60¢ ■ MAR. 1972

Radio-Electronics

IND

FOR MEN WITH IDEAS IN ELECTRONICS

SPECIAL ISSUE—4-CHANNEL STEREO

Battle of the 4-channel discs
- CBS Matrix
- RCA Discrete

4-channel adapter roundup

R-E tests cassette tapes

Unusual Ways To Use Semiconductors

Bob Scott's Technical Topics

Circle 1 on reader service card

Radio-Electronics

FOR MEN WITH IDEAS IN ELECTRONICS

March 1972

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←*Circle 2 on reader service card*

looking ahead

Home VTR

The Cartrivision home color video tape recorder developed by Cartridge Television Inc. has gained another adherent. Scheduled to introduce 19-inch and 25-inch combination color receivers and VTRs later this year is the West Coast television manufacturer Teledyne Packard Bell. The combination sets are expected to start at close to $1,000. Pre-recorded tapes may be rented, a feature film going for three dollars a day. Other brand names expected to be offering color sets in combination with Cartrivision recorder-players are Admiral, DuMont, Emerson, Montgomery Ward and Sears Roebuck.

Cartrivision uses half-inch tape in cartridge form. Tentative prices for blank tape cartridges are $20 for one hour, $33 for two hours, $15 for 30 minutes and $10 for 15 minutes. Pre-recorded rental tapes are designed to be played only once by the renter and cannot be rewound except on a special machine. An accessory black-and-white camera will be available at about $200. The recorder can record either from the camera or the television receiver.

New uhf tuner

Beginning some time later this year, you'll see a new type of uhf tuner start to come into common use. It's a midget unit with detents which click into place for each of the 70 uhf channels, the exact channel number appearing in a window. The FCC has approved a change in its "comparable tuning" regulations to permit use of the new tuner. The previous rules have classified as "comparable" only uhf tuners with memory fine tuning, and this has led to tuning systems with six uhf positions, which are set by the television dealer or the consumer to bring in specified local uhf channels. While the new type of tuner lacks memory tuning, it has the advantage of easily tuning any uhf channel available any place without pre-setting. Channel identification systems for the new tuner will use such devices as counters similar to automobile odometers, and transparent back-lighted plastic tapes with channel numbers printed on them.

Under the FCC's comparable-tuning rule, 10% of each TV set makers' models now in production are required to have the same tuning ease for uhf as for vhf. By July 1, the proportion will rise to 40%; on July 1, 1973, the rule will apply to 70% of TV models, going to 100% on July 1, 1974. The purpose of the rule is to encourage viewing of uhf channels.

TV to cable?

A proposal to revamp the nation's television service by switching most or all of it to cable has been made by Motorola's chairman, Robert W. Galvin. Under the plan, there would be a gradual switchover, while new standards would be set for television—Galvin suggested possibly an 800 or 1000-line picture to make possible 3-by-4-foot wall displays without line structure. Television would be merely the first service on the broadband cable, which could accommodate other forms of one-way and two-way communications systems. For rural areas, some on-the-air broadcasting would continue, perhaps by direct satellite transmission.

The spectrum space freed by moving television to the cable would be earmarked to a large extent for new consumer services, including "personal communications, remote control applications, security products and even the revitalization of amateur radio with expanded functions."

4-channel broadcasting

The FCC apparently is just as confused as everybody else about quadraphonic sound, and it plans to take plenty of time before it authorizes any discrete four-channel FM broadcasting systems, except on an experimental basis. Two discrete four-channel systems actually are on the air, but just for test purposes. The Dorren system is being tested by KIOI in San Francisco, while General Electric is experimenting with its own system during non-broadcast hours on its own WGFM in Schenectady, N.Y. Other systems have been proposed or are being developed by Toshiba and Matsushita (Panasonic) in Japan and by McMartin Industries and William Halstead and Leonard Feldman in the United States.

The proponents of the Dorren system have asked the FCC for approval of regular broadcasting, but have run into opposition from both CBS and NBC, among others. Both networks urged the Commission to look into all systems before approving any one as the standard. Staff sources at the Commission have indicated that the selection of a discrete four-channel system, if one is selected at all, will have a fairly low priority. This doesn't mean there'll be no four-channel broadcasting, though. At press time, at least 70 stereo-FM stations were broadcasting matrixed quadraphonic material, which requires no FCC approval. Matrixed four-channel may be received as regular two-channel stereo, or mono. To receive it in four channels, the listener uses a decoder—the same decoder used for four-channel disc recordings. Most stations now broadcasting matrixed material are using the Electro-Voice system.

If the FCC should eventually approve a discrete four-channel broadcasting system, it obviously would seek complete compatibility with both mono and stereo receivers. There's no assurance that the Commission will even begin to look at such systems in 1972, so it could be a long, long time before there's any regular discrete broadcasting. As a guide to how long it may take—it was seven years from the introduction of stereo records until the FCC's selection of a stereo-FM broadcasting system in 1962.

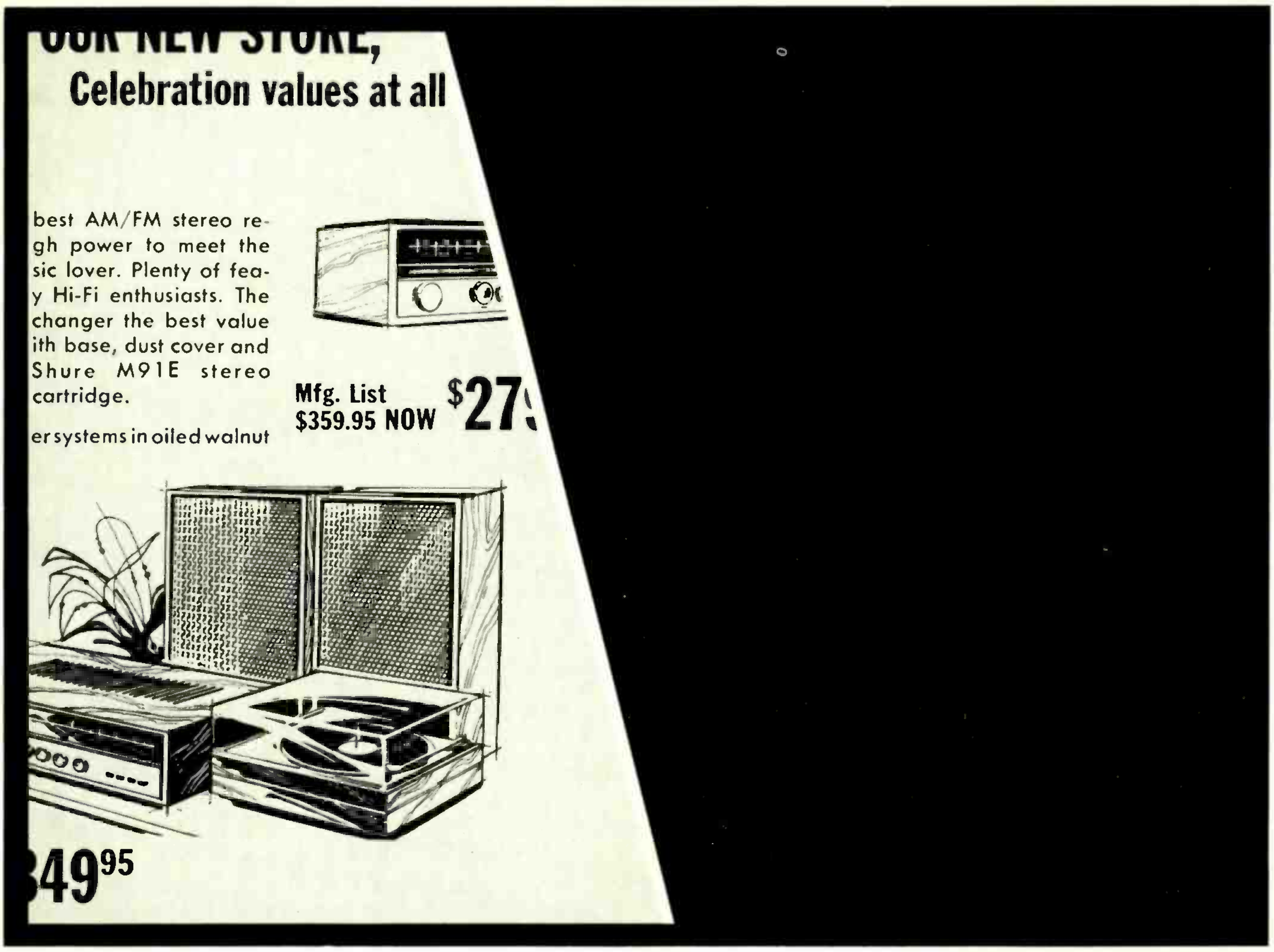
Car stereo census

The vast majority of car radios are bought as original equipment at the time the car is purchased. But with stereo tape players, it's quite the other way around. The average car-stereo owner picks his player after he has the car. For example, last year it's believed that Americans bought between 2,500,000 and 3,000,000 automobile tape players. Yet, in the 1971 automobile model year, American car manufacturers sold only 288,800 cars equipped with tape players at the factory.

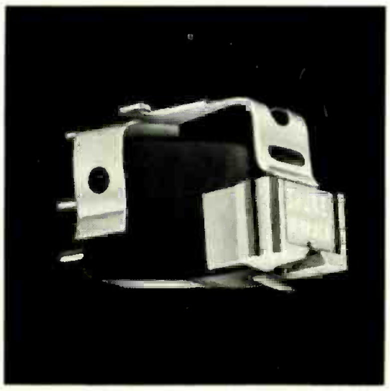
General Motors led the way among auto makers in factory tape installations in the 1971 models, with 197,200 units as compared to 63,100 for Ford Motor Co., 27,100 for Chrysler Corp. and 1,400 for American Motors.

Except for Chrysler, the American car makers offer only eight-track cartridge players as accessories. Chrysler offers both eight-track players and cassette recorders, and in the 1971 model year it sold more cars equipped with cassettes (16,100) than eight-tracks (11,000).

