an individual stage or component, the instrument is switched to its conventional wide-band oscilloscope function.

When operating as a standard scope, the PS148 uses a balanced push-pull arrangement in both the horizontal and vertical channels which maintains a constant average voltage on the deflection plates. Having a constant average voltage on the deflection plates eliminates the need for an astigmatism control. The intensity and focus controls are tied into a voltage divider so that the focus voltage changes at the same time that the intensity changes; hence, the beam remains sharply focused at all intensity settings.

The scope has a 3-dB vertical sensitivity of 17 mV (r.m.s.)/inch from 5 Hz to 6.5 MHz. A calibrated vertical input attenuator makes it simple to measure peak-to-peak voltages of any TV waveform. The scope incorporates a standby feature that disconnects the output of the low-voltage rectifier while heater voltages and high voltages remain on. This keeps the scope in a "ready" condition.

The *Sencore* PS148 employs a 5-in CRT with a viewing hood. Price is $219.50 including a low-capacitance probe. ▲

Fig. 1. Ideal vectorscope display of color-bar-detected signals. The TV set's (R-Y) output is applied to the top vertical-deflection plate, while the set's (B-Y) output is applied to the right-hand horizontal-deflection plate. The other plates of the CRT are grounded. The combined effect of these two signals is the display shown.



EVALUATING D.C. VOLTAGE SOURCES

By DONALD LUDWIG

THE increasing demand for accuracy in laboratory experiments makes it necessary to know the characteristics of the voltage source being used. When a voltage source is new, its regulation, ripple, and drift will usually be within the manufacturer's specifications, but due to aging the ratings of the source may change. This article describes methods for determining these characteristics for a d.c. voltage source.

The accuracy of the measurements will be commensurate with the accuracy of the equipment being used and the care employed when performing each test. All leads should be as short as possible and their connections firmly made. Before each test the voltage source should be turned on and allowed to warm up. Taking a sufficient number of readings when conducting the tests will permit curves to be plotted.

Regulation

Regulation is the change in output voltage as a result of variations in either the line voltage or load current, when all other parameters are held constant. Voltage regulation is usually expressed as a percent of the original output voltage with the equation $[(V_o - V_c)/V_o]\,100$, where V_o is the original output voltage and V_c is the change in output voltage due to some variation.

When performing the test for determining the regulation due to a change in line voltage, such as shown in Fig. 1, the voltage source is checked over both the a.c. input voltage range and the d.c. output voltage range. This allows the regulation to be checked at different line voltages while the source is operating at different output voltages. Readings of both a.c. input and d.c. output voltages should be made for each particular setting of the variable transformer.

To perform this test, the variable transformer is first set at the lower a.c. input limit and the d.c. output is set at some desired potential. The a.c. input voltage is increased in small increments and both voltages are observed and recorded. This procedure is repeated until the upper a.c. voltage input limit is reached. The variable transformer is then returned to the lower input limit and the output voltage is set to a new potential. The test procedure is then repeated.

To determine the regulation due to changes in load current, the full range of available current from the voltage source should be checked. The test setup is shown in Fig. 2.

The d.c. output of the voltage source is set at the desired potential and the current and output voltage are recorded. Load resistor *R* is then varied and the new values of current and output voltage are recorded. Resistor *R* is varied to cover the full range of current available from the voltage source. In most cases, the voltage *vs* current values can be plotted on a graph for easy interpretation.

Ripple

Ripple is defined as the a.c. component superimposed on the d.c. output voltage, and is usually expressed in r.m.s. or peak-to-peak values. An increase in ripple may occur when the line voltage or load current is varied.

When determining the amount of ripple, the voltage source should be checked over the same ranges that are checked in the regulation tests.

To determine the amount of ripple due to changes in line voltage follow the same procedure and setup used to determine regulation due to variations in line voltage (see Fig. 1). An r.m.s. meter, or oscilloscope, is used in place of the d.c. voltmeter. When the d.c. output is reset, the d.c. voltmeter may be reinserted to monitor the voltage.

The test set-up and operations to detect ripple due to changes in load current are the same as the methods used to determine regulation due to variations in load current (see Fig. 2). The d.c. voltmeter is replaced by an r.m.s. meter or an oscilloscope.

Drift

Drift is the deviation in output volt-

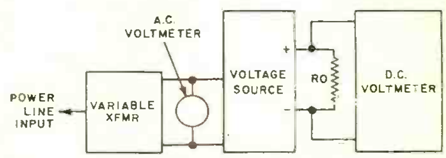


Fig. 1. Test setup for determining regulation due to a change in line voltage.

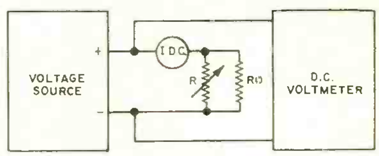
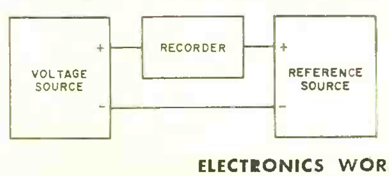


Fig. 2. Test setup for determining regulation due to changes in load current.

Fig. 3. Test setup for checking drift of a voltage source over a time period.



age from its set value over a period of time. The drift of a voltage source may be affected by component aging, temperature changes, and line-voltage variations.

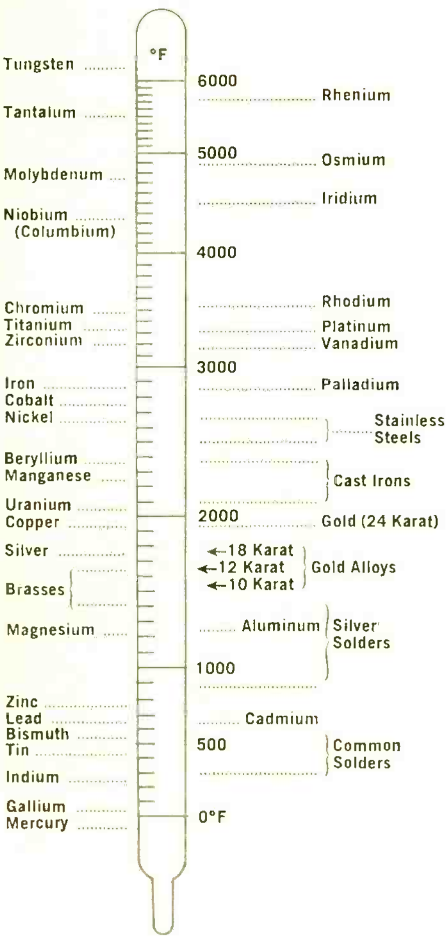
The test setup for checking the drift of a d.c. voltage source is shown in Fig. 3. The voltage source is balanced against the reference source and a recorder is used to detect the drift. Using a recorder will permit drift to be checked over long periods of time.

The above tests are methods for determining regulation, ripple, and drift for d.c. voltage sources. When performing these tests, the environmental conditions should be taken into account. Any change in regulation, ripple, and drift when conducting the above tests should be studied to determine if the voltage source is still within specifications and if it can be used for certain experiments. ▲

METAL MELTING TEMPERATURES

IN the chart below, the approximate melting points of the various metals are given only as a guide for material selection since many factors, including atmosphere, type of process, mounting, etc., all affect the operating maximum obtainable.

Our thanks to Omega Engineering, Inc. for permission to reproduce this chart for our readers. ▲



Differential Transformers

(*Continued from page* 50)

aiding, the ampere-turns of both units are kept the same. This is an important advantage since the balance point is relatively unaffected by resistive change in the primary circuit caused by internal heating effects or by changes in ambient temperature. Furthermore, small fluctuations in the power line do not interfere with the proper functioning of the servo system so that a regulated voltage supply is unnecessary.

Applications

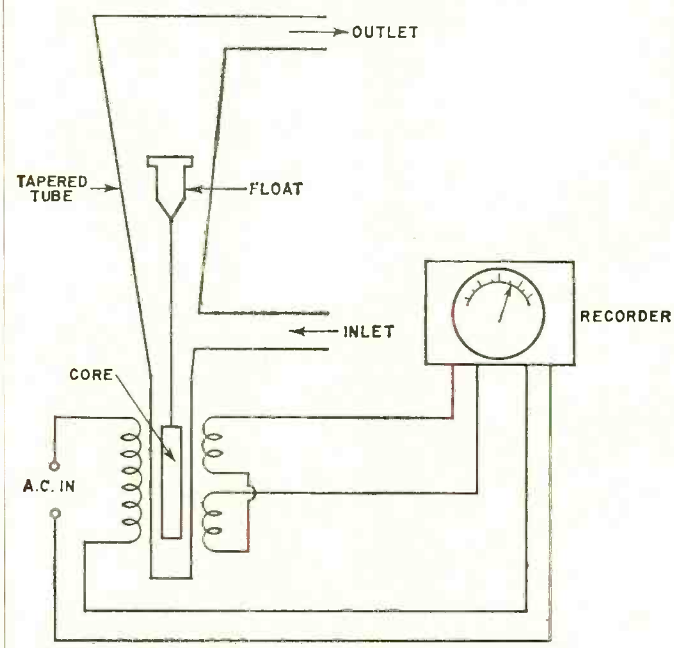
In industrial process control, differential transformers are frequently employed to detect the magnitude of fluid pressure, in conjunction with such pressure-sensitive devices as the Bourdon tube. The Bourdon tube is a curved, hollow, metallic element in which the fluid pressure to be measured is applied through one end while the other end is closed off.

Fig. 14 shows a method of accurately sensing absolute fluid pressure changes which are measured above zero pressure as a reference level. In this arrangement, the differential pressure between the internal fluid pressure and the external atmospheric pressure exerts a straightening action on the sensing tube, which is transmitted to the core of transformer *T1*. A reference Bourdon tube, thoroughly evacuated and sealed, is coupled to the core of transformer *T2* and serves to compensate for variations in atmospheric pressure. The net output signal consists of the algebraic sum of the voltage outputs of both differential transformers, and is proportional to the absolute pressure of the fluid being measured or controlled.

In liquid flow measurements, differential transformer cores may be designed to operate in working fluids while readings are taken on a remote indicator. Since lead lengths may be quite long in this application, low-impedance transformers should be used in order to minimize stray pick-up.

Fig. 15 shows a variable-area flowmeter, or rotameter, in which the flow rate varies directly as the rise and fall of a float in a tapered tube. The float adjusts the size of the flow area by rising when the rate of flow increases and dropping when the rate of flow is reduced. By this means, the fluid pressure differential is kept constant when the rate of flow changes. The differential transformer core follows the float travel and generates an a.c. signal which is fed to

Fig. 15. Industrial rotameter used for flow measurement.



the recorder. The output voltage may also be amplified and used to actuate a flow regulating valve, so that the rotameter becomes the primary sensing element in a flow controller.

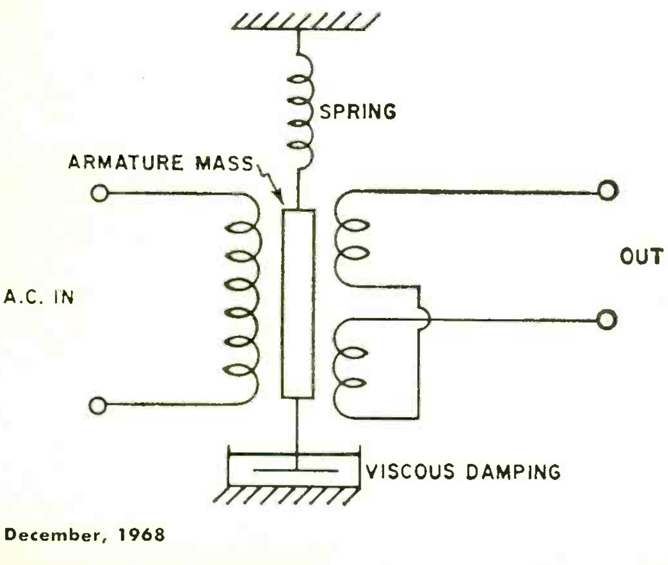
By virtue of their ruggedness and high resistance to extreme environmental conditions, differential transformers are ideally suited as the sensing element in the design of linear accelerometers for the accurate measurement and control of linear accelerations. These devices serve as a major component in the guidance control systems of aircraft and missiles, and for the dynamic testing of ground vehicles. Basically, modern accelerometers are seismic devices which consist of a known mass, a damped spring, and a transducer.

In Fig. 16, the armature core of a differential transformer is utilized as the seismic mass which is suspended from a case by a frictionless spring assembly. The case is attached to the vehicle whose acceleration is to be measured or controlled. Upon acceleration of the vehicle, the armature mass (due to inertia) tends to remain in position, but transmits its force through the spring. The spring assembly is deflected by an amount which is proportional to the applied acceleration so that the acceleration is converted to a proportional electrical output. The output signal may then be fed to a recorder calibrated in g's or transmitted to a control system. In this application, the use of a differential transformer for the suspension of the mass allows action along only one axis, so that unwanted response to accelerations at right angles to the sensitive axis is avoided. To prevent the seismic system from vibrating and producing signals after the applied acceleration has disappeared, the system is damped by a viscous damping fluid and is maintained at a uniform temperature by a thermostatically controlled heater.

Based on the differential transformer principle, the transducing of straight-line motion is not subject to friction errors or wear since no bearings, pivots, or sliding contacts are used. Consequently, exceptional accuracy, reliability, and long life may be expected even under adverse operating conditions involving exposure to hazardous nuclear radiation.

In a more sophisticated application, differential transformers serve as multiple-point displacement transducers in industrial instrumentation systems. Here the core of each transformer is fixed to a gage head whose movement determines whether the points being gaged are "over" or "under" the nominal dimension. The gage heads are mounted on the equipment to be measured, in a manner dependent upon the geometry of the surface and the number of points to be sensed. Using a sequential switching system, the gage outputs are connected to a single amplifier and the readout displayed on a continuous recording device (such as a profiler) or tape printout. ▲

Fig. 16. Linear accelerometer using differential transformer.



Efficient Inverter

New circuit concept increases the efficiency of sine-wave inverters. As a result, military and industrial power systems can be smaller.

CALL IT Staggered Phase Carrier Cancellation (SPCC). It's a new concept developed by engineers at the *Westinghouse Research Laboratories*, and it promises to reduce the size and weight of sine-wave inverters and raise their efficiency from about 65 percent to 90 percent or more.

According to one company spokesman, the inverters may be used in high-power military and industrial systems; or in spacecraft power systems where small size, light weight, and high efficiency are at a premium. They would convert the d.c. power of self-contained power sources, such as fuel cells and thermoelectric generators, to a.c. and boost it to higher voltages of suitable frequency.

In commercial systems they could be used for high-powered audio amplifiers—with output power of several kilowatts—for public address systems, for sonar systems, or for large sonic machines to provide stress analysis of airplanes or spacecraft.

SPCC is a technique wherein pulse-width modulated (PWM) waveforms with the same low-frequency modulation but differing carrier time phases are combined to synthesize the desired low-frequency waveform. This technique increases the carrier frequency by four and reduces size of the output filter.

In conventional inverters that use the PWM technique, the carrier frequency is limited to about 10 kHz by the switching speed of the power transistors. This means the output filter must have a cut-off frequency below 10 kHz, consequently its size and weight are impractical in many applications.

Using SPCC with four carrier waveforms displaced 90 degrees in time (phase), the carrier frequency is completely cancelled. The low-frequency modulation is also strengthened and the original carrier and its second and third harmonics (10, 20, and 30 kHz) are cancelled. With an effective 40-kHz carrier, the output filter can be reduced to about one-fourth the original size and weight.

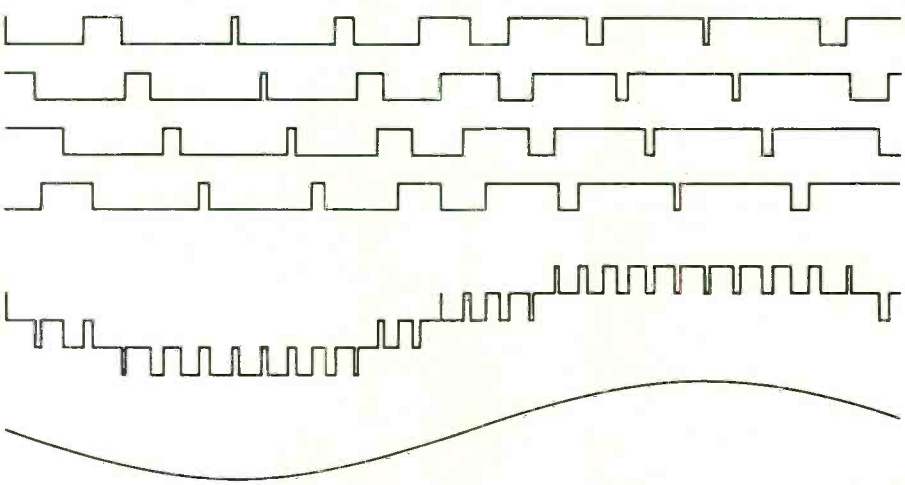
The new inverter concept is feasible because semiconductor manufacturers have developed new fast-switching diffused power transistors with peak inverse voltage levels greater than 300 volts and high-current carrying capacity. The storage time of these devices is made negligibly small by using special drive circuits which clamp the voltage drop of the conducting device just at the edge of saturation for all conditions of loading.

Also, recirculating diodes connected across each power transistor keep voltage spikes appearing across the transistors from exceeding the d.c. supply voltage, and recirculate energy from the load to the power supply. This makes the inverter operation independent of load power factor.

The small output filter provides the additional benefit of reduced output impedance and phase shift.

According to Richard J. Ravas, supervisor of new semiconductor applications at *Westinghouse Research Laboratories*, 3-phase, 400-Hz sine-wave inverters rated at several kilowatts can be built. Increased system capacity can be met by using multiple inverters operating in parallel. ▲

In staggered phase carrier cancellation, each of the four carriers has same modulation but differs in time (phase).



IC Frequency Dividers
(*Continued from page* 35)

adjacent to the pin numbers in Fig. 8 have a special significance. If the number is associated with an input terminal it is called the "input load factor." If the number is associated with an output terminal, it is called the "output drive factor." The input load factor is a measure of the input signal power required to drive the device. The output drive factor is a measure of the signal output power available from the device. A large load or drive factor implies a low-impedance input or high power output, as the case may be.

When one or more inputs are driven from an output, the sum of the input load factors of the driven devices must not exceed the output drive factor of the driving device. For example, one 9923 FF (output drive factor = 10) can be used to drive a 9900 buffer (input load factor = 6) in parallel with a single 9914 gate (input load factor = 3) with a little power to spare. The high output drive factor of the 9900 buffer as compared to the two other elements supports the earlier statement about its ability to deliver output current.

On all three devices, V_{cc} is connected to pin 8 and pin 4 is grounded (pin 4 is the power and signal return). The recommended value of V_{cc}, the supply voltage, is +3.6 V d.c. ±10%. All unused input pins should be grounded.

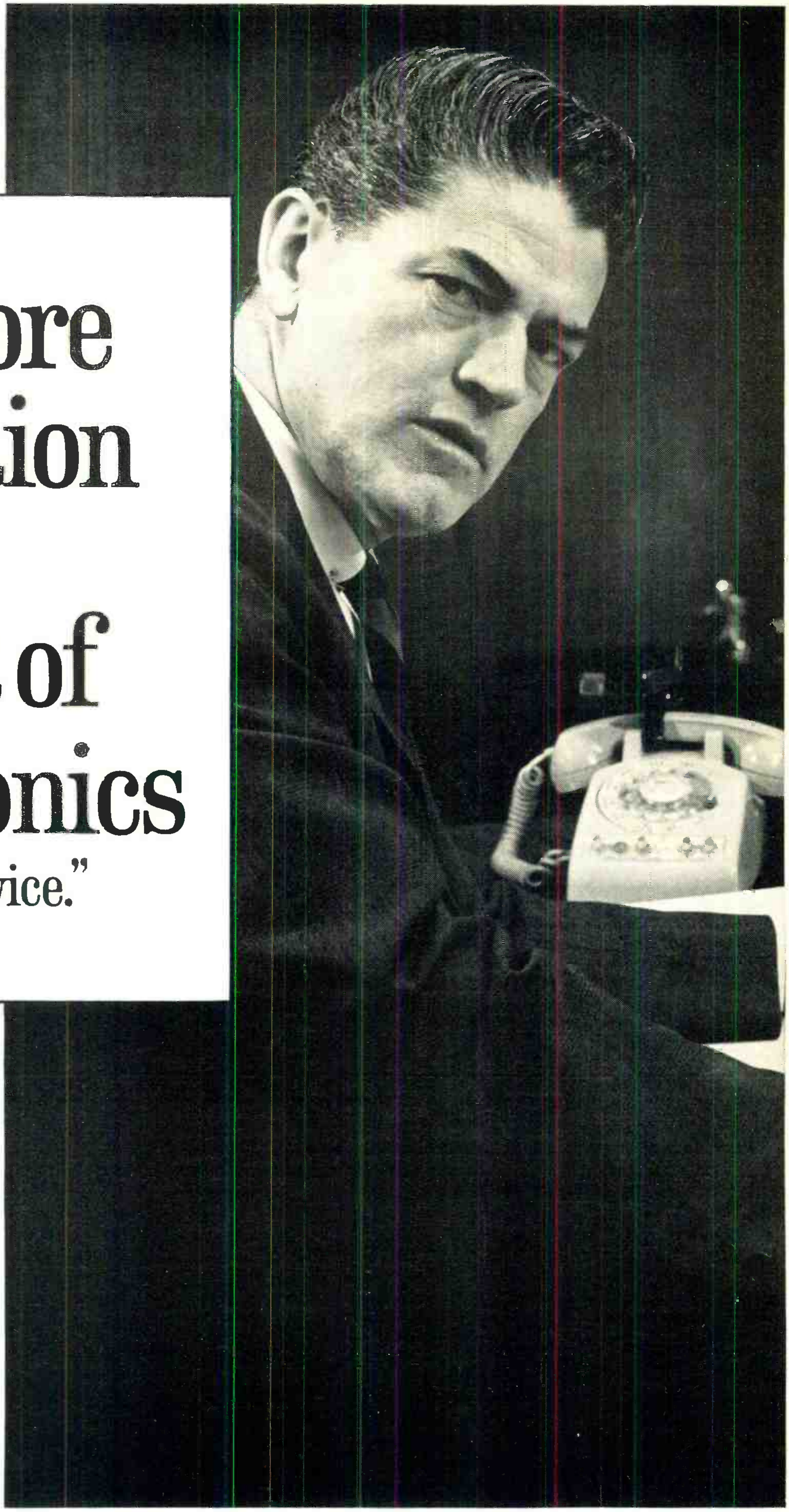
Unbuffered JK FF's are sensitive to capacitive loading. Capacitance from pins 5 or 7 of the 9923 JK FF to ground should not exceed 100 pF total, or 50 pF at each of the two pins.

JK FF's require that their S and C input signals be present for some minimum time (called *setup time*) before the arrival of a CP, and maintained for some minimum time (called *release time*) after the arrival of a CP. A setup time of 50 nanoseconds and a release time of 50 nanoseconds should be adequate for the 9923 JK FF.

Propagation delay can be defined approximately as the time required for a voltage change at the input of the device to appear at the output of the device. The propagation delay of the 9900 buffer is 32 nanoseconds; for the 9914 it is 20 nanoseconds for a decreasing output level and 32 nanoseconds for an increasing output level; and for the 9923 JK FF it is 50 nanoseconds for a decreasing output level and 80 nanoseconds for an increasing output level. These propagation delays are taken from the manufacturer's data sheet.

Part 2 of this article will show applications of these IC "building blocks" to practical divider and counter systems.