DAVID LACHENBRUCH
CONTRIBUTING EDITOR



How to read a hi-fi ad



Puzzle picture: find the clue that tells you how good the advertised system probably is. Our advice is to check the one component that is the *source* of the sound — the phono cartridge. We say this because we know that the dealer who's assembled a superior package at a fair price is going to complete it with a superior cartridge within the available price range. This dealer ad above, for example, includes a Shure M91E Hi-Track. Even if you weren't aware of the effortless way it meets your most rigorous trackability demands, you should know that it, as well as virtually every Shure cartridge, has been acclaimed by hi-fi critics and authorities as best in its class, or best for the cost. That's why you see so many of them teamed with "best-in-their-class" components, and why they invariably mean a more-for-the-money total system that's going to make you very happy.

Shure Brothers Inc.,
222 Hartrey Ave., Evanston, Ill. 60204

SHURE

Circle 3 on reader service card

new & timely

FTC power output rule

A decision by the FTC to get industry comment on what kinds of test conditions should be set in order to get an accurate measurement of high fidelity amplifiers' power output will delay implementation of their trade rule on output until the 1973 model year.

However, the Commission's decision probably insures that the rule will be issued, after industry comments are received and studied. The rule will require that all advertisements and labels on high fidelity sets must show the continuous RMS power of the amplifier's bandwidth. The measurement must also be the minimum power output of the amplifier as measured against the entire bandwidth. The practice frequently seen in advertisements of listing the power of sets as 150 watts peak power will be halted by the new rule when it goes into effect.

In-warranty service payments

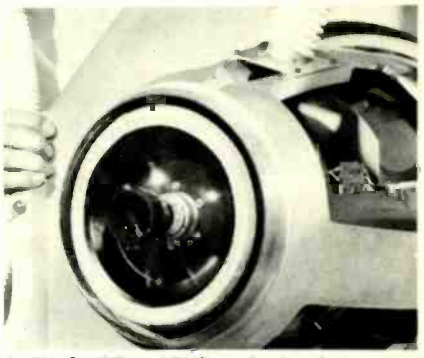
NEA recently completed a survey which indicated a wide variation in the amounts paid by manufacturers for repairs on warranteed TV sets and stereo consoles to individual shops across the country. Although the prices paid are slightly higher in California, Oregon, and Texas, the surprising results of the random sampling of service dealers all over the country show that the greatest variations are not by area.

For example, one dealer is paid $15.00 by a manufacturer to make an in-home service call on a black-and-white TV console. Another dealer is paid $7.00 for the same service call performed for another manufacturer. Bench service charges on a black-and-white TV varied between $5.00 and $45.00; pick up and delivery varied between $3.00 and $15.50; and color TV service calls fluctuated from $7.00 to $17.50.

Although the prices paid to one dealer may be very different from those paid to another for the same service, only one of the TV manufacturers *averaged* far from the other companies when compared in the mean price paid for service.

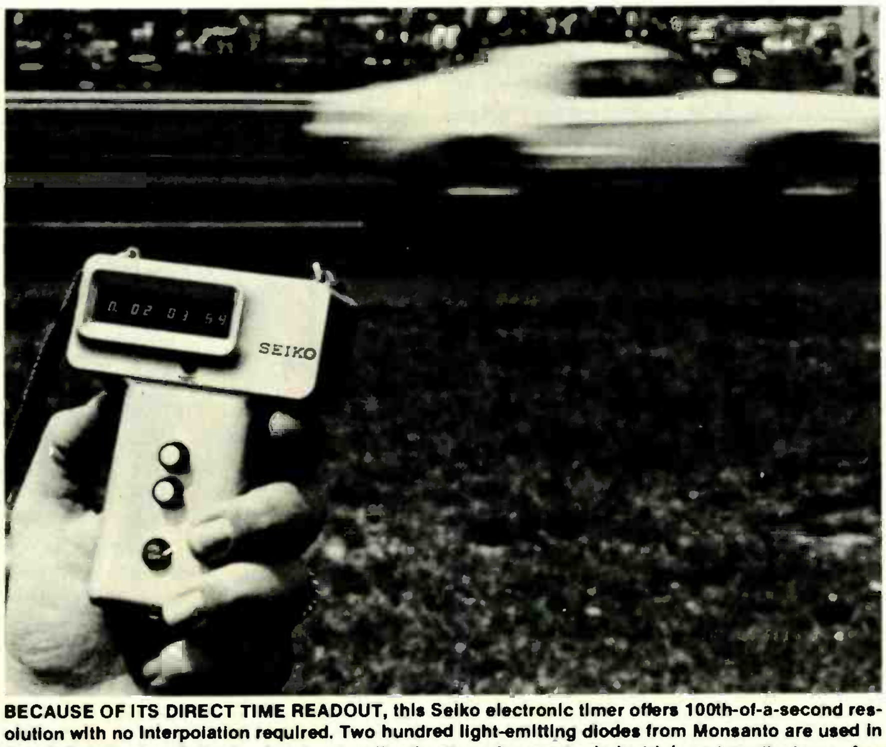
Here are the average prices paid nationwide:

$47.46:—Includes in-home service call on a color TV; taking the receiver to the shop for a major repair; performing bench service and returning the set to the home. (One manufacturer paid only **$13.00** for the works!)



A TV CAMERA LENS protrudes from nosecone of Maverick missile. The missile, recently developed by Hughes Aircraft Company, does most of the work while the pilot is left free to make the decisions. While the missile is attached to the aircraft's wing pylon, its camera presents a picture to the pilot on a cockpit screen. When the pilot selects a target, he centers the camera's cross-hairs on it, locks on and launches the missile. After launch the pilot is free to veer away, attack other targets, or leave the vicinity. The missile continues under its own control, independently guided to the spot on which its camera is focused.

For a service call on a black-and-white TV set, the average payment was $11.83; on a color set, $12.83; on a stereo console, $12.40. For bench service, major repair in the shop, on a b-&-w TV set, $22.10; color TV, $31.37; stereo console, $22.71. Pickup and delivery charges were $11.82 on the average, while carry-in shop service, for minor repairs, on black-and-white sets was $8.29; for color TV's, $11.78; and for stereos, $8.90.



BECAUSE OF ITS DIRECT TIME READOUT, this Seiko electronic timer offers 100th-of-a-second resolution with no interpolation required. Two hundred light-emitting diodes from Monsanto are used in the digital display. Seiko is planning to offer the timer for sports, industrial, and medical use. Any other applications where stop watches are now being used, but where better accuracy and resolution are desirable, are appropriate.

David Sarnoff dies

One of the foremost figures in the world of communications, David Sarnoff, Honorary Chairman of RCA, died in New York City after a lengthy illness on December 12, 1971. He was 80 years old.

General Sarnoff arrived in this country from his birthplace in Minsk, Russia, when he was 9 years old. As a young wireless operator at the Marconi station atop Wanamaker's department store, he and his wireless were catapulted to world prominence when the *Titanic* struck an iceberg and sank with the loss of over 1000 lives. Young Sarnoff picked up the message reporting the *Titanic*'s distress signal and made the news available to the world. From the rescue ship he received a list of survivors and other important messages related to the disaster. He remained on duty for 72 hours, and President Taft ordered every other wireless station along the East Coast to maintain silence to pre-

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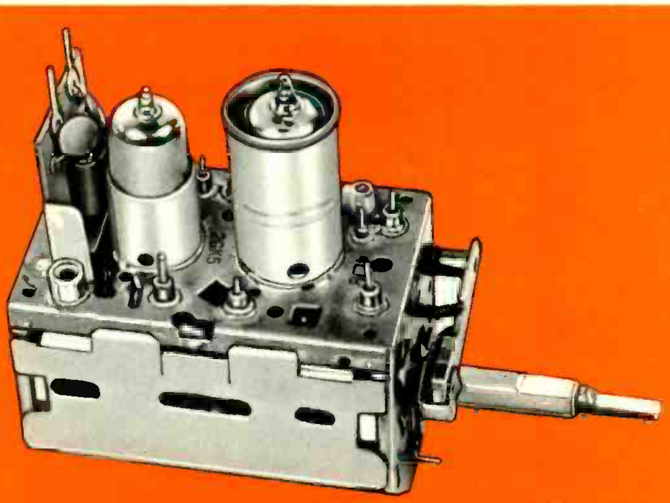

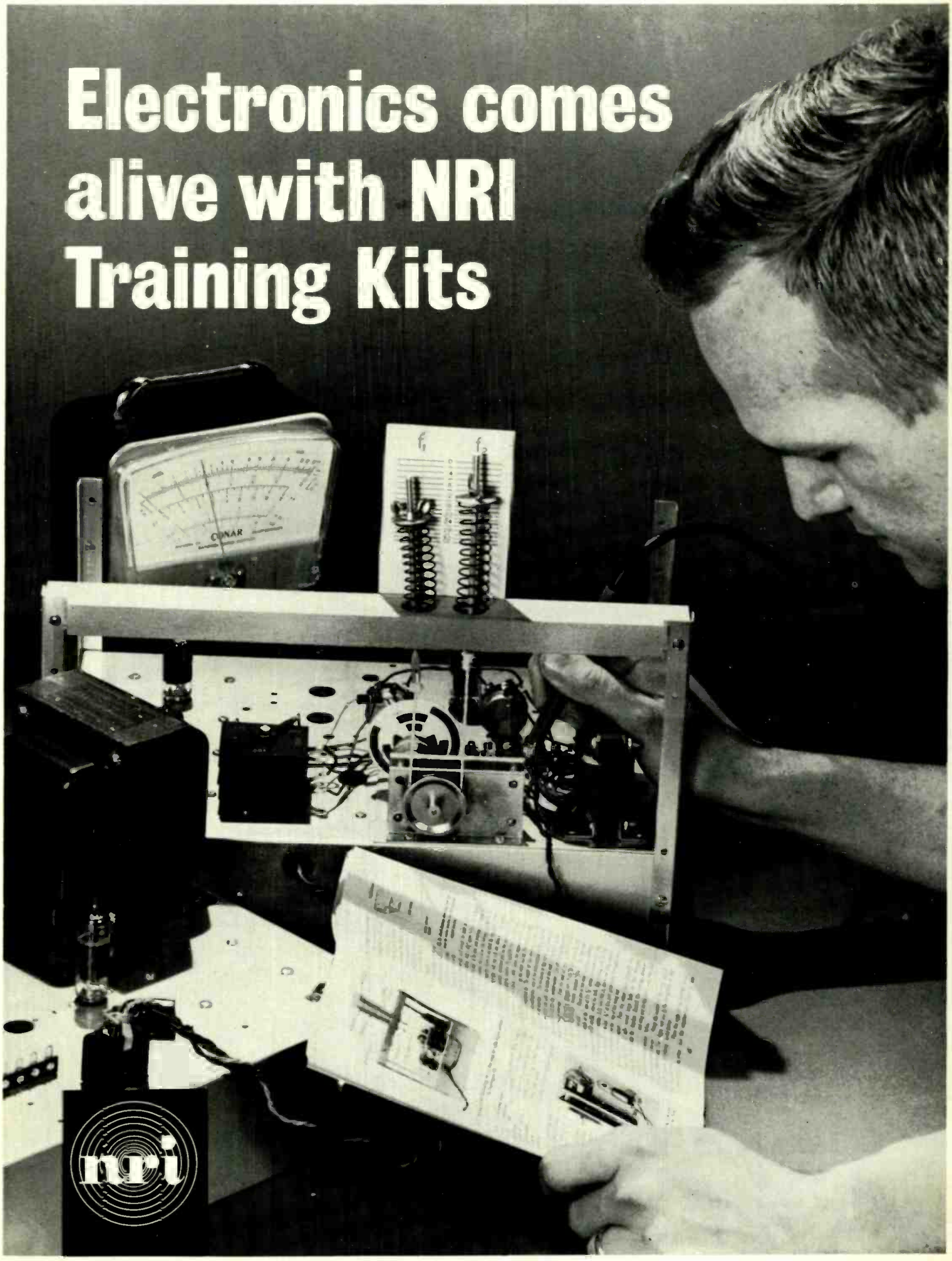
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4. FCC LICENSE* — Prepares you for 1st Class FCC License exams. Begin with fundamentals, advance to required subjects in equipment and procedures.