(*Concluded Next Month*)



Multiplex Demodulator

(*Continued from page 43*)

peak (controlled by *R*20) becomes sharply defined and is just slightly removed from the oscillating condition. The calculated values for *R*20 and *C*14 are 2800 ohms and 3000 pF, respectively; the final values will be close to these. The time spent trimming *R*20 and *C*14 is worthwhile because noise rejection is improved by optimizing the "Q" of the filter amplifier. With proper tuning, the gain from input to terminal 7 should be in the vicinity of 60 dB (A_v = 1000) and the "stereo on" lamp, *PL*1, should be at full brilliance. Fig. 3 (left) shows the waveforms at pins 5 and 7 of the CA3035. Some unbalance may occur in the outputs but this will not affect performance. The Darlington amplifier's input and output of the doubler diodes, are in Fig. 3 (right).

The 38-kHz oscillator is best adjusted by observing the Lissajous figure formed by the 19-kHz pilot signal and the 38-kHz oscillator signal at terminals 7 of the CA3035 and 11 of the CA-3001. Fig. 4 (left) indicates the proper frequency and phase relationship (the 38-kHz signal is connected to the vertical axis and the 19-kHz is tied to the horizontal axis). *R*32 is adjusted to obtain the pattern in Fig. 4. *R*31 will affect the amplitude of the 38-kHz oscillator and may be selected to provide 2 to 5 volts peak-to-peak at terminal 11. The output at terminal 11 should be a fairly clean sine wave, as shown in Fig. 4 (right). If necessary, sacrifice amplitude for waveform purity. Fig. 4 (right) also shows the 19-kHz pilot signal in its proper phase relationship to the 38-kHz oscillator output.

At this point, a stereo signal should be fed to the input and *R*12 should be set to give a 1.5-volt peak-to-peak signal at pin 7 of the CA3035. Readjust *R*20 for a peak at terminal 7 and recheck the Lissajous figure between pilot and oscillator, readjusting *R*32 if necessary to complete the alignment. Threshold control *R*12 should be adjusted until the stereo lamp is at full brightness.

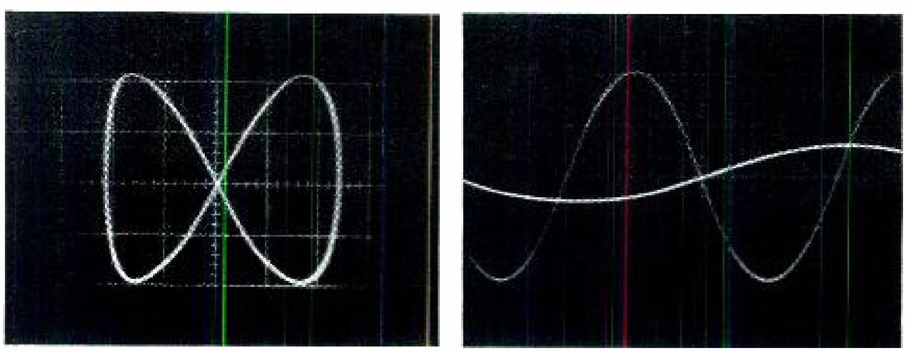
Table 1 gives voltage readings at all IC terminals under no-signal and limiting-signal conditions. Voltages were measured with a *Cubic* V-71 digital voltmeter at 11-megohms input impedance.

A parts list is included with Fig. 2 for those who wish to build their own demodulator. The circuit layout is not critical; however, care should be exercised in the area of the 19-kHz selective amplifier. Resistors should be 5% tolerance and *C*16, *C*17, *C*21, and *C*23 should be high quality capacitors, such as dipped mica. Where particular manufacturers are specified in the parts list, these components have been selected basically on a cost per item basis. ▲

Terminal No.	CA3018		CA3035		CA3001	
	No Sig.	Limited Sig.	No Sig.	Limited Sig.	No Sig.	Limited Sig.
1	0.0	0.0	1.2	1.2	5.2	5.2
2	NC	NC	0.0	0.0	5.2	5.2
3	6.8	6.8	1.8	1.8	0.0	0.0
4	6.0	6.0	0.71	0.71	0.0	0.0
5	11.5	11.5	5.1	4.0	NC	NC
6	0.8	0.7	0.75	0.74	5.4	5.2
7	0.1	0.1	3.5	3.5	NC	NC
8	0.5	4.4	0.0	0.0	6.7	8.5
9	0.0	0.0	9.1	9.2	11.5	11.5
10	0.0	0.0	0.0	0.0	0.0	0.0
11	15.1	1.1			10.0	8.2
12	15.1	1.1			NC	NC

Table 1. IC terminal voltages at no and limited signal conditions.

Fig. 4. Lissajous pattern (left) shows the frequency and phase relationship between 19-kHz pilot and 38-kHz oscillator signals. (Right) 38-kHz sine wave is superimposed on the 19-kHz signal.



TV SWEEP WAVEFORM QUIZ

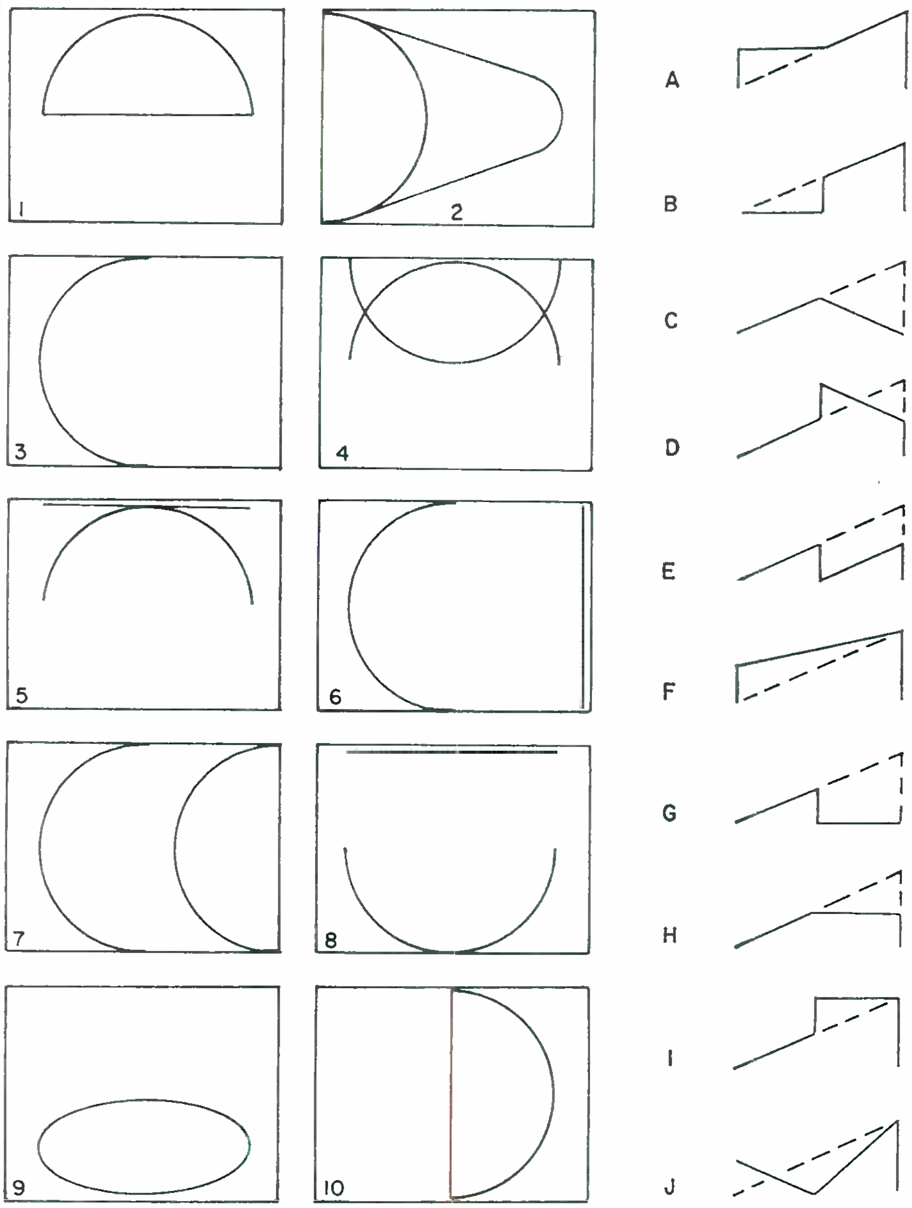
By ROBERT P. BALIN

(*Answer on page* 90)

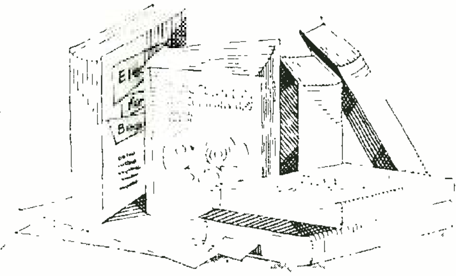
WHEN the horizontal and vertical saw-tooth-shaped sweep waveforms in a TV set become distorted, so does the picture on the screen. Understanding the relationship between the two can help you determine where to look for a possible cause of the distortion: non-linearity at the bottom of the screen is usually due to trouble in the vertical height control circuit and the vertical oscillator tube; distortion at the top of the screen usually means difficulties with the vertical linearity control circuit and the vertical output tube; distortion on the left-hand side of the screen often means faulty operation in the damper and the horizontal linearity control circuit; and distortion on the right-hand side is generally due to problems located in the horizontal output tube circuit.

To test your skill at finding the relationship between sweep and screen, try to match the distorted sweep-current waveforms (A through J) with the resulting appearance of the test pattern circles (1 through 10) on the screen.

The waveforms can represent either a horizontal or vertical saw-tooth and are drawn so that the lower left-hand portion of the saw-tooth places the beam at the top or left side of the screen, and the upper right-hand portion of the saw-tooth places the beam at the bottom or right side of the screen. Retrace lines are not visible on the screen. The normal appearance of the waveform is shown by the dashed lines. ▲



BOOK REVIEWS



"FEEDBACK AMPLIFIERS AND OSCILLATORS" By Robert E. Sentz & Robert A. Bartkowiak. Published by *Holt, Rinehart and Winston, Inc.*, New York. 213 pages. Price $3.95. Soft cover.

This volume is directed to students at technical institutes or junior and community colleges. Prerequisite are a course in a.c. and d.c. circuits, an understanding of basic electron devices, the methods of interstage coupling, and a working knowledge of algebra and trigonometry.

With this much background, the student can then tackle the fundamental types of feedback; single-stage feedback amplifiers; stability, phase shift, and frequency response; the simple oscillatory circuit and four-terminal *LC* oscillators; crystal oscillators; negative-resistance oscillators, *RC* phase-shift oscillators; and u.h.f. and microwave oscillators.

The authors' style is simple and informal and there is no reason why this book couldn't be used as a home-study text. Answers are provided for the odd-numbered problems appended to each chapter so the student studying on his own can check his progress.

* * *

"HANDBOOK OF OSCILLOSCOPES: THEORY AND APPLICATION" by John D. Lenk. Published by *Prentice-Hall, Inc.*, Englewood Cliffs, N.J. 209 pages. Price $7.95.

This thoroughly practical handbook of oscilloscope usage should be of interest to service and lab technicians as well as students and engineers. It is designed to bridge the gap between the manufacturer's operating instructions for his particular scope and its final application to the circuit.

This volume makes it possible for any scope user to get the maximum value from his instrument. The first four chapters deal with the scope itself and cover basics, operating controls, specifications and performance, probes and accessories. Even those familiar with scopes will find this material a good "review." The balance of the book treats the specific applications for scopes: operating procedures and recording methods; measuring voltage and current; measuring time, frequency, and phase; using scopes with sweep generators; checking individual components; checking amplifiers and amplifier circuits; and checking communications equipment, industrial equipment, and TV.

* * *

"TRANSISTOR CIRCUIT ACTION" by Henry C. Veatch. Published by *McGraw-Hill Book Co.*, New York. 306 pages. Price $6.95.

This book is designed to meet the needs of service technicians, students at technical institutes, in adult education courses, and those studying on their own. The treatment is non-mathematical, clear, and concise. All projects discussed by the author are designed to be built by the student and checked with just a v.o.m. or service scope.

The text is divided into 16 chapters covering semiconductor materials; the *p-n* junction diode; the junction transistor; characteristic curves; transistor circuits; common-emitter, common-collector, common-base circuits; d.c. analysis method; graphical analysis; temperature characteristics; analysis of linear circuit; linear-circuit examples; transistor oscillators; power supplies; and transistor types. Each chapter has questions and problems appended, answers for which are given for the odd numbered items. A glossary and bibliography complete the volume. The text is informally written and well illustrated. It should have wide appeal for those wanting to know more about transistor circuits but without the engineering background required for tackling the more advanced texts.

* * *

"ELECTRONIC DEVICES AND CIRCUITS" by G.J. Pridham. Published by *Pergamon Press Inc.*, 44-01 21st Street, Long Island City, N.Y. 11101. 340 pages. Price $7.00. Soft cover edition $5.00.

This is the first volume of a projected three-volume edition designed for professional and technician engineers working on the various degree and certificate courses in Great Britain.

After an introduction and listing of symbols used in the text, the author covers network theory, passive components, basic physical theory, diodes, triodes and transistors, rectification and power supplies, amplifying circuits, oscillators, and electronic instruments. The treatment is mathematically rigorous and those without the necessary trigonometry and advanced algebra will find this hard going. The text is well illustrated and each chapter has test questions appended for classroom assignment or self-checking. Answers to the numerical examples are included.

* * *

"UNDERSTANDING ELECTRONIC ORGANS" by Thomas Jaski. Published by *Hayden Book Company, Inc.*, New York. 201 pages. Price $4.95. Soft cover.

This volume is intended as a "why" and "how" of electronic organs in general rather than a detailed catalogue of circuits and features of specific organ models.

The book is divided into ten chapters covering sound and music; pipes, waveforms, and scales; elements of organ classification; organ characteristics and tone generators; special tone generators—filters and formants; tremolo, vibrato, and special-effects circuits; tone changers, amplifiers, and power supplies; mechanical details; organ accessories and accessory instruments; and purchasing an organ and making simple repairs.

While the author has addressed his remarks to the owner and user of an electronic organ, some of the chapters require a technical and mathematical background for complete understanding. Probably those who will get the most from this book are musically inclined technicians and electronics hobbyists familiar with transistor circuitry. The text is lavishly illustrated with charts, graphs, partial schematics, and photographs of commercial organs. Those working with organs and those with some technical know-how will find this little volume worthwhile.

* * *

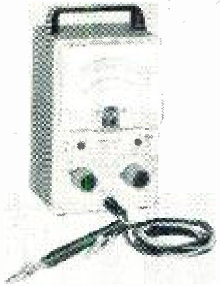
"AMPLIFYING DEVICES AND LOW-PASS AMPLIFIER DESIGN" by E.M. Cherry & D.E. Hooper. Published by *John Wiley & Sons, Inc.*, New York. 1015 pages. Price $29.95.

It is the authors' contention that too many students in engineering courses lack the all-important practical experience in designing circuits that are physically realizable—not theoretically possible.

To make up for this lack in their formal education, the authors have selected the design of low-pass amplifiers for rigorous treatment—because amplifiers are used in virtually all electronic equipment. Written principally for students in engineering courses, the book is divided into two main parts. Part 1 is intended as a first course in electronic circuits while Part 2 is intended as a second course. By the end of the second course the student is prepared to design a practical, workable circuit.

As is the case with textbooks designed for students in engineering faculties the treatment is mathematical. Practicing engineers who wish to sharpen their design techniques will find this volume helpful. Others without the requisite mathematical skills are hereby warned. ▲

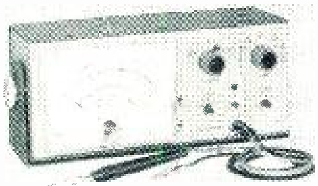
Make This Christmas



Kit IM-18
$28.50
Wired IMW-18
$47.95

NEW HEATHKIT IM-18 VTVM

The new IM-18 is a direct decendent of the world's most popular VTVM — the Heathkit IM-11, and continues the features that made the IM-11 famous . . . 7 AC and 7 DC voltage ranges that measure from 0-1500 volts full scale . . . 7 ohms ranges for resistance measurements from 0.1 ohm to 1000 megohms . . . single probe convenience that ends tangled leads & enables you to change from AC to DC/Ohms measurements with a flip of the switch on the probe . . . the light circuit loading of 11 megohm input impedance . . . ±1 dB 25 Hz to 1 MHz response . . . precision 1% resistors . . . DC polarity reversing position on the function switch . . . measurement capability for RMS and Peak-To-Peak AC voltages and dB . . . precision 4½", 200 uA meter for extra sensitivity. In addition, the new IM-18 includes wiring options for 120V. or 240 VAC operation and a three-wire line cord for added safety. 5 lbs.



kit IM-28
$36.50
Wired IMW-28
$56.95

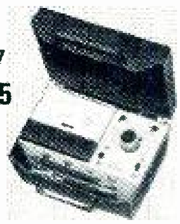
NEW HEATHKIT IM-28 "Service Bench" VTVM

The new Heathkit IM-28 bears the proud tradition of the IM-13, and it has the same performance specifications as the new IM-18 above — an unbeatable combination! But it also has a number of features that put it in a class by itself, like a large 6" meter with easy-to-read markings . . . extra 1.5 and 5 volt AC ranges for additional accuracy . . . a secure gimbal mounting that allows you to put the IM-28 above, below or in front of your most convenient mounting surface . . . "Set and Forget" calibration — all calibration controls are screwdriver adjustable from the front panel to eliminate disassembly . . . smooth ten-turn vernier control of Zero and Ohms Adjust for greater accuracy and easier setting . . . dual primary transformer for 120/240 VAC operation . . . safe 3-wire line cord as well. The new look of Heathkit instrument styling is evident too — handsome beige & brown color scheme, and new knobs that are easy to turn and fast to read. 7 lbs.

Kit IM-38
$39.50
Wired IMW-38
$54.95

NEW HEATHKIT IM-38 Laboratory AC VTVM

For all around general service work, audio design and trouble-shooting or laboratory analysis, you couldn't find a better value than the new Heathkit IM-38 AC VTVM. Here's why — 10 voltage ranges measure from 0.01 to 300 volts RMS full scale . . . an extended frequency response of 10 Hz to 500 kHz at ±1 dB . . . 10 megohm input on all ranges for higher accuracy and minimal circuit loading . . . wide dB range: —12 to +2 on the meter and ten switch-selected ranges from —40 to +50 in 10 dB steps . . . VU-type ballistic meter damping . . . amplifier filament voltage transformer winding that's balanced to ground for low AC noise . . . 120/240 AC wiring options and new Heathkit styling in sharp beige & brown with an easy-to-grasp, easy-to-read knob. Heathkit engineering has made assembly easy and performance tops. 5 lbs.



kit IM-17
$21.95

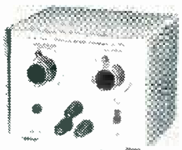
HEATHKIT IM-17 Solid-State Volt-Ohm Meter

Another very popular volt-ohmmeter from Heathkit engineering and it's easy to see why — all solid-state circuitry . . . high impedance FET input, 11 megohms on DC, 1 megohm on AC . . . 4 AC voltage ranges . . . 4 DC voltage ranges . . . 4 ohm ranges . . . 4½" 200 uA meter . . . 3 built-in test leads . . . DC polarity reversing switch . . . zero-adjust & ohms-adjust controls . . . continuous 12-position function switch. And that's not all — the IM-17 is battery powered for complete portability and comes in a rugged polypropylene case with built-in handle. Simple circuit board assembly. 4 lbs.

kit IT-18
$24.95

HEATHKIT IT-18 In-Circuit Transistor Tester

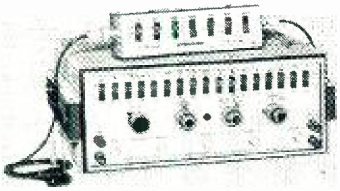
In-Circuit transistor testers don't have to be expensive, and the IT-18 is proof of that . . . tests DC Beta 2-1000, in or out-of-circuit . . . leakage Icbo and Iceo current 0-5000 uA out-of-circuit . . . identifies NPN or PNP devices . . . tests diodes in or out-of-circuit for opens & shorts . . . identifies unknown diode leads . . . matches PNP & NPN transistors. The IT-18 is completely portable — runs on just one "D" cell. Easy to use too . . . rugged polypropylene case, attached 3' test leads, big 4½" 200 uA meter, all front panel controls, 10-turn calibrate control. 4 lbs.



kit IP-18
$19.95

HEATHKIT IP-18 1-15 VDC Power Supply

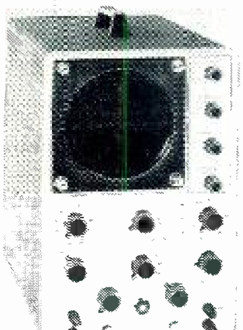
If you work with transistors, this is the power supply for you. All solid-state circuitry provides 1-15 VDC at up to 500 mA continuous. Features adjustable current limiting, voltage regulation, floating output for either + or — ground, AC or DC programming, circuit board construction, and small, compact size. 110 or 220 VAC. 5 lbs.



kit IG-57
$135.00
wired IGW-57
$199.00

HEATHKIT IG-57 Solid-State Post Marker/Sweep Generator

The new IG-57 plus a 'scope is all you need . . . no external sweep generator required. Switch selection of any of 15 crystal-controlled marker frequencies (you can view up to six different frequencies on one 'scope trace). Select the sweep range and you are ready to instantly see the results of any changes you make. Four markers for setting color bandpass, one for TV sound, eight at IF frequencies between 39.75 & 47.25 MHz plus picture and sound carrier markers for channels 4 & 10. Three sweep oscillators produce the 5 most-used ranges . . . color bandpass, FM IF, color & B&W IF and VHF channels 4 & 10. Save hundreds of dollars and put full alignment facilities in your shop too — order your IG-57 now. 14 lbs **Kit IG-14**, same as IG-57 w/o the sweep, 11 lbs. **$99.95.**



kit IO-18
$84.95
wired IOW-18
$139.95

HEATHKIT IO-18 Wide-Band 5" 'Scope

The New Heathkit IO-18 is destined to be the world's most popular 'scope, just as its predecessor, the IO-12 was. Features 5 MHz bandwidth, the famous Heath patented sweep circuit — 10 Hz to 500 kHz in 5 ranges, two extra sweep positions which can be preset to often-used rates, frequency compensated vertical attenuation, built-in P-P calibration reference, Z-axis input, retrace blanking, wiring options for 120 or 240 VAC operation and new Heathkit styling in beige and brown. 24 lbs.

A Heathkit® Holiday

Wish Your Family Merry Christmas This Year With A New Heathkit Color TV . . . A Better Buy Than Ever With New Lower Prices

NEW Deluxe Color TV With Automatic Fine-Tuning—Model GR-681

kit GR-681 **$499.95** (less cabinet)

The new Heathkit GR-681 is the most advanced color TV on the market. A strong claim, but easy to prove. Compare the "681" against every other TV — there isn't one available for any price that has all these features. Automatic Fine Tuning on all 83 channels . . . just push a button and the factory assembled solid-state circuit takes over to automatically tune the best color picture in the industry. Push another front-panel button and the VHF channel selector rotates until you reach the desired station, automatically. Built-in cable-type remote control that allows you to turn the "681" on and off and change VHF channels without moving from your chair. Or add the optional GRA-681-6 Wireless Remote Control described below. A bridge-type low voltage power supply for superior regulation; high & low AC taps are provided to insure that the picture transmitted exactly fits the "681" screen. Automatic degaussing, 2-speed transistor UHF tuner, hi-fi sound output, two VHF antenna inputs . . . plus the built-in self-servicing aids that are standard on all Heathkit color TV's but can't be bought on any other set for any price . . . plus all the features of the famous "295" below. Compare the "681" against the others . . . and be convinced.