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8. AVIATION COMMUNICATIONS* — Prepares you to install, maintain, service aircraft in-flight and landing systems. Earn your FCC License with Radar Endorsement.

9. MARINE COMMUNICATIONS* — Covers electronic equipment used on commercial ships, pleasure boats. Prepares for FCC License with Radar Endorsement.

10. MOBILE COMMUNICATIONS* — Learn to install, maintain mobile transmitters and receivers. Prepares for FCC License exams.

11. ELECTRICAL APPLIANCE REPAIR — Learn to repair all appliances, including air conditioning, refrigeration, small gas engines. Leads to profitable part or full-time business.

12. ELECTRONICS FOR PRINTERS — Operation and maintenance of Electronic equipment used in graphic arts industry. From basics to computer circuits. Approved by major manufacturers.

*You must pass your FCC License exams (any Communications course) or NRI refunds in full the tuition you have paid.

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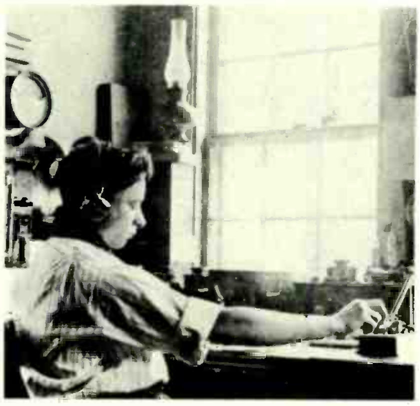
vent interference.

After the world-wide attention focused on General Sarnoff, both the potential of radio and of the young man were recog-



nized. In 1915 General Sarnoff wrote a memorandum proposing a "radio music box" that would receive programs broadcast for public information and entertainment. In 1919, when RCA was formed at the request of the U.S. Government, Sarnoff was named Commercial Manager of the new company. He became General Manager in 1921, and Vice President in 1922. His vision in 1923 was of television as a parallel service to radio broadcasting.

In 1926, Sarnoff organized the National Broadcasting Company as a subsidiary of RCA. He was elected President of RCA in 1930 and Chairman of the Board in 1947. He retired in 1969 to be elected the

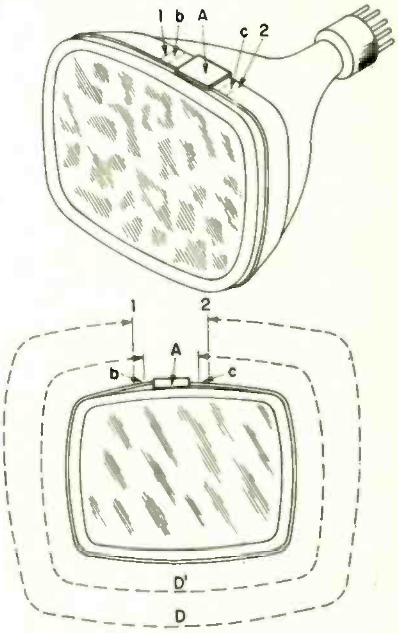
company's first Honorary Chairman.

In addition to his scientific and industrial activities, General Sarnoff achieved wide recognition for his efforts in military communications, especially during World War II. He was promoted to the rank of Brigidier General in 1944 and was decorated by both the French and United States governments. A recipient of 27 honorary degrees from American colleges and universities, he also received many honors and awards from scientific, industrial, military, civic and cultural associations both here and abroad.

CRT implosion protection

A simple and effective non-destructive method of determining the tension in bands used for implosion protection on cathode ray tubes has been developed by IBM engineer, Charles Selzo. The method, which involves no additional equipment except for a linear measuring tool, is readily adaptable to CRT production lines, and shows when the tension band around the periphery of the cathode ray tube is properly applied to provide the protection intended. Insufficient tension would result in loss of implosion protection.

As the sketch shows, the band is marked at **points 1** and **2**. **Distance D** is measured and then tension is applied to the band. As the tension increases, the



band stretches **(points b, c)**, forcing **points 1** and **2** closer together. The **distance D'** is then measured. "The differ-

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We compared our new deluxe preamp to a 10¢ piece of wire.

First we ran a signal through a 10¢ length of shielded cable. What came out the other end was, of course, audibly identical to what went in. Then we ran the same signal through our new TA-2000F preamplifier, and ran an A-B comparison between its output and the wire's. Both were audibly identical. As we'd expected.

This is not to say that sufficiently precise instruments could not detect inaudible differences between our preamp's signal transmission and a wire's. Whereas a straight wire has no distortion whatsoever, we must admit to having some—three hundreths of one per cent harmonic, and five hundreths of one per cent intermodulation, maximum, at rated output. And whereas a wire theoretically does generate some noise, its signal-to-noise ratio is still somewhat better than the 73dB obtained through the TA-2000F's phono inputs, or even the 90dB obtained through our Aux, Tape and Tuner inputs.

But, as you'd expect, the big difference in price between our deluxe preamp and two feet of cable, buys a great deal more than just a pure, clean signal. As our preamp's 58 levers, switches, meters, knobs and jacks would indicate.

NEARLY 2,000 RESPONSE SETTINGS

Six of those controls are devoted to precise adjustment of frequency response. The calibrated, 2dB-per-step, bass and treble controls have switches that adjust their turnover frequencies, so you can choose how deeply the tone controls will affect —or not affect the midrange. Still another switch cuts the tone controls out of the circuit altogether. And a single knob controls the sharply-cutting, 12dB-per-octave, 50Hz and 9kHz filters. Together, these six controls give you a choice of 1,935 *precisely repeatable* response settings including flat (10Hz-100kHz. +0, −2dB) response.

The facilities for tape recording are exceptional and unique; you can record on two tape decks at once, monitoring either (or your program source) at the flick of a switch. You can dub from one machine directly to the other, without external patching or connections. For straight microphone recordings, there's a mic input position on the function selector knob; for voice-over-music, there's a separate mic level control that diminishes all other input signals as it increases the microphone level.

And, of course, the two, front-panel VU meters, are as useful for testing as they are for monitoring record levels.

TOTAL INPUT AND OUTPUT FLEXIBILITY

The TA-2000F can feed two stereo amplifiers (and an additional monophonic or center-channel amp) at one time, at either a 1 volt or 300mV level. The second amplifier output could also be used for still another tape recorder, should you wish to use the ultra-versatile tone controls and filters in recording. The front-panel output jack feeds both high- and low-impedance headphones, or can be used as a tape output, by suitable adjustment of its independent level control; the same knob also controls the center-channel output.

Five of the 8 rear-panel stereo inputs have rear-panel level adjustments. A sixth—the Phono 1 input — has a switch that selects three separate input impedances at the normal 1.2mV sensitivity setting, and two more impedances at the 0.06mV setting that lets you use even the lowest-output cartridges.

96 TRANSISTORS VERSUS A SINGLE WIRE

But all these features merely make our TA-2000F more versatile than any wire. They don't explain how we can come so close to the wire's pure, unadulterated performance. That explanation will rest with our circuit designers, and with the 96 *high voltage*, and Field Effect transistors they used.

THE TA-3200F: AN AMPLIFIER TO TRULY COMPLEMENT OUR PREAMP

A preamplifier like the TA-2000F deserves, of course, its complement in a power amplifier. Not too surprisingly, we make one: the Sony TA-3200F. Its fully direct-coupled circuitry produces 200 watts continuous (RMS) at 8 ohms, with power bandwidth from 5 to 35,000Hz. IHF Dynamic Power is rated at 320 watts into 8 ohms (and fully 500 watts into a 4 ohm load). Its distortion, at a listening level of one half watt, matches the preamplifier's at 0.03%; at full rated output, it is still a mere 0.1%. And the signal-to-noise ratio is 110dB.

Our amplifier's facilities nearly match our preamp's. The 3200F has controls you've rarely, if ever, seen on power amps before: switch-selected stereo input pairs; a speaker selector switch; a power limiter (which holds output down to 25 or 50 watts, should you so desire), and a rear-panel switch that lets you limit bass response below 30Hz., instead of letting it extend to 10Hz.

For further information, see your Sony dealer, or write us. Or wire. Sony Corporation of America, 47-47 Van Dam Street, Long Island City, N.Y. 11101.