GRA-295-4, Mediterranean cabinet shown **$119.50**
Other cabinets from $62.95

Deluxe "295" Color TV...Model GR-295

now only **$449.95** (less cabinet)

Big, Bold, Beautiful . . . and packed with features. Top quality American brand color tube with 295 sq. in. viewing area . . . new improved phosphors and low voltage supply with boosted B+ for brighter, livelier color . . . automatic degaussing . . . exclusive Heath Magna-Shield . . . Automatic Color Control & Automatic Gain Control for color purity, and flutter-free pictures under all conditions . . . preassembled IF strip with 3 stages instead of the usual two . . . deluxe VHF tuner with "memory" fine tuning . . . three-way installation — wall, custom or any of the beautiful Heath factory assembled cabinets. Add to that the unique Heathkit self-servicing features like the built-in dot generator and full color photos in the comprehensive manual that let you set-up, converge and maintain the best color picture at all times, and can save you up to $200 over the life of your set in service calls. For the best color picture around, order your "295" now.

GRA-295-1, Walnut cabinet shown **$62.95**
Other cabinets from $99.95

Deluxe "227" Color TV...Model GR-227

now only **$399.95** (less cabinet)

Has same high performance features and built-in servicing facilities as the GR-295, except for 227 sq. inch viewing area. The vertical swing-out chassis makes for fast, easy servicing and installation. The dynamic convergence control board can be placed so that it is easily accessible anytime you wish to "touch-up" the picture.

GRA-227-1, Walnut cabinet shown **$59.95**
Mediterranean style also available at $99.50

Deluxe "180" Color TV...Model GR-180

now only **$349.95** (less cabinet)

Same high performance features and exclusive self-servicing facilities as the GR-295 except for 180 sq. inch viewing area. Feature for feature the Heathkit "180" is your best buy in deluxe color TV viewing . . . tubes alone list for over $245. For extra savings, extra beauty and convenience, add the table model cabinet and mobile cart.

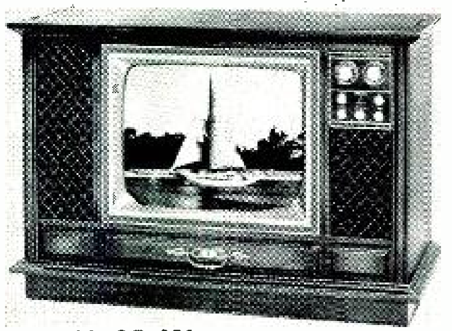
GRS-180-5, table model cabinet and cart **$39.95**
Other cabinets from $24.95

Now, Wireless Remote Control For Heathkit Color TV's

Control your Heathkit Color TV from your easy chair, turn it on and off, change VHF channels, volume, color and tint, all by sonic remote control. No cables cluttering the room . . . the handheld transmitter is all electronic, powered by a small 9 v. battery, housed in a small, smartly styled beige plastic case. The receiver contains an integrated circuit and a meter for adjustment ease. Installation is easy even in older Heathkit color TV's thanks to circuit board wiring harness construction. For greater TV enjoyment, order yours now.

kit GRA-681-6, 7 lbs., for Heathkit GR-681 Color TV's **$59.95**
kit GRA-295-6, 9 lbs., for Heathkit GR-295 & GR-25 TV's **$69.95**
kit GRA-227-6, 9 lbs., for Heathkit GR-227 & GR-180 TV's **$69.95**

Now There Are 4 Heathkit Color TV's . . . All With 2-Year Picture Tube Warranty



kit GR-681

kit GR-295

kit GR-227

kit GR-180

New Wireless TV Remote Control For GR-295, GR-227 & GR-180 **$69.95**

New Wireless TV Remote Control For GR-681 **$59.95**

CIRCLE NO. 108 ON READER SERVICE CARD

ABOUT YOUR SUBSCRIPTION

Your subscription to ELECTRONICS WORLD is maintained on one of the world's most modern, efficient computer systems, and if you're like 99% of our subscribers, you'll never have any reason to complain about your subscription service.

We have found that when complaints do arise, the majority of them occur because people have written their names or addresses differently at different times. For example, if your subscription were listed under "William Jones, Cedar Lane, Middletown, Arizona," and you were to renew it as "Bill Jones, Cedar Lane, Middletown, Arizona," our computer would think that two separate subscriptions were involved, and it would start sending you two copies of ELECTRONICS WORLD each month. Other examples of combinations of names that would confuse the computer would include: John Henry Smith and Henry Smith; and Mrs. Joseph Jones and Mary Jones. Minor differences in addresses can also lead to difficulties. For example, to the computer, 100 Second St. is not the same as 100 2nd St.

So, please, when you write us about your subscription, be sure to enclose the mailing label from the cover of the magazine—or else copy your name and address exactly as they appear on the mailing label. This will greatly reduce any chance of error, and we will be able to service your request much more quickly.

NEW CELL ENERGY

By PAUL GALLUZZI

Battery charger gives new life to old energy cells.

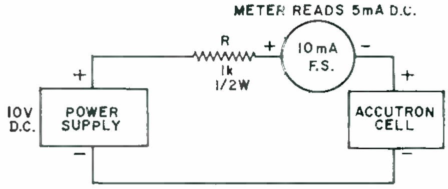
POWER cells for *Bulova's* Accutron watches are guaranteed to keep the timepiece running for at least a year. But many power units have been known to operate effectively for a year and a half without replacement, and a simple recharging circuit can stretch the battery's useful life even longer.

All that is required is a 10-volt d.c. regulated power supply (with a capacity of 5 milliamperes minimum), a 0 to 10 mA (full-scale) meter, and a 1000-ohm (approximate) half-watt current-limiting resistor arranged as in the circuit of Fig. 1.

The first indication of a dead or failing power cell is the watch's inability to keep accurate time. However, before removing the battery from the watch for revitalization, fashion a hold-down assembly. A wooden clothespin (spring type) makes an effective clamp. Take a small piece of copper to which a length of red wire has been soldered and bond it to one of the clothespin's two teeth. To the clothespin's other tooth bond a piece of copper and a length of black wire. Now when the battery is removed from the watch, place it between the teeth of the clothespin so that the piece of copper with the red wire attached makes contact with the positive electrode. Now connect the red lead to the meter and the black lead to the power supply, as shown in Fig. 1.

For full power potential, keep the battery charging for about 24 hours. The usual charging rate is about five or six mA, decreasing to near zero as the unit becomes fully energized. Cells can be recharged as often as necessary and several months' service should be obtained from each recharge. ▲

Fig. 1. Accutron cell recharging circuit.



NEW PRODUCTS & LITERATURE

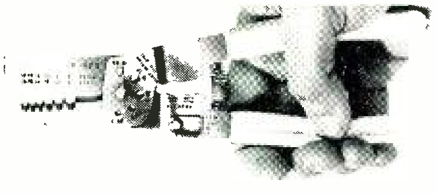
Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

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

WIRING TOOL

A new wiring tool that can strip, cut, loop, and size wire; cut bolts; crimp terminals and ream conduit is being introduced as the "Big-7."

The wire-stripping holes are precision ground to strip or size No. 18 solid or stranded, through



No. 6 solid and No. 8 stranded wire. Cutting blades are ground to cut all popular aluminum and copper conductors, including UF and Romex cable.

Unhardened machine screws, Nos. 4-40, 6-32, 8-32, 10-32, and 10-24 can be sized and cut to length. Insulated or plain terminals and connectors from Nos. 22-10 can be crimped.

A spring holds the tool open and ready for use. When not being used, the tool is held closed with a cam lock. It has large, cushion-grip handles and measures 8" over-all. It weighs 7 ounces. Holub

Circle No. 126 on Reader Service Card

11-PIECE DRILL KIT

An 11-piece 3/8" drill kit consisting of a Model 820 drill, six drill bits (1/16", 1/8", 3/16", 1/4", 5/16", and 3/8"), a fitted carrying case, 3-wire six-foot cord and adapter, and 3/8" geared chuck with key is now available as the Model 820K11.

The drill comes with a 3.2-A, 117-V a.c. high-torque motor which delivers a constant drilling speed of 1100 r/min; needle bearings at heavy load points; ball thrust spindle bearing; and double-reduction heavy-duty gear train. The drill motor has a welded burnout-proof armature. The drill measures 9" x 7 1/4" x 2 1/2" with chuck. Wen

Circle No. 1 on Reader Service Card

TOROIDAL INDUCTOR

The EC30AL subminiature line of toroidal inductors is available in a wide selection of inductance values from 1.82 mH to 1.78 H in 2.5% increments with ±1% tolerance. The inductors offer high "Q" for their size.

Housed in a crystal-can type enclosure, the 0.33 x 0.73 x 0.75 inch units have 0.1-inch grid leads for PC boards. A data sheet with complete specs is available on request. Magnetic Circuit Elements

Circle No. 127 on Reader Service Card

DIGITAL PANEL METER

A digital panel meter which features integrated circuits is now being marketed as the Model 2800. With the exception of the readout lights, the meter is completely solid-state. Three full-time digits use cold-gas glow tubes with a rated life of 200,000 hours. The new units require a panel space 2.84" x 4.75" and are only 7.36" deep.

The meter is available in five d.c. ranges covering voltages from 00.0 to 99.9 mV up to 000.00 to 999 volts, and five d.c. current ranges from 0.00 to 9.99 μA up to 00.0 to 99.9 mA. Linear overrange to 180% of full-scale is offered as standard. The number "1" automatically lights to the left of the other digits to indicate overrange operation. It will flash when the measured value exceeds the overrange capacity. Underrange or reverse polarity is automatically indicated by a light to the right of the digits. Linear underrange of 5% permits reading negative values. The display is non-blinking. Storage capability changes reading only when the measured value changes.

A data sheet, P-603, giving complete specs on the meter will be forwarded on request. Simpson

Circle No. 128 on Reader Service Card

IC-REGULATED SUPPLY

The new "Com-Pak Mark II" LC series is the industry's first all-silicon a.c.-d.c. power supply using an integrated circuit to provide the regulation system (exclusive of input and output capacitors, rectifiers, and series regulation transistors).

The number of parts in this new series has been reduced by a ratio of 2:1, with over 30 dis-

crete components eliminated. This has resulted in greatly reduced package size and improved reliability and MTBF, according to the company.

The supply measures 1 11/16" x 3 5/32" x 3 9/32". Regulation is 0.01% + mV; ripple and noise is 250 μV r.m.s.; 1 mV peak-to-peak. Input voltage and frequency range is 105-132 V a.c., 53-63 Hz. Lambda

Circle No. 129 on Reader Service Card

100-W POWER TRANSISTOR

A new series of 100-watt "n-p-n" and "p-n-p" power transistors with high-frequency performance of 30 to 40 MHz minimum and with beta linearity guaranteed from 10 mA to 10 A, has been added to the line of complementary silicon power transistors.

The "n-p-n" additions are the 2N5006 and 2N5008, with collector-to-emitter sustaining voltage of 100-V minimum, and the 2N5288 and 2N5289, with LV_{CEO} of 80 volts. The "p-n-p" complements are the 2N5007 and 2N5009 (100 volts) and the 2N5290 and 2N5291 (80 volts). All units feature high power dissipation and a maximum current saturation voltage of 1.5 volts at 10 amps. Fairchild Semiconductor

Circle No. 130 on Reader Service Card

LOW-COST PANEL METER

The three-digit panel meter, Model VT-100, will measure voltage, current, and resistance; display d.c. voltage over four ranges; d.c. current

over five ranges; and a.c. voltage and current over three ranges each; and show resistance over four ranges.

Designed for the OEM, the meter features automatic zero and interchangeable PC cards to facilitate servicing. BCD output and remote encoding capability is available as a factory option to permit the user to record immediately the variable being measured.

Accuracy is 0.2% of reading, +1 digit with an input impedance of 1000 megohms and a rate of measurement at 1 per second. Basic range of the meter is 1.0 V d.c. With plug-in options, this range can be extended to measure d.c. and a.c. voltage from 100 mV to 100 V full-scale, d.c. and a.c. current from 100 μA to 1 A full-scale, and resistance from 100 to 100,000 ohms full-scale.

The meter weighs 4.4 pounds and measures 2.8" high x 5.6" wide x 9.1" deep. Honeywell Test Instruments

Circle No. 131 on Reader Service Card

SNAP-ACTION ROCKER SWITCHES

A new line of lighted and unlighted rocker switches featuring instant snap-in action and fit has just been introduced. The new line is supplied in s.p.d.t. and d.p.d.t. Exclusive holding clips lock the switch in place in the circuit for safe, secure electrical connections.

The switches have an unbreakable nylon case, shatterproof plastic lens, and silver alloy contacts. In the lighted version, the rocker of the switch also acts as the lens. It is available in 120- to 240-volt neon and 4- to 48-volt incandescent types. The lenses are furnished in red, green, yellow, opal, and clear. Chicago Switch

Circle No. 132 on Reader Service Card

10-IN-1 ELECTRONIC KIT

The new 10-in-1 project kit contains parts and instructions for building a germanium radio, transistor amplifier, germanium radio with transistor, code-practice oscillator, low signal oscillator, radio-TV signal generator, dual code practical oscillator, a transistor radio receiver, signal tracer, and wireless microphone.

The circuits can be assembled without soldering. Numbered parts and point-to-point connections permit quick, safe assembly. An 18-page illustrated instruction booklet helps the constructor and suggests additional circuits which can be assembled from the parts included. Radio Shack

Circle No. 2 on Reader Service Card

SOLID-STATE POWER SUPPLY

A low-cost, low-voltage solid-state regulated power supply has been introduced as the IP-18.

Voltage is regulated to a 40-mV variation from no-load to full-load; there is less than 0.05% change in output with an input change from 105 to 125 V a.c. The unit is current-limiting and continuously variable from 10 to 500 mA. Ripple and noise are under 0.1 mV and the transient response is 25 μse. Output impedance is 0.5 ohm or less up to 100 kHz. The unit can be programmed for either a.c. or d.c. (3-mA driving current on d.c.).

Circuit-board construction makes the power supply easy and quick to assemble and lightweight. Heath

Circle No. 3 on Reader Service Card

INDICATOR LIGHTS

A new series of indicator lights using long-life, built-in T-1 incandescent lamps has been introduced as the CM34 "Relia-Lites."

Each light mounts on $^{11}/_{32}$" centers in panels up to $^{3}/_{16}$" thick and is available in either macro-dome or cylindrical cap styles for full 180° light dispersion. Hot-stamped legends are available on cylindrical caps and both styles are available in any of six different colors. Operating voltage is from 3.0 to 28.0 V with mean spherical candlepower levels from 0.001 to 0.22. A hex mounting nut and six inches of #26 A.W.G. wire leads facilitate installation. Chicago Miniature Lamp

Circle No. 133 on Reader Service Card

HI-FI—AUDIO PRODUCTS

HI-FI MUSIC SYSTEM

A three-piece ensemble combining a 12-W solid-state FM-stereo receiver, a four-speed record player with diamond stylus stereo pickup, a cassette stereo tape recorder with a pair of matched two-way bookshelf speaker systems is now being marketed as the RK-570.

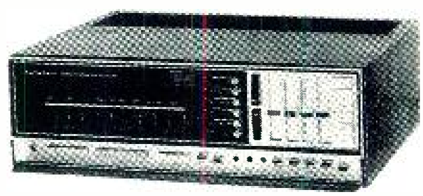
The FM section features an FET front end rated at 2.5-μV (IHF) sensitivity. The amplifier is rated at 6-W/ch music power into 8 ohms with a response of 20-30,000 Hz ±2 dB. A sloping front panel puts all controls within easy reach. These include power "on-off", bass, treble, balance, volume, program selector, loudness, and speakers "on-off". There is a vu meter for tape playback and record and a stereo indicator light.

The control center measures 20¾" w. x 14½" d. x 3⅜" h. The speakers measure 12" x 7" x 8". Lafayette

Circle No. 4 on Reader Service Card

160-WATT FM-STEREO RECEIVER

A 160-watt FM-stereo receiver that features fully automatic motor tuning coupled with precision manual motor tuning has been introduced



as the SA-4000. In addition, a preset memory master tuning system allows the listener to preselect up to five stations by means of push-buttons.

The circuit incorporates four FET's and six IC's. Computer logic circuits plus tuned circuits and a unique ceramic filter provide automatic mono/stereo switching and prevent accidental triggering of the stereo indicator lamp. A comprehensive complement of audio and tuner controls are included on the front panel for easy accessibility. The receiver comes in a walnut wood cabinet. Panasonic

Circle No. 5 on Reader Service Card

CASSETTE RECORDER

The Model 1150 cassette recorder is a solid-state battery/a.c. unit designed for pop-up cassette loading and removal. Response is 200-11,000 Hz and the unit will record and play up to 2 hours mono on standard Philips-type cassettes.

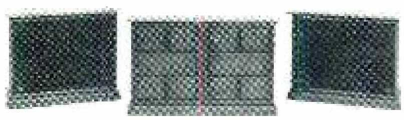
The recorder is operated with keyboard-type push-buttons including a pause button and fast forward and rewind. A switchable automatic level control prevents fading and overload distortion. The recorder also has a tone control, monitor switch, battery level meter, and provision for recording from radio, tuner, phonograph, or TV.

The Model 1150 measures 9⅜" x 6" x 2⅝" and weighs 4 pounds. It comes with a remote start-stop dynamic microphone, cassette, carrying case, and shoulder strap. Allied Radio

Circle No. 6 on Reader Service Card

TWO-WAY SPEAKER SYSTEM

The new Alpha series matches a two-way speaker system with an equipment cabinet. The Alpha I is augmented above 7000 Hz to enhance harmonics. The Alpha II matching equipment cabinet is compact but can accommodate a wide



variety of hi-fi components. The speaker system includes 12-inch low-frequency speaker, matching passive radiator, a 5-inch transducer for the mid- and high frequencies, and the company's LE20-1 for the overtones.

The Alpha series is finished in hand-rubbed russet oak with burnt sienna grille cloth. JBL

Circle No. 7 on Reader Service Card

COMPACT SYSTEM

The AD-27 "Component Compact" incorporates the AR-14 stereo receiver, a BSR McDonald

500 4-speed turntable, and Shure diamond-stylus cartridge, all housed in a walnut cabinet with solid walnut sliding tambour door.

The amplifier portion features 15-W/ch music-power output, all solid-state circuitry, and a frequency response of 12-60,000 Hz ±1 dB. Channel separation is 45 dB and harmonic and IM distortion is less than 1%. The output impedance is 4 to 16 ohms to match external speaker systems of the user's choice. The FM-stereo section has four i.f. stages, 5-μV sensitivity, and hum and noise rating of −45 dB.

Complete specifications and ordering information will be forwarded on request. Heath

Circle No. 8 on Reader Service Card

DUAL-IMPEDANCE MICROPHONE

The 11/171 dual-impedance microphone has been designed specifically for those who want a good cardioid dynamic microphone at a budget price. The microphone comes with a removable anti-hiss shield windscreen, 25 feet of cable, and a holder in non-reflective lustre-chrome finish. It carries the company's standard 2-year warranty. American Geloso

Circle No. 9 on Reader Service Card

COMPACT MUSIC SYSTEM

The SC2350 compact music system incorporates an AM-FM-stereo tuner, a four-speed Garrard record player with diamond-tipped phono pickup, a 50-W (IHF) power-output amplifier, and two newly designed speakers with omnidirectional radiation patterns. Harman-Kardon

Circle No. 10 on Reader Service Card

CASSETTE/AM RADIO

The Model F-95 AM cassette Radiocorder permits AM listening, off-the-air recording, and tape playing. Recording is push-button actuated and the automatic record level control permits uniform recording without adjusting the sound level each time.

The F-95 can be used for live tape recording with the dynamic remote-control microphone and for playing back prerecorded cassettes. The unit operates on batteries and 117-V a.c. Concord

Circle No. 11 on Reader Service Card

FM TUNER CARTRIDGE

A new cartridge-type FM tuner which converts any 4- or 8-track stereo cassette player into an FM radio is now on the market. To operate, the cartridge is inserted into the tape slot and tuning is accomplished with the recessed control knob.

The tuner measures 6½" x 4" x ⅞" and weighs ¼ pound. The circuit uses 8 transistors and 3 diodes. It provides full coverage of the FM band. Stereo-Magic

Circle No. 12 on Reader Service Card

CB-HAM-COMMUNICATIONS

HAM/SWL RECEIVER

The Model A-2515 receiver is a five-band, AM-c.w.-SSB unit featuring solid-state circuits and coverage of all amateur bands from 80 to 10 meters, international short-wave, aircraft, marine, and other short-wave broadcasts, as well as the standard AM broadcast band. Bands covered are 150-400 kHz, 550-1600 kHz, 1.6-4.8 MHz, 4.8-14.5 MHz, and 10.5-30 MHz.

Of the 24 semiconductors in the circuit, two are FET's in the r.f. stage to provide maximum sensitivity and low noise level. Four mechanical filters are used for sharp station separation; noise limiter and automatic volume control reduce noise, blasting, and fading. There is built-in variable b.f.o. and product detector to give clear reception of code and SSB. The receiver has an illuminated "S" meter and illuminated slide-rule dial.

Equipped with dual power supplies, 117 volts a.c. and 12 volts d.c., the receiver can be operated from house current, cars, boats, trailers, and at camp sites. It measures 7⅝" high x 15" wide x 10" deep. It requires a separate speaker which is available at additional cost. Allied Radio

Circle No. 13 on Reader Service Card

2-METER TRANSCEIVER

The Model HW-17 transceiver covers the amateur 2-meter band and also includes extended coverage to 143.2 to 148.2 MHz for working MARS, CAP, and Coast Guard Auxiliary operators.

The input to the hybrid transmitter (solid-state and tubes) is 18 to 20 watts; output is 8 to 10 watts, AM, on any of four crystal frequencies or external v.f.o. The push-to-talk operation is relay-less.

The dual-conversion solid-state receiver has a 1-μV sensitivity and features a prebuilt, prealigned FET tuner, a.n.l, squelch, spot function, lighted dial, and a signal-strength/relative power output meter. A "battery saver" switch on the front panel activates the receiver portion only, and draws 100 mA.

Estimated assembly time is 20 hours. A gimbal mounting bracket makes the unit usable for either mobile or fixed operation. The built-in power supply is 120/240 V a.c. An optional mobile power supply is also available. Heath

Circle No. 14 on Reader Service Card

DUAL-CONVERSION SSB UNITS

A new series of single-sideband transceiver equipment covering the 2 to 20 MHz range and available with p.e.p. output power ratings of

400, 250, and 150 watts is now available. Any model in any of the three power ratings is available with from one to six channels plus a number of options including selectable sideband, compatible AM, and VOX/c.w.

Dual-conversion is used in both receiver and transmitter so that a single h.f. oscillator crystal can be used for both upper and lower sideband operation, reducing complexity and cost. These oscillator frequencies are sufficiently removed from the operating frequencies to provide greater attenuation of spurious signals particularly at the higher frequencies.

Except for final amplifier stages, the units are all solid-state including the power supplies which operate from 117 V a.c. and all standard d.c. sources. Power supplies are normally outboard but can be obtained integral with the transceivers. Linear Systems

Circle No. 15 on Reader Service Card

MANUFACTURERS' LITERATURE

SEMICONDUCTOR MODULES

A two-color, 8-page brochure describing a complete line of integrated semiconductor modules for use in all types of stripline and coaxial r.f. structures from d.c. to 18 GHz is now available as Catalogue D-68.

The publication describes the electrical and mechanical details of several types from single-pole, single-throw and single-pole, multi-throw switch modules to digital phase shifter modules. A detailed theory and applications section is provided in addition to numerous photographs, drawings, and performance curves throughout. Alpha Industries

Circle No. 134 on Reader Service Card

ADJUSTMENT POTS

An 8-page brochure on adjustment potentiometers has been issued. It features the nomenclature, dimensions, specifications, price listings, and detailed photos of more than 50 Cermet, high-performance wirewound, special-purpose and general-purpose wirewound, and general-purpose and special-purpose carbon element adjustable pots. Specifications include resistance tolerance, power rating, maximum temperature, adjustment turns, standard resistance, and humidity. Special dimensions and specifications for mounting hardware are also included. Bourns

Circle No. 135 on Reader Service Card

D.C. POWER SOURCES

A 12-page catalogue which briefly describes a comprehensive product line of high- and low-voltage d.c. regulated power sources is now available. It includes photographs and listings of precision high-voltage sources, general-purpose laboratory power supplies, a family of precision d.c. sources, and the universal power module family of modular power sources. Also listed is a group of NIM configuration power sources for those utilizing nuclear instrumentation. Power Designs

Circle No. 136 on Reader Service Card

MATV EQUIPMENT CATALOGUE

A 16-page catalogue which covers an extensive line of MATV antenna equipment is available as Catalogue SYS-68.