SONY®

Circle 5 on reader service card

new & timely

(continued from page 12)

ence between **D** and **D'** indicates the amount of tension on the band," said Mr. Selzo. "A minimum **D—D'** distance must be determined for the implosion protection threshold while a maximum **D—D'** figure is required to ensure the band's elastic limit is not exceeded," he continued. Once the limits are determined, this simple test assures implosion protection on cathode ray tubes.

Hugo Gernsback scholarship winner

John L. Spina of St. Louis, Missouri, has been selected by National Technical Schools to receive the Hugo Gernsback Scholarship Award for 1972. The grant of $125.00 is given annually by **Radio-Electronics** magazine to each of eight students learning electronics at home study schools.

In addition to his studies with NTS, Mr. Spina works as electrical foreman in the area of environmental control installations at the Johnson Control Company. Although this is his first home study course, he has also completed a four-year electrical apprenticeship and a number of courses in air-conditioning, basic and semi-conductor electronics, and commercial blue-print reading.

Mr. Spina is 33 years old, has three teenage daughters, and for recreation enjoys water skiing and boating. About his present NTS training program he says: "I am very interested in the behavior of electronic circuitry and electronic equipment. I hope to work in the field of electronics with much more depth than I have in the past."

Free membership grant

Mr. M. L. Finneburgh, Sr., E.H.F., the Chairman of the Board of the Finney Company, announced a remarkable grant of $35,000 contributed to the cause of national service technician associations membership. The contribution was explained at the NEA Board of Directors meeting held in New Britain, Connecticut.

To qualify, a shop applies for membership in either NEA or NATESA, sending along its check for the first year's dues. When the shop is accepted, the association will forward the new member a merchandise certificate in the amount of the first year's dues, which can be used on the purchase of Finco products at dealer's net cost. In this way the shop dealer not only gets back the cost of his membership in the association, he also makes his normal mark-up on the merchandise.

The $35,000 grant from the Finney Company, makers of antennas, accessories, MATV systems, components, and other electronic merchandise, covers the dues for 1,000 new members.

Leap seconds

A new time scale incorporating "leap seconds" went into effect on January 1st, by international agreement. "Leap seconds" are actually atomic seconds, slightly shorter in duration than the astronomical or earth seconds previously used. These leap seconds, or earth seconds, are added when needed to make the new time scale agree with time kept by the earth's rotation. Those government and scientific laboratory clocks, precisely set, will need resetting about once a year, to add a leap second. To the rest of us, with watches that vary a second or more in a year, the change won't make any noticeable difference.

The term "leap second" is used the same way "leap year" is used: to describe a rectification made periodically to compensate for slight variations in our calculations of the duration of time caused by using the earth's rotation and motion as part of our standard.

Home VTR's

RCA is becoming increasingly active in the videoplayer field. While still working on its holographic videoplayer system, which is still several years off, it now working to get competitive manufacturers to adopt its *SelectaVision* video tape system as the standard (both the holographic and the magnetic systems will use RCA's *Selecta-Vision* trade name). Although RCA's tape system uses the same ¾ inch tape system as the Sony system, the two are not compatible. RCA claims its magnetic recording system is potentially the lowest priced, most reliable method proposed to date, but at this time no technical details have been released. **R-E**

letters

THE "THIRD WIRE"

I just read Jack Darr's *Appliance Clinic* in the December 1971 issue of **Radio-Electronics**, the one about the "Third Wire." It is the best I've read.

The three-wire outlet is much more common here in the Southwest, where much of the construction is relatively new, and where the codes are apparently very strict. There is a *new* safety problem that comes up under these conditions that might deserve mention.

It is just a fact of life that many people here have both 3-wire and 2-wire appliances in their kitchens. All the 3-wire appliances have a *grounded* metal case (if it is metal), which means that there are far more chances for touching a "grounded object" than there used to be. And there is still a pretty good chance that a 2-wire appliance will develop leakage to its metal case.

The probability of getting a shock is the same as the probability of touching *both* a hot and a grounded object at once. The 3-wire appliances *increase* the probability of touching a grounded object, at the very same time they decrease the probability of touching a "hot" object. The *net* result is not easy to be precise about, but my guess is that here there may be *more* probability of getting a shock, not less. There is such a proliferation of small, cheap, never-serviced, 2-wire kitchen appliances these days, and they sit next to stoves, refrigerators, dishwashers, etc., that are grounded.

In my case I found a situation in two different apartments with furnished kitchens where the 2-wire refrigerator *was* hot (enough to light an incandescent bulb). The nearby electric stove was grounded. Fortunately, I fixed it before anything happened, but I wonder how lucky others have been.

JOHN HUNTLEY
Las Vegas, Nevada

TESTING CAPACITORS

Henry Rinton's article in the December 1971 issue of **Radio-Electronics**, "Testing Capacitors Fast," describes an extremely practical gadget. For the past five years I've been using a similar device so I'd like to clarify a few things and make some suggestions for improvement.

This capacitor checker is really just a leakage checker. It shouldn't be used to estimate capacitance, especially electrolytic capacitance, where the inherent leakage of these units would upset your estimations. But the unit is perfect for showing leakage of small capacitors—the real cause of trouble in non-electrolytics. It will work fine for checking leakage in capacitors down to 0.5 pF, instead of 0.001 μF as stated in the article.

Incidently, an interesting use for the checker is checking leakage between the windings of i.f. transformers. This method will spot bad i.f.'s fast. (Also diodes!)

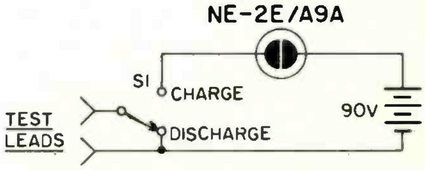


Fig. 1—ADDING AN SPDT SWITCH provides a measure of safety. Wire the switch so that you push to test, release to discharge.

A word of caution about using the checker around solid-state components. The current and voltage can wipe out FET's and transistors faster than you can say **Radio-Electronics**! But because of the ratings of the parts in these circuits, it is very unlikely that you would use the device here.

Here are a few improvements that will provide better performance from this project. The first addition, shown in Fig. 1, is an spdt push button switch. By adding it you won't get a shock from a charged capacitor or from the leads of the unit. This unit can be extremely sensitive to leakage, so the circuit shown in Fig. 2 may be necessary.

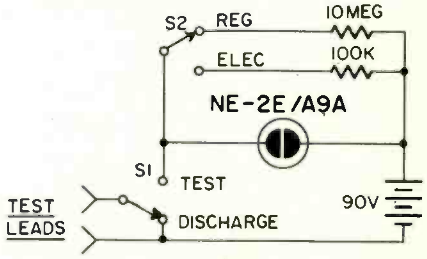


Fig. 2—ELIMINATE FALSE INDICATIONS of leakage by adding S2 and two resistors to control sensitivity and accuracy.

I hope these modifications and suggestions help. I'm presenting them to aid the reader and not to knock the author of this extremely interesting article.

GARY MCCLELLAN
Fort Huachuca, Ariz.

ANTIQUE RADIO BUFFS REVISITED

In the November 1971 issue of **Radio-Electronics** we called for information from our readers about clubs and associations for antique radio fans, and sources to purchase antique radios. Although the response was not overwhelming, we did receive a few good leads we thought we would pass on to you now.

Society of Wireless Pioneers
P.O. Box 530
Santa Rosa, Calif. 95402
William A. Breniman, Executive Director

Antique Wireless Association
Holcomb, New York 14469
Bruce Kelley, Secretary

Three gentlemen told us that they have collections of old radios. The makes include Atwater Kent, Radiola, Westinghouse, etc. They also have tubes, horns, parts, electric radios, and books and manuals on the subject.

Walter J. Christy, Jr.
423 Hemlock Lane
Rancocas Woods, N. J. 08060

Robert A. Lane
2603 Independence Ave.
Kansas City, Missouri 64124

Wilford D. Wilkes
Box 43
Brisbin, Pa. 16620

They ask that if you write to them you include a self-addressed, stamped envelope for a reply.

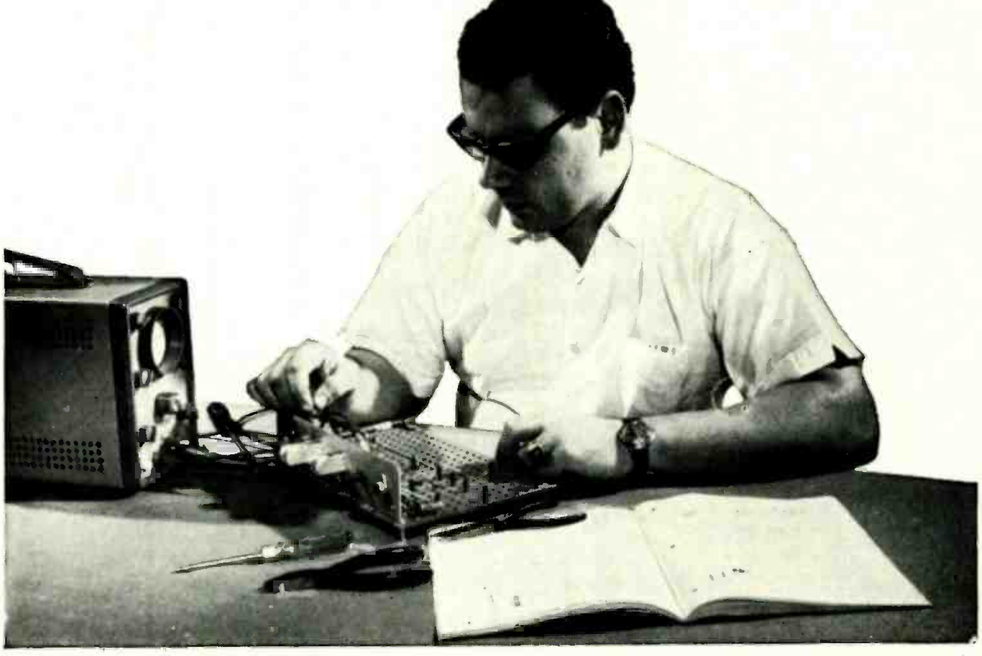
If you know of any associations or clubs for antique radio enthusiasts, or if you stock old radios, let us know and we'll let all **Radio-Electronics** readers know.

Editor's Note: *A good source of old radios is the "swap and flea" markets, often found operating in drive-in movies on Sunday afternoon.* **R-E**

The blue ones were your pills. You took the brown ones . . . some capacitors.

10 Reasons why RCA Home Training is

your best investment for a rewarding career in electronics:



Performing transistor experiments on programmed breadboard — using oscilloscope.

appliance clinic

ELECTRICALLY-OPERATED VALVES

JACK DARR
SERVICE EDITOR

IN ALL-ELECTRIC APPLIANCES, THE CONTROLS are switches. In any appliance using gas, water, or anything else but electricity, we need controls, too. They, too, are switches, but they "switch" water, gas, etc. To get automatic operation of the unit, they are electrically-operated. Let's see how they're made.

First and foremost, they must have one feature; they *must* be "Fail-Safe"! In other words, if anything at all goes wrong; the electrical power supply fails, the gas supply fails, or *anything* else, the instant and automatic reaction of these devices must be to **SHUT OFF.** So, there's the one most important thing to look for, when servicing; if the unit lets anything go through with no power applied, it is **BAD**, and must be fixed!

The basic design of these units includes some sort of spring-loaded "actuator". The spring holds the valve mechanism in the off or closed position; when power is applied, the actuating coil pulls a plunger up, which opens the valve. Fig. 1 shows the "schematic" of

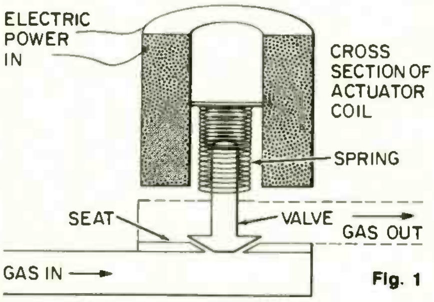


Fig. 1

this kind of unit. The spring forces the valve itself into the seat, keeping it closed. The valve itself may be of brass or any other material, but the upper part, the cylinder, will be made of soft iron. So, when electrical power is applied to the actuating coil, this rod is lifted or pulled into the coil, opening the valve. This is called a "solenoid" (and some day I'm going to look up the origin of that word.)

As long as everything is copasetic; normal operating power applied, the valve stays open. If the power fails, or if the regular "turn-off" switch opens (control thermostat, etc.) the spring pushes the valve shut, quickly and positively. This basic action leads to a distinct resemblance between all types of these valves, whether they control gas, water, oil or anything else.

The operating voltage will vary, of course. Some work on 117 volts ac, (or even 240 Vac), others work on 24 volts ac (from a small transformer) and some even work on the very minute voltages developed by a thermocouple (See "Millivolt Systems" in the *November, 1971* issue) This will give us different values for test readings, but we can always use the same basic check; apply normal operating power to the thing and see if it works!

For a general rule, if we can read the normal operating voltage across the coil terminals, but the valve will not open, it's defective. In most cases, you'll hear a little "click" or thump when the valve operates. If the control has been taken off, for testing, you can blow into the input connection, then apply power and see if it opens. Simple but effective.

If the coil is open, it will show up on an ohmmeter test. The resistance of the coils will vary. The higher the operating voltage, the lower the coil-resistance. Some of the millivolt-system coils will have a pretty high resistance—they need quite a few turns, of fine wire, to develop a usable magnetic field from such a little supply. By the way, in some of the millivolt systems, you'll find coils that are not intended to *pull* the valve open. When the thermocouple heats up, it will develop enough power to *hold* the valve open, but you will have to push a lever, etc., to open it manually. Others are designed to pull the valve open; often with what is called a "bleeder" diaphragm. The gas pressure helps to open the valve. More on this in a future issue.

If the coil checks good, but the valve will not open, there's a good possibility that the actuating rod in the solenoid is being bound or jammed by dirt, foreign matter, etc. that has gotten into the valve from the gas or water supply. A great many of these can be taken apart and cleaned without too

(continued on page 75)

UNANIMOUS ACCLAIM!

First test reports on the Zero 100 by the industry's leading reviewers

Brief excerpts reprinted below. Let us send you the full reports.

HIGH FIDELITY Sept. 1971

Altogether, this new arm strikes us as an excellent piece of engineering; it probably is the best arm yet offered as an integral part of an automatic player. ☐ Operation is simple, quiet, and reliable. ☐ All told, we feel that Garrard has come up with a real winner in the Zero 100. Even without the tangent-tracking feature of the arm, this would be an excellent machine at a competitive price. With the novel (and effective) arm, the Zero 100 becomes a very desirable "superchanger" with, of course, manual options.

AUDIO July, 1971

The Zero-100 performed just about as we expected after reading the specifications. Wow measured .08 per cent—that is in the band from 0.5 to 6 Hz. Flutter, in the band from 6 to 250 Hz, measured .03 per cent, both of which are excellent. ☐ Thus, the Garrard Zero 100 is certainly the finest in a long line of automatic turntables which have been around for over 50 years. ☐ We think you will like it.

Stereo Review July, 1971

Indeed, everything worked smoothly, quietly, and just as it was meant to. If there were any "bugs" in the Zero 100, we didn't find them. ☐ Garrard's Zero 100, in basic performance, easily ranks with the finest automatic turntables on the market. Its novel arm—which really works as claimed—and its other unique design features suggest that a great deal of development time, plus sheer imagination, went into its creation. In our view, the results were well worth the effort.

The GRAMOPHONE August, 1971

Reproduction quality was excellent with no detectable wow, flutter or rumble under stringent listening conditions. End of side distortion, which is always a possibility with pivoted arms, was virtually absent, due no doubt to the tangential tracking arm.

Popular Electronics August, 1971

Our lab measurements essentially confirmed the claims made by Garrard for the Zero 100. We used a special protractor with an angular resolution of about 0.5°, and the observed tracking error was always less than this detectable amount. The tracking force calibration was accurate, within 0.1 gram over its full range. ☐ The Garrard Zero 100 operated smoothly and without any mechanical "bugs."

ROLLING STONE Sept. 16, 1971

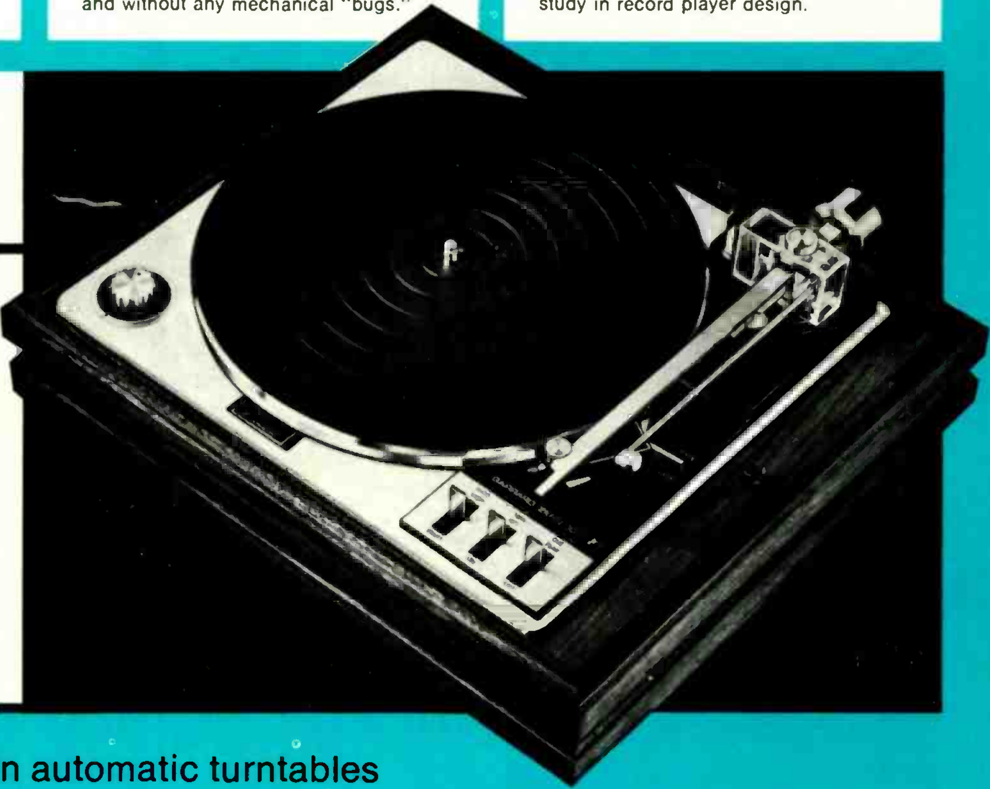
This unit has every imaginable gadget and gewgaw one might possibly desire, and *it works*. And considering how much it does, and how well it does it, at 190 bucks it doesn't even seem expensive. The changer has so much in it that an analysis of its innards is almost a case study in record player design.

HI-FI Fall, 1971

One could go on cataloguing the virtues of the Zero 100 indefinitely.

For 8-page test reports booklet and a 12-page brochure on the Zero 100 and the entire Garrard series mail to British Industries Company, Dept.C242, Westbury, N.Y. 11590.

Name__________
Address__________
City__________
State__________ Zip__________



A genuine step upward in automatic turntables

GARRARD ZERO 100

The only automatic turntable with Zero Tracking Error

189^{50}
less base and cartridge

Mfg. by Plessey Ltd. Dist. by British Industries Co.

Matrix system makes it possible to put four channels of audio into the grooves of a conventional stereo record

4 CHANNEL STEREO

4 Channels on a Disc

CBS - Sony SQ matrix

by FRED PETRAS

QUADRAPHONIC—FOUR-CHANNEL—SOUND HAS ACTIVELY been on the audio scene for close to three years, but tens of thousands of sound buffs are still enjoying two-channel stereo—and are bypassing this new medium that was to "revolutionize" the world of sound. They've read every word of every article about the several approaches to four-channel sound, but are still biding their time because they are not yet fully convinced that four-channel sound is *that* much better than two-channel, and, if it is, who has the RIGHT system to reproduce it?, and who has enough software (records, tapes) to really make the investment worthwhile?

Four-channel stereo sound was conceived as a discrete system, in which four distinct channels of sound information would be engraved on four separate tracks of tape, the tape played through a four-channel stereo machine into four channels of amplification, with the sound emanating from four speaker systems. The first commercial tapes of such sound were introduced back in 1961 by Nortronics Co., Inc., under the "Stereo-Four" (patented) designation. But the concept was apparently ahead of its time, and faded from the audio scene.

The multi-source sound idea reappeared in the summer of 1969, under the aegis of Vanguard Recording Society which had been experimenting with the concept for about four years, and Acoustic Research, a company that conducted the first public demonstrations of the four-channel Vanguard tapes labelled "Surround Stereo." Columbia Records joined with experimental 4-channel tapes, which were also demonstrated by AR (Acoustic Research) in its New York City and Cambridge, Mass., demonstration rooms.

In September of 1969, Peter Scheiber, an audio buff/engineer/musician, startled the industry with a "compatible" four-channel stereo phonograph matrix record. It was heralded as the salvation of the new medium since it could be played in the home on a standard stereo record playback system (in conjunction with add-on decoder, etc.), be broadcast in FM stereo, and heard on existing FM stereo receivers (equipped with the needed add-ons).

In the spring of 1970 along came David Hafler, then president of Dynaco, with the "Dynaquad" system, which derived four-channel sound from existing stereo LP records and decoded matrixed records at moderate cost, via a $30 enhancer/decoder and an additional pair of speaker systems.

Shortly thereafter, RCA Records debuted its "Q-8" 8-track, 4-channel discrete cartridge tapes, and Motorola Automotive Products announced that it would produce auto tape players for them. Simultaneously, RCA Corp. showed prototypes of the first low-priced 4-channel home cartridge tape equipment, in compact form, for marketing later in the year.

At the Consumer Electronics Show in June 1970, Sansui Electronics Corp. bowed its QS-1, another form of disc matrixing and playback. In September, JVC announced its CD-4 discrete four-channel disc system, and demonstrated the concept at the October Audio Engineering Society annual meeting. (See separate story on the JVC system elsewhere in this issue.) It was at this same meeting that Electro-Voice took the wraps off its E-V "Stereo-4" matrix system, applicable to discs, tapes and broadcasts.

During this period, and beyond, other were experimenting with various approaches to four-channel sound, in cassette form, in record form, and in radio broadcast form.

And during this period the audio marketplace was seeing all kinds of action—and inaction. Droves of people were coming into stores, listening, asking questions, comparing the sparse offerings of equipment and software, but buying little. Discrete reel tapes were in minimal supply; they were nearly double the price of regular stereo tapes. Full-capability reel tape equipment was beyond the reach of many audiophiles.

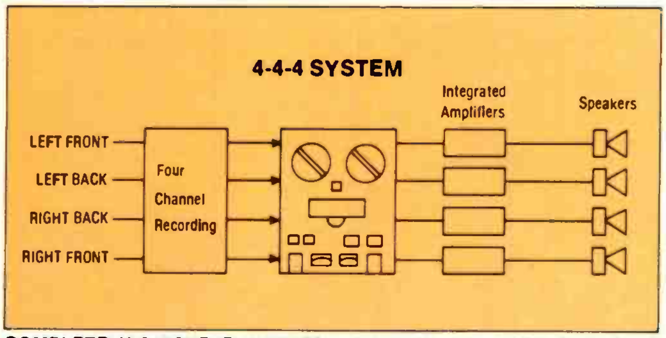
Q-8 tapes were in short supply, stocks of equipment for them were meager. The concept was wrong, said industry observers. Four-channel sound would never take off while restricted to the medium of tape, even if availabilities improved and prices dropped. It would not become popular until it was available in LP disc form—the most widely used medium for prerecorded sound—and in FM stereo broadcast form.

Despite all the announcements about 4-channel phonograph record systems, the pickings were slim in terms of equipment, and in terms of records, the latter largely from small companies, lesser-known artists. What was needed said the industry observers, was "a BIG company willing to get into the four-channel sound business with both feet." The thinking was that a big company with a big roster of "name" artists and a lot of influence could be instrumental in bringing about a standard, ending the problem of non-compatibility between the quadraphonic record systems, another element keeping four-channel sound from becoming the mass-market medium it was supposed to become.

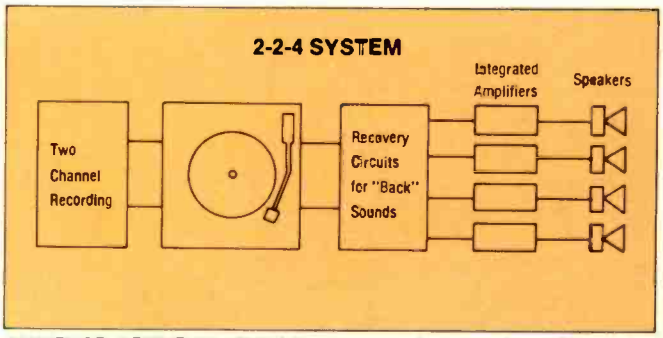
Enter Columbia Records, with a new matrix system called "SQ"—for stereo/quadraphonic—developed by its CBS Laboratories, and co-sponsored by Sony Corp., giant Japanese electronic equipment manufacturer and also a producer of phonograph records in Japan . . .

How the SQ system works

Like most of today's stereo recordings, an SQ disc is recorded in a studio on a multi-track master tape recorder with sound picked up from as many as 24 microphones and inscribed on the tape. The SQ *master tape* is then edited or "mixed down", a process that converts the many channels into the four that are basic 4-channel sound.



COMPLETELY DISCRETE SYSTEM maintains four separate channels all the way from the recording studio through the playback equipment and into four separate speaker systems in the listening room.

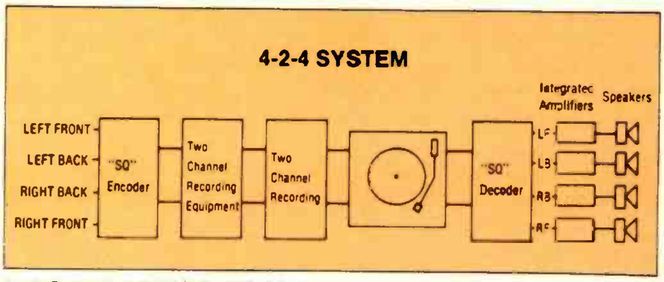


AMBIENCE RETRIEVAL SYSTEM approximates four-channel reproduction. The system retrieves sounds at the side and back during recording.

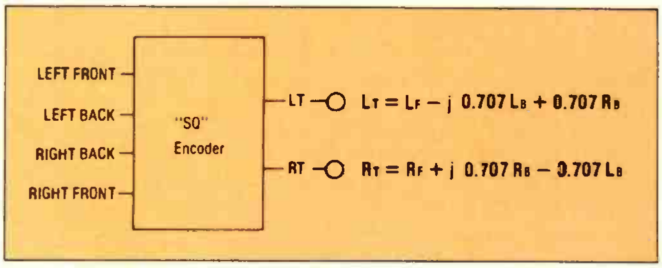
Next, these four channels are converted via an SQ *encoder* into two channels of sound that are "cut" into the SQ *master record.* Heart of the SQ encoding process is a new double-helical modulation concept. In addition to retaining the traditional 45-degree/45-degree lateral-vertical left and right channel modulations, which evolve as left and right front sound channels, the system provides additional modulations for the remaining two channels—left back and right back. These recording stylus modulations are circular; as the master record rotates and the groove advances, a clockwise helix is produced for the left back channel, and a counter-clockwise helix is produced for the right back channel.

The stylus during playback does not actually rotate clockwise or counter-clockwise and follow the conventional 45/45 groove tracing at the same time. What is actually happening is that all four channels of information combine to form a complex single stylus motion that represents the four individual signals. The record groove that the stylus traces is shown in the photo.

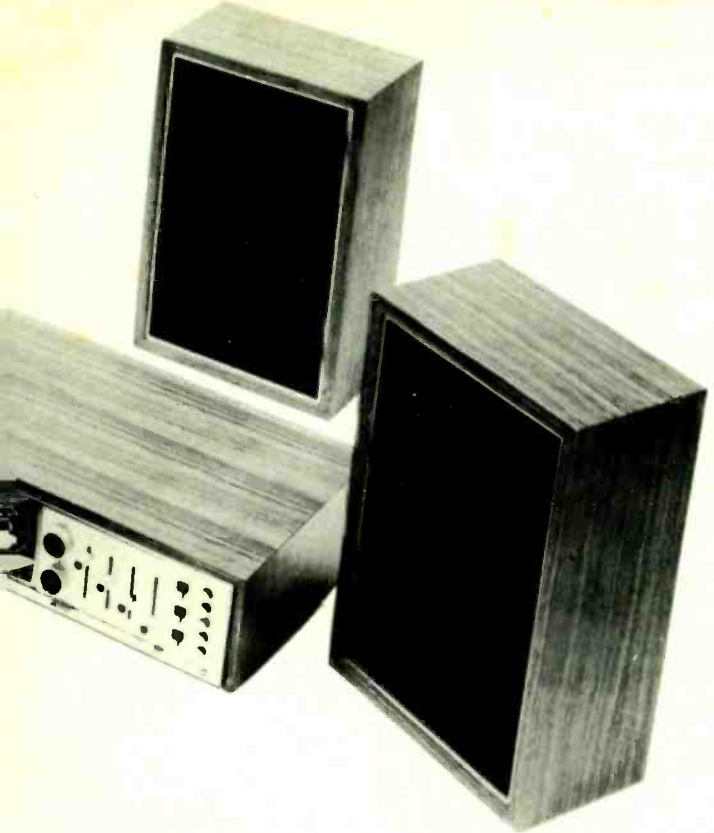
To hear the program material reproduced as 4-channel sound on playback, an SQ *decoder* is needed, along with four channels of amplification and four speaker systems, plus, of



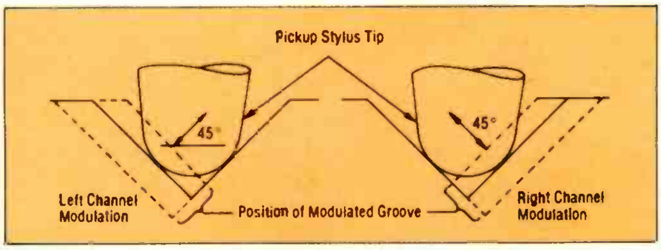
BASIC OPERATION OF CBS-SONY SQ system is shown in this block diagram. Note how we both start and finish with four separate audio channels.



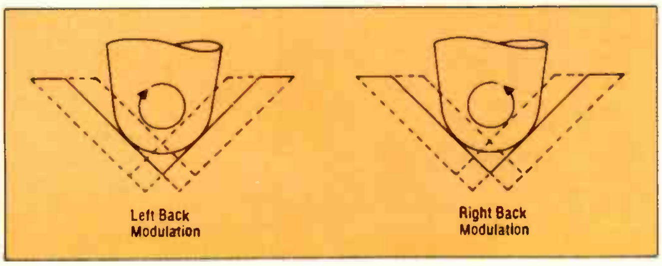
WHEN FOUR INPUT CHANNELS GO THROUGH the SQ encoder they look quite different coming out. You can see how the various channels are intermixed by the encoder to produce a 2-channel signal for recording.



CBS FOUR-CHANNEL music system including SQ-444 decoder/receiver.



LEFT-FRONT AND RIGHT-FRONT channels are recorded on the two side walls of the groove just as they are in normal stereo records, by cutting-stylus motion along the 45° lines shown here.



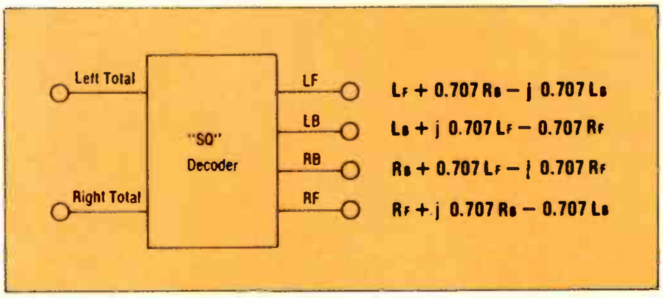
REAR CHANNELS APPEAR IN RECORD GROOVE as a circular motion of the stylus—clockwise for one rear channel counterclockwise for the other. As the record turns, this produces a helical groove cut.

FOUR SQ RECORD GROOVES each with only one channel of information recorded on it. From this photo you can see how the different channels appear on the disc. Of course all four signals are combined in an SQ record.

course, a record player. The latter can be any good stereo model, preferably—but not necessarily—with a high-compliance cartridge. The playback system can be made up of an existing two-channel stereo component-type outfit with tape monitoring facilities, plus two additional speaker systems, and a decoder such as the Sony SQA-200 that contains the additional two amplifier channels. Or a system can be made up of a four-channel receiver, straight SQ decoder, plus four speaker systems and record player. There are other possible combinations, including one built around a four-channel receiver/Q-8 tape cartridge player from CBS' Masterwork division. (By the time this appears in print there will probably be a fair supply of other SQ-oriented equipment to choose from.)

In playback the SQ decoder senses the four basic SQ modulations from the phono cartridge, separates them, and produces four new signals, each containing predominantly the sounds of the corresponding original four channels before they were encoded. These signals are fed to the four amplifier circuits and four loudspeaker systems placed in four corners of the listening room or listening area, and result in a highly realistic reproduction of the original quadraphonic master tape. Some reports indicate it is almost as realistic as discrete four-channel sound—the ultimate.

An SQ record can be played on regular two-channel stereo phonograph equipment and sound not only as good as any regular stereo disc, but with an added spaciousness that enhances the listening pleasure. Thus, a person wanting to go the SQ route can buy and enjoy SQ records as they are released, on his present equipment, while waiting for the day that he invests in an SQ playback system. According to Columbia Records, playing an SQ record on conventional stereo



SQ DECODER TAKES ENCODED SIGNAL (see last diagram on facing page) and reconverts it into four-channel sound. Note that there is some crossover between channels although logic circuits can be used to improve front-to-back separation.

equipment will not harm the records four-channel capabilities in any way.

Unlike some other matrixing approaches, the SQ system permits FM stereo broadcasts of SQ records without the need for an encoder at the radio station—a saving of major importance to smaller stations around the nation. Equally important, the FM station can broadcast SQ now. However, the listener does need the full complement of equipment as noted above to receive the program as four-channel sound. Otherwise it will be received as conventional two-channel stereo.

The foregoing is the basics. But there are other ramifications to the SQ concept. Columbia states that *center front* sounds are recorded in the same manner as with a conventional stereo record; they result in a horizontal or lateral modulation of the groove. Furthermore, the sound can be "panned"—caused to move—between the front left and front right loudspeakers in just the same way as with traditional stereo records. This similarity is the basis for the excellent compatibility of SQ with regular stereo record playing equipment.

Sound can also be made to move at will between any adjacent pair of speakers. Any sound at the *center back*, Columbia claims, is fully reproduced and accurately placed in four-

(continued on page 83)

"At ComSonics we encourage all our technicians and engineers to enroll with CREI. Know why?"

WARREN BRAUN, *President, ComSonics Inc., Virginia Engineer Of The Year, ASE International Award Winner,* **CREI Graduate**

4 Channels on a Disc

RCA-PANASONIC-JVC discrete

4 independent full-frequency channels in one record groove! Playback takes a special cartridge and decoder.

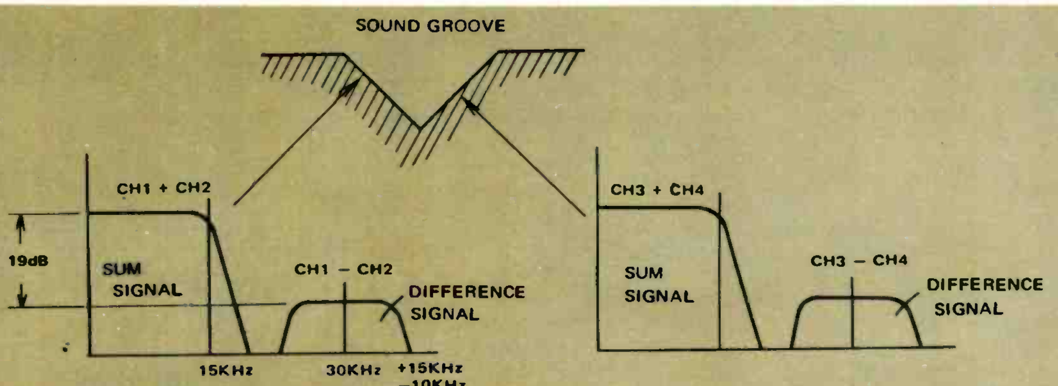
by DAVID LACHENBRUCH
CONTRIBUTING EDITOR

FOR ITS ENTRY INTO THE FOUR-CHANNEL RECORD FIELD, RCA Records has chosen a discrete system based on the principles of multiplex broadcasting technology. The system, currently known as CD-4 (for *C*ompatible *D*iscrete *4*-channel)—although RCA may rename it for commercial purposes—actually is the outgrowth of a technique developed eight years ago by the Victor Corporation of Japan (also known as JVC) to provide three-channel sound from phonograph records. Finding no market for three-channel discs, JVC shelved the development, but reworked it in 1970 as a four-channel system in light of the new interest in quadraphonics.

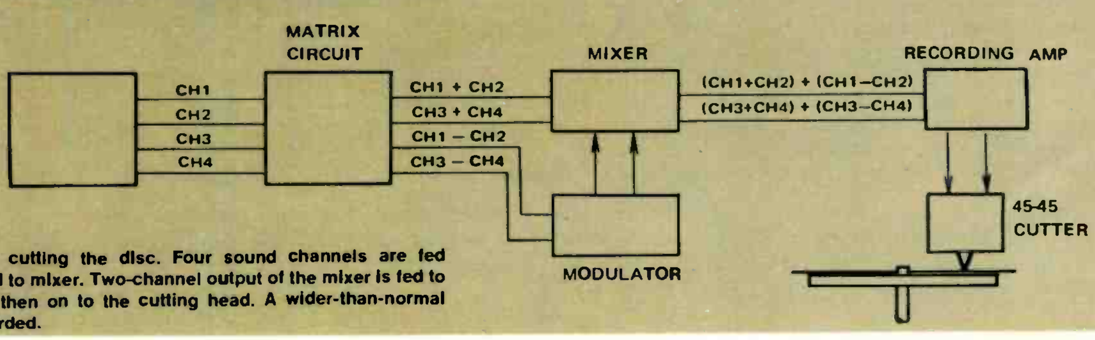
Last year, JVC introduced to the Japanese market the first CD-4 playback equipment and records, including some made from RCA master tapes. JVC has no corporate relationship with RCA, but is the licensee for RCA Records in Japan—that is, it manufactures and distributed discs there featuring RCA artists and occasionally bearing the RCA label. RCA became interested in the CD-4 system in its search for a method of recording and reproducing discrete four-channel material on phonograph discs as an alternative to the use of matrixing techniques which it regarded as "simulated four-channel."

Although RCA decided JVC's CD-4 system was the best available method for putting quadraphonics on record, it also found some drawbacks, and last summer it started a crash program to eliminate them before introducing discrete four-channel records in the United States. The major disadvantage was the lack of total and universal compatibility with two-channel stereo systems, which has necessitated the issuance in Japan of two versions of each record release—CD-4 and conventional stereo—reminiscent of the days when stereo and mono discs were issued for each selection. RCA says it will not offer four-channel discs until it has developed complete compatibility for the system, so that it can issue a single line of records which may be played monophonically, stereophonically or quadraphonically. RCA Records President Rocco Laginestra recently reported "phenomenal" progress toward this goal, but declined to predict when RCA would release its first quadraphonic disc selections.

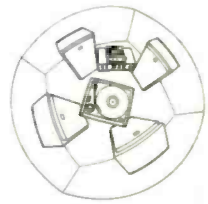
While RCA is working to perfect the disc, two other



FOUR CHANNELS ARE IN THE GROOVE, but both walls are at an angle of 45°—same as for a conventional stereo record. However, two signals are recorded in each wall. One is sum of two channels, the other a frequency-modulated difference signal.



RECORDING PROCESS for cutting the disc. Four sound channels are fed through matrix circuit and fed to mixer. Two-channel output of the mixer is fed to the recording amplifier and then on to the cutting head. A wider-than-normal range of frequencies is recorded.



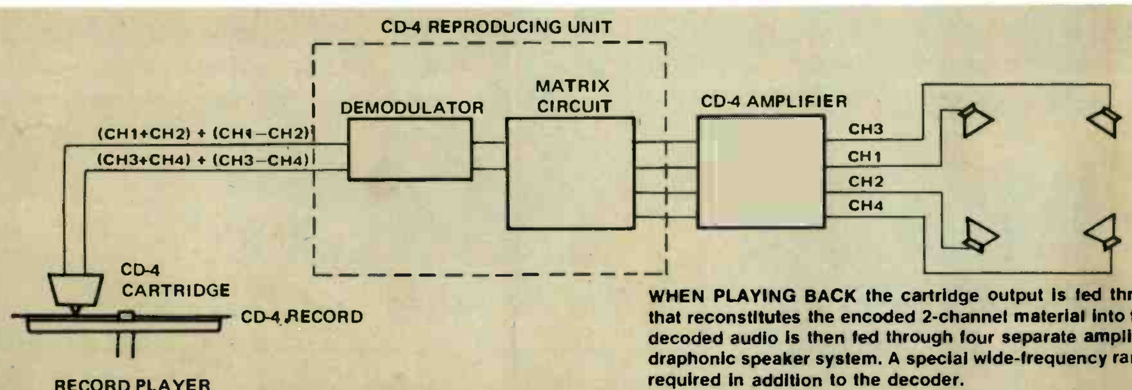
manufacturers are cooperating to have the playback equipment ready on time and in sufficient quantities. These firms are JVC and Panasonic, both affiliated with Japan's giant Matsushita Electric Corporation. Other manufacturers, including RCA's own Consumer Electronics operation, are expected to join later in producing equipment.

How CD-4 works

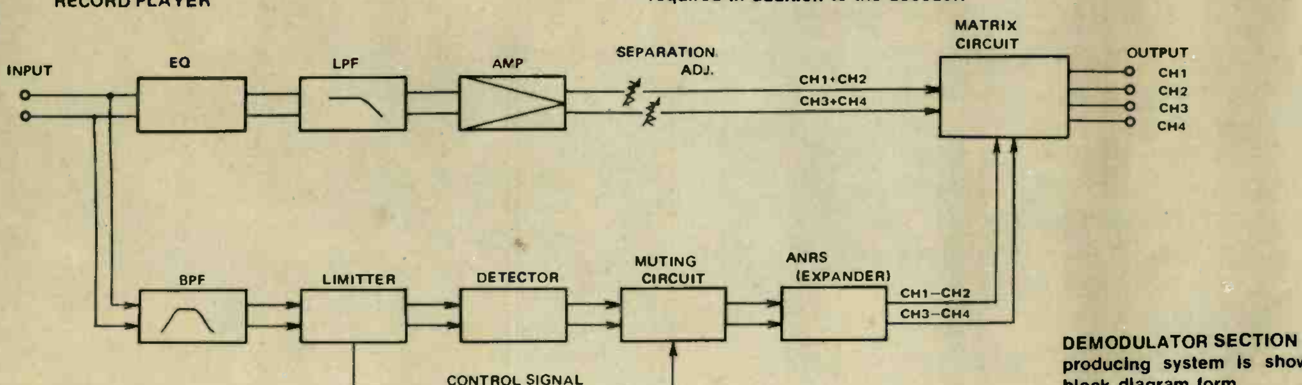
The CD-4 disc operates on the same basic plus-and-minus principle used in stereo FM broadcasting. The record itself is similar to the standard "45-45" stereo disc, with the two groove walls at 45-degree angles to the vertical. However, instead of one signal, two signals are recorded in each groove wall—a sum signal and a difference signal. One groove wall contains the left-front-plus-left-rear signal and the left-front-minus-left-rear signal, the other the right-front-plus-right-rear and the right-front-minus-right-rear. The sum signals are recorded in the same manner as left and right are recorded on conventional stereo discs, while the difference signals are modulated on a 30-KHz carrier frequency, using a combination of frequency modulation and phase modulation.

Since the 30-KHz carrier, and therefore the difference signals impressed on it, are well above the audible range (and generally above the capabilities of existing stereo cartridges), the listener hears only the sum signals when the record is played through a conventional stereo system, and of course he hears the sum of all four signals if the record is played monophonically. To hear the record in four-channel sound, the listener must insert a demodulator between the pickup cartridge and his four-channel amplifier. The demodulator unscrambles the sum-and-difference signals into left front, left rear, right front and right rear signals and feeds them into the proper amplifier channels, in much the same way a stereo FM receiver decodes L + R and L−R it receives off the air into left and right signals. When a standard stereo record is played through CD-4 equipment, the demodulator is simply switched out of the circuit.

In addition to the demodulator, one other ingredient is needed to play the discs in the 4-channel mode. This is a highly compliant cartridge which can pick up and pass signals



WHEN PLAYING BACK the cartridge output is fed through a decoding circuit that reconstitutes the encoded 2-channel material into four audio channels. The decoded audio is then fed through four separate amplifier channels to the quadraphonic speaker system. A special wide-frequency range playback cartridge is required in addition to the decoder.



DEMODULATOR SECTION of reproducing system is shown in block diagram form.

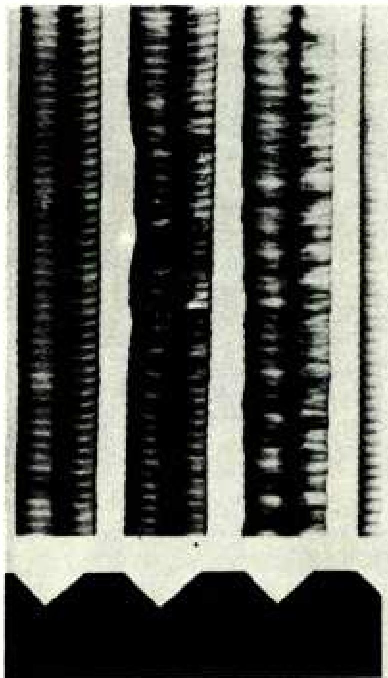
up to about 45 KHz (the carrier frequency plus the signal's maximum deviation). This sounds like a tough assignment when you consider that heretofore it's been necessary only for cartridges to pass the audible frequency spectrum, up to about 15 KHz or so. But cartridge manufacturers have said that development of a 45-KHz cartridge isn't particularly difficult—they've just never done it because there was never any earthly need for such a gadget. Such cartridges are already available in Japan, and more refined and less costly versions are under development there, in Europe and in the United States. RCA says the initial price will be the same as that of a good stereo cartridge—about $30 and up for starters. Stylus pressure can be as high as three grams.

The system is claimed to have full frequency response (30 to 15,000 Hz) on all four channels, plus a front-to-rear separation of 20 to 25 dB, or about the same as that between left and right channels.

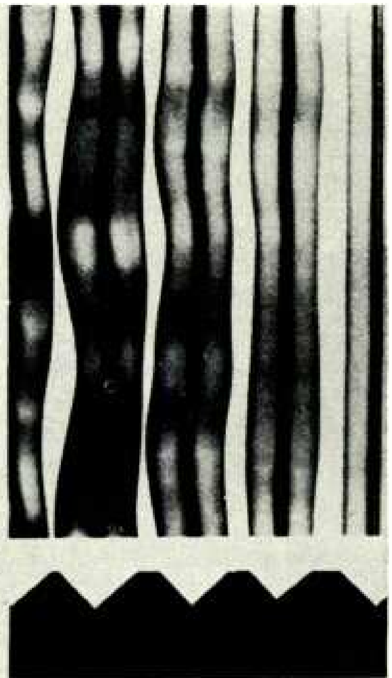
Panasonic and JVC plan to introduce playback equipment in several configurations and price ranges: Complete systems for those starting from scratch, combination demodulators and two-channel amplifiers for those converting their conventional stereo equipment, and separate demodulators to add to existing four-channel systems. The initial cost of a separate demodulator will be about $50, but prices are expected to come down as mass-production versions are designed. The demodulator eventually will be supplied to equipment manufacturers on an IC chip. The first complete systems are expected to sell for about $300 and up.

Here's how the compatibility situation stands today, according to RCA: A CD-4 disc can be played on standard stereo equipment with results and life equivalent to that of a standard stereo disc. A CD-4 disc may be played on four-channel equipment with playing life equal to that of stereo records at the time of stereo's introduction, without any sacrifice in basic signal-to-noise ratio. A stereo disc may be played on CD-4 equipment with "enhancement" due to the use of four speakers. The one problem arises when a four-channel record is played on conventional stereo equipment, and then played later on four-channel equipment. The standard stereo cartridge and stylus has a tendency to wipe out part of the high-frequency carrier. This problem is being attacked on two fronts: RCA is developing a more durable plastic base material for records, and the equipment manufacturers are working on more sensitive demodulators.

RCA, in its progress report, said: "Partial mixed-system playback compatibility has been achieved. Discrete discs, played first on stereo equipment and then on four-channel equipment, have a playback life which has been greatly increased." Although RCA won't estimate when the system will be ready for marketing in the United States, there have been indications that progress has been encouraging enough to warrant hope for introduction this year. R-E



GROOVES AND CROSS-SECTIONS OF CD-4 SYSTEM RECORD



GROOVES AND CROSS-SECTIONS OF CONVENTIONAL STEREO RECORD

SPECIFICATIONS

Characteristics of the disc

Rpm & Size: same as conventional records

Compatibility: compatible with 2-channel stereo records and mono records.

Frequency Range: Sum—30 to 15,000 Hz
Difference—20,000 to 45,000 Hz

Cross Talk: Between left and right—25 dB
Front to rear ±20 dB

Signal to Noise Ratio: better than 50 dB

Life: Same as standard stereo disc

Characteristics of 4-channel reproducer

Pick-up Cartridge:

Frequency Response: 20 to 45,000 Hz