Covering many new items in the 82-channel "Channel Smoothline", the publication includes broadband and single-channel antennas; broadband and single-channel head-end amplifiers; active and passive accessories; filters and traps; tap-offs, matching transformers, and wallplates; pre-amplifiers, amplified couplers, connectors, and cable. JFD

Circle No. 16 on Reader Service Card

PULSED TRANSFORMERS

Information and technical data on a line of pulsed transformers and chokes is included in a new publication. The trigger transformers cover a range up to 40 kV, standard chokes range from 22 μH up to 850 μH, and special and custom chokes and trigger transformers are also available.

Full specifications, figures, and circuit diagrams are included on the data sheet. EG&G

Circle No. 137 on Reader Service Card

ADHESIVES CATALOGUE

A new 20-page, 8½" x 11" catalogue listing official U.S. Government specifications and Federal stock numbers for a wide variety of adhesives, coating, and sealers is now available.

The catalogue lists government specifications and federal stock number descriptions, intended application, and the corresponding company adhesive, coating, or sealer that meets the specifications. 3M

Circle No. 138 on Reader Service Card

RELAY CATALOGUE

A 28-page illustrated catalogue which lists all in-stock and standard relays available in the line is now ready for distribution.

Included in the technical information are styles and dimensional drawings of the various cases, pin configurations, terminal arrangements, and internal wiring diagrams. The tables include part number and electrical characteristics, such as pull-in voltage (or current), coil resistance, drop-out voltage (current), number of poles, watts requirement per pole, and other engineering data.

Relay categories covered include sensitive, ultrasensitive, crystal can, general purpose, miniature telephone-type, and military relays. Kurman Instruments

Circle No. 17 on Reader Service Card

TOOL CATALOGUE

An 80-page tool catalogue plus a 20-page supplement covering assembly and maintenance of the latest in microminiature electronics is now available for distribution.

Items range from micro tweezers in over 100 different styles and materials to automatic wire stripping and ultrasonic cleaning equipment. Specialties include standard custom-made assembly kits for production and lab work stations in addition to "Delicut", a new concept in microminiature component assembly tools. Techni-Tool

Circle No. 18 on Reader Service Card

CRYSTAL FILTERS

A four-page bulletin describing a line of monolithic crystal filters, their components, applications, and advantages is now available.

Included are specifications for the complete line of monolithic filters and the various types of designs available, such as transitional Butterworth-Thomson, Butterworth, Gaussian, Chebyshev, and equi-ripple phase. The bulletin is illustrated. Damon

Circle No. 139 on Reader Service Card

CIRCUIT PROTECTORS

A new 12-page brochure, Bulletin 16E-12, contains detailed information on single- and multi-pole electromagnetic circuit protectors of the hermetically sealed, panel-mount type. Curves and charts show delay characteristics, rupture capabilities, and impedance values. Types UP, with UL listing, and AP-MIL, produced for military qualification, are also described. Airpax

Circle No. 140 on Reader Service Card

LIGHTING GUIDE

A 16-page lighting guide, Catalogue LG-468, has been designed to aid in the selection of lamps and lampholders best suited to particular applications or products. Sections include a lamp selection guide, a lampholder selection guide, a bracket guide, plus a condensed catalogue of indicator lights.

The lamp selection guide shows 14 different lamp types and gives complete specifications for 62 lamp numbers. Leecraft

Circle No. 141 on Reader Service Card

ELECTROMECHANICAL COMPONENTS

A new 100-page catalogue which lists an extensive line of electromechanical components and equipment from all major manufacturers is now available. Included are such items as accelerometers, counters, meters, motors, precision pots, selsyns, servos, test equipment, and timers. Special complete sections are included on relays, pressure transducers, and gyros. American Relays

Circle No. 142 on Reader Service Card

HEX SOCKET SCREWDRIVERS

Bulletin N568 describes a new pocket-size set of eight midget hex-type socket screwdrivers which the company claims are easier and faster to use than conventional keys, especially in delicate, precision, close-quarter work.

Photos show how the "piggyback" torque amplifier handle included in this set can be slipped over the top of the midget drivers to provide larger gripping surface, extended reach, and increased driving power. The bulletin also contains a selector chart with item specifications and a list of various types and sizes of screws which each driver fits. Xcelite

Circle No. 19 on Reader Service Card

CROSS-REFERENCE GUIDE

A new cross-reference guide which lists almost 18,000 semiconductors with their equivalents in the company's HEP line is now available. It lists EIA-registered 1N and 2N numbers, foreign devices, and many house numbers used by both semiconductor and equipment manufacturers.

The 64-page guide is a convenient 4¼" x 11" and is punched with three standard spaced holes. It includes not only the table of equivalents, but tips on using replacement devices, and outline drawings and dimensions. Copies of HMA07-4 are available on request. Motorola

Circle No. 20 on Reader Service Card

POWER-TUBE BROCHURE

A new booklet describing its line of vacuum power tubes has been announced. This 16-page publication describes power triodes, pulse triodes, power tetrodes, and vacuum diodes. A separate section describes accessories for the tubes, such as water and air jackets, "O" rings, and connectors.

The booklet concludes with a handy section on application maintenance notes for power tubes. ITT Electron Tube Div.

Circle No. 143 on Reader Service Card

SOLID-STATE MULTIMETER

A four-page, four-color brochure which gives complete specifications on the X-3A digital multimeter with v.t.v.m. capabilities is now available for distribution. It includes features, applications, and pricing information. Non-Linear Systems

Circle No. 144 on Reader Service Card

CORD SET LINE

A four-page booklet describing an extensive line of cord sets for use in appliances, power tools, radio & TV receivers, office machinery, and other electrical and electronic equipment is available as Brochure ME-7.

Stock cord sets and custom cord sets and cord assemblies are illustrated and details on materials and molding techniques are included. A check list provides a handy guide for preparing quotation requests. Miller Electric

Circle No. 145 on Reader Service Card

DIGITAL TEMPERATURE UNIT

A four-page, two-color brochure which describes the Series 1400 low-cost, solid-state digital temperature indicators is now available as No. 1400-39.

Complete specifications—mechanical and electrical—are included in both tabular and reading-copy form. The brochure is illustrated and carries information on a line of interchangeable thermister probes. Instrulab

Circle No. 146 on Reader Service Card

SPECIAL-PURPOSE TUBES

A brochure describing a line of special-purpose tubes is now available. It describes in 12 pages the characteristics and type numbers of traveling-wave tubes, direct-view storage tubes, electro-optic tubes, high-power vacuum types, gas-discharge tubes, and xenon lamps. ITT Electron Tube

Circle No. 147 on Reader Service Card

CERAMIC CAPACITORS

A four-page catalogue covering a new series of NPO ceramic capacitors is now off the press. The capacitors are offered in four styles with axial and radial leads and in chip form. Capacitance values range from 10 to 2700 pF, standard temperature characteristic is 0 ± 30 ppm/°C, and "Q" is 1000 (min.) at 125°C. Voltage ratings on the encapsulated units are 200 V d.c. at 85°C and 100 V d.c. at 125°C.

Complete electrical and mechanical specifications, dimensional drawings, ordering information, typical curves, and other pertinent information in included. Vitramon

Circle No. 148 on Reader Service Card

CATALOGUE SUPPLEMENT

A 12-page supplement to the firm's catalogue "Power Supplies Unlimited" is now available for distribution. The catalogue covers a wide range of module power-supply units and appropriate rack and panel adapters for the SC, HT, HS, FS, and SP series.

The supplement is illustrated and includes complete specs in tabular form. Page references and convenient charts make it easy to cross-index the right module power-supply unit for a specific need. NJE

Circle No. 149 on Reader Service Card

POWER SUPPLIES

A 12-page, two-color catalogue covering voltage reference standards, power supplies, accessories, overvoltage protectors, potentiometer voltage supplies, and optional features for power supplies is now ready for distribution.

In concise tabular form, complete details are provided on an extensive line of products, including photographs, mechanical details, construction information, and electrical specs. Dynage

Circle No. 150 on Reader Service Card

TECHNICAL BOOKS

A 16-page catalogue covering over 100 current and forthcoming books in the areas of broadcasting, basic technology, CATV, electric motors, electronic engineering, television, radio and electronics servicing, audio and hi-fi, hobby and experiment, test instruments, and transistors is now available on request. Tab Books

Circle No. 21 on Reader Service Card

PARAMETRIC EQUIPMENT DATA

A 20-page booklet which describes the principle of operation of parametric equipment is now available. Entitled "The Paraformer", the booklet provides a description of the new passive power conversion device. Its unique filtering and regulating qualities are discussed and comparisons made with other devices in similar applications.

Included are illustrations of waveforms, symbols, pictorial views, and curves covering the operation and construction of the device. Wanlass

Circle No. 151 on Reader Service Card

LASER DATA

A 22" x 24" data compilation chart which folds so that it can be put into a notebook has been issued. It includes all of the formulas, wavelength conversions, energy conversion, output wavelength and fluorescent lifetime of various lasing systems, indices of refraction, angular-to-linear conversion, physical constants, recommended unit prefixes, beam-shaping formulas, xenon flashlamp approximations, simple auto collimator schematic, and a layout for aligning optical components of lasers. Laser Nucleonics

Circle No. 152 on Reader Service Card

RELAYS AND SWITCHES

A six-page product line summary that features a comprehensive selection of electromechanical relays and switches is now available. The components illustrated include many industry standard types, as well as new proprietary specialties developed by the company.

The summary includes printed-circuit relays, general-purpose and telephone relays, polarized, counting-and-selecting, dry and mercury-wetted relays, contactors, and standard, miniature, PC rotary and track switches. ITT Jennings

Circle No. 153 on Reader Service Card

CONNECTORS & HARDWARE

A 56-page catalogue which contains information on a complete line of phone plugs and jacks, phono plugs and jacks, binding posts and boards, banana plugs and jacks, anode connectors, alligator clips, adapters, coaxial jacks, microphone connectors, fuse and diode holders, interlocks, lugs, brackets, contacts, test prods and test lead sets, terminal strips and boards, etc., is currently available. National Tel-Tronics

Circle No. 154 on Reader Service Card

TELECASTING ACCESSORIES

A five-unit series of technical data sheets (2610 Series) covering seven major accessories for broadcast television has been issued. Specifications and photographs are included for the black burst generator, dot-bar generator, color-bar generator and color-bar encoder, chroma detector, driver generator, and colorlock. Cohu

Circle No. 155 on Reader Service Card

ELECTRIC POWER TOOLS

A new 16-page catalogue, Form No. 158, which lists an extensive line of industrial-rated electric power tools is now available for distribution.

Included are pictures and complete electrical specifications on drills and accessories, reciprocating and power jig saws, circular saws, sander-polishers, electric planes, grinders, sanders, and soldering guns. Wen

Circle No. 22 on Reader Service Card

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1968 INDEX
VOLUMES 79-80

As a service to our readers we are again presenting a complete listing of all feature articles which appeared in ELECTRONICS WORLD during 1968. We suggest you keep this for reference.

COMMUNICATIONS

COMPONENTS

HIGH FIDELITY & AUDIO

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SOLID-STATE

TELEVISION & RADIO

TEST EQUIPMENT & MEASUREMENTS

PRODUCT REPORTS

PLEASE. . . .
Save this Annual Index for future reference to all the feature material which has appeared during 1968.

Answer to TV Waveform Quiz appearing on page 76

1 - H	6 - I
2 - J	7 - D
3 - C	8 - B
4 - E	9 - F
5 - G	10 - A

"Looks like the structural engineer might have been a little uncertain of his design."

ELECTRONICS MARKET PLACE

COMMERCIAL RATE: For firms or individuals offering commercial products or services. 85¢ per word (including name and address). Minimum order $8.50. Payment must accompany copy except when ads are placed by accredited advertising agencies. Frequency discount: 5% for 6 months; 10% for 12 months paid in advance.

READER RATE: For individuals with a personal item to buy or sell. 50¢ per word (including name and address). No minimum! Payment must accompany copy.

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

FOR SALE

JUST starting in TV service? Write for free 32 page catalog of service order books, invoices, job tickets, phone message books, statements and file systems. Oelrich Publications, 6556 W. Higgins Rd., Chicago, Ill. 60656.

GOVERNMENT Surplus Receivers, Transmitters, Snooperscopes, Radios, Parts, Picture Catalog 25¢. Meshna, Nahant, Mass. 01908.

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

CONVERT any television to sensitive big-screen oscilloscope. Only minor changes required. No electronic experience necessary. Illustrated plans, $2.00. Relco-A22, Box 10563, Houston, Texas 77018.

MUSIC LOVERS, CONTINUOUS, UNINTERRUPTED BACKGROUND MUSIC FROM YOUR FM RADIO, USING NEW INEXPENSIVE ADAPTER. FREE LITERATURE, ELECTRONICS, 11500-Z NW 7th AVE., MIAMI, FLORIDA 33168.

SURVEILLANCE COUNTERMEASURES BROCHURE $1.00. ENGINEERING LABORATORIES, BOX 1036, ANDERSON, INDIANA 46015.

"ARCTURUS SALE"

- **Tube cartons 6AU6 etc. size, $2.15 per 100. 6SN7 etc. size, $2.55 per 100. 5U4GB size, $2.95 per 100. 5U4G size, .3¢ each.**
- **7" 90° TV bench test picture tube with adapter. No ion trap needed. Cat. #7BP7, $7.99.**
- **Silicon rectifier, octal-based replacement for 5U4, 5Y3, 5AS4, 5AW4, 5T4, 5V4, 5Z4. With diagram. Cat. # Rect 1, 99¢ each.**
- **5 transistor circuit boards containing up to 6 transistors, plus diodes, resistors, capacitors, etc. Cat. # TB10. 99¢.**
- **Kit of 30 tested germanium diodes. Cat. #100, 99¢.**
- **RCA-110° flyback transformer, latest type, includes schematic diagram. Applicable to any TV. Cat. # BR-1, $2.99.**
- **Color yokes. 70° for all around color CRT's. Cat. # XRC70, $12.95. 90° for all rectangular 19 to 25" color CRT's. Cat #XRC90, $12.95.**
- **Transistorized U.H.F. tuners used in 1965 to 1967 TV sets made by Admiral, RCA, Motorola, etc. Removable gearing may vary from one make to another. Need only 12 volts d.c. to function. No filament voltage needed. Easy replacement units. Cat. # U.H.F.—567, $4.95.**
- **U.H.F. Tuner-original units as used in TV sets such as RCA, Admiral, etc. covering channels 14 through 82, as part #94D173-2. Complete with tube. Drive gearing is removable. Can be used in most sets. Cat. # U.H.F.—3, $4.95.**
- **F.M. tuner-Hi/Fi amplifier tuning unit. Tunes from 88 to 108 mc. Contains two 10.7 Mc. I.F. transformers, one 10.7 sound discriminator, R.F. oscillator and mixer tages and 12DT8 tube. I.F.'s are standard "K" type. Circuit diagram for building F.M. radio included. Also plan for building F.M. tuner. Sam's photofact #620 shows 2 applications, 1 for radio, 1 for Hi-Fidelity tuner and amplifier. Cat. #FM-20, $4.95.**

Send for our free catalog listing thousands of similar best buys in tubes, parts, transistors, rectifiers, etc. Orders under $5.00, add $1.00 handling charge. Include 4% of dollar value of order for postage. Canadian postage $1.00 extra.

ARCTURUS ELECTRONICS CORP.

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Phone: 201-UN 4-5568

CIRCLE NO. 123 ON READER SERVICE CARD

'BUG' DETECTORS, SURVEILLANCE TV, CONFERENCE RECORDERS, TELEPHONE ACCESSORIES, INTRUSION ALARMS. FREE DETAILS: SECURITY ELECTRONICS EW, 13 EAST 43RD STREET, NEW YORK, N.Y. 10017.

CRYSTALS . . . largest selection in United States at lowest prices. 48 Hr. delivery. Thousands of frequencies in stock. Types include HC6/U, HC18/U, FT-241, FT-243, FT-171, etc. Send 10¢ for catalog with oscillator circuits. Refunded on first order. Jan Crystals, 2400E Crystal Dr., Fort Myers, Fla. 33901.

TREASURE HUNTERS! Prospectors! Relco's new instruments detect buried gold, silver, coins. Kits, assembled models. Transistorized. Weighs 3 pounds. $19.95 up. Free catalog. Relco-A22, Box 10839, Houston, Texas 77018.

NEW Sensitive Treasure Metal Detectors. New low prices. Professional models from $29.95 to $129.50. Write for free catalog today. Jetco Electronics, Box 132-E, Huntsville, Texas 77340.

WHOLESALE components: Manufacturers and distributors only. Request free catalog on business letterhead. **WESCOM,** Box 2536, El Cajon, California 92021.

BARGAIN FLYER AND SIX NEW RESISTORS— 25¢ (stamps or coin) **BIGELOW ELECTRONICS,** Bluffton, Ohio 45817.

LAW ENFORCEMENT AGENTS AND LEGAL INVESTIGATORS ONLY. FREE LITERATURE, LATEST ELECTRONIC AIDS. REQUEST MUST BE ON YOUR OFFICIAL LETTERHEAD. R. CLIFTON, 11500-J NW 7th AVE., MIAMI, FLORIDA 33168.

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ELECTRONIC ignition, various types. Free literature. Anderson Engineering, Epsom, N.H. 03239.

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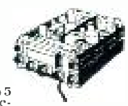

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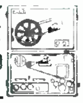

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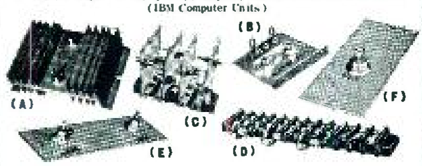

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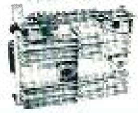

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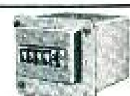

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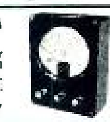

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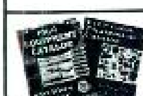

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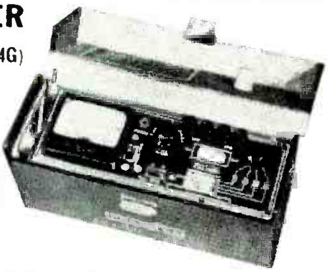

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ELECTRONICS WORLD DECEMBER 1968 ADVERTISERS INDEX

CLASSIFIED ADVERTISING 91, 92, 93, 94, 95, 96

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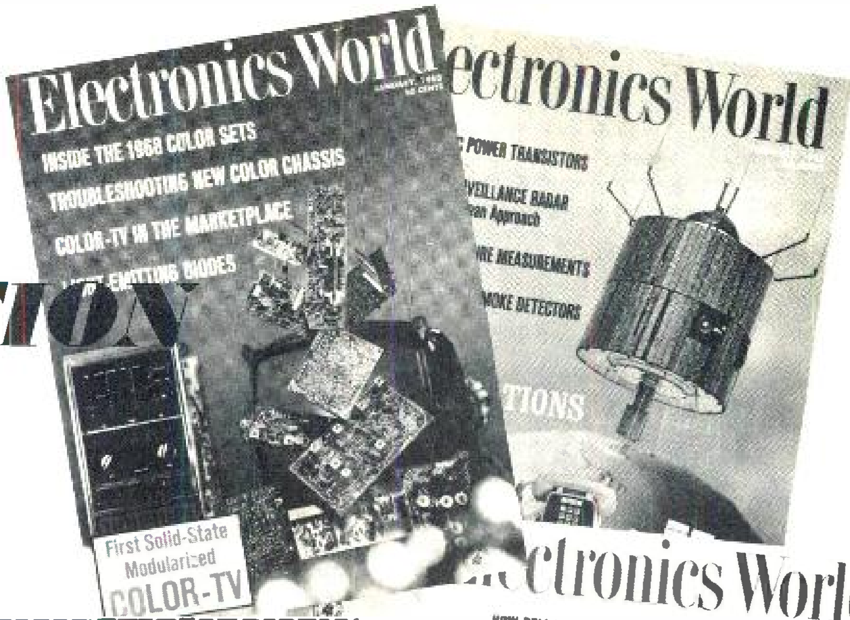

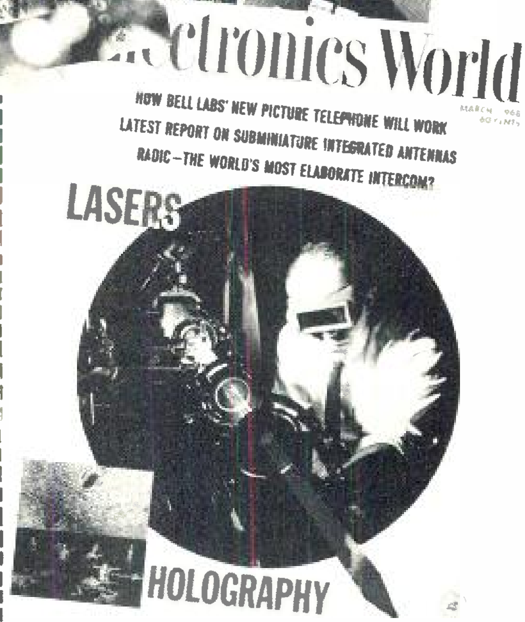

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If you want a better receiver, *don't be misled* — pick the one with the honest price. You owe it to yourself to compare the SX-1500T with any other receiver on the market regardless of price.

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PIONEER ELECTRONICS U.S.A. CORP., 140 Smith Street, Farmingdale, L. I., New York 11735

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170 WATTS, FET FRONT END, AND 4 IC's

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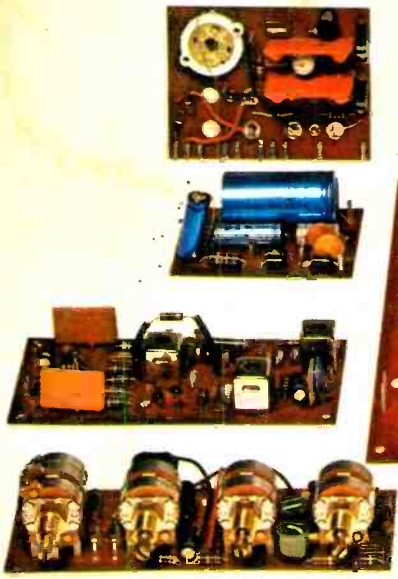

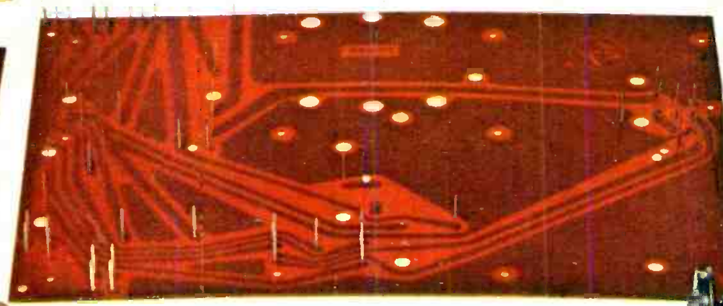

We call it "Mother"!

Model E-V 1282 80 watt receiver, $266.00. CWR1 case, $22.00.

Our big etched circuit board is at the bottom of a significantly better way to make stereo receivers. With one stroke, Electro-Voice has eliminated hand-wiring from almost every signal circuit.

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"Mother" helps in other ways, too. For instance, even slight movement of ordinary wiring can "de-tune" vital RF circuits. But our modular circuits are permanently etched in place—to within .015". So you receive full performance from our Field Effect Transistors and Integrated Circuits. And good ideas like thick-film hybrid circuits simply plug in place. In short—laboratory specifications are exactly duplicated in every production Electro-Voice modular receiver.

Look into any new E-V receiver. We offer four. Your choice of 40 or 80 watts (IHF) with Stereo FM or AM/Stereo FM. From $199.95. Just tell the man "mother" sent you.

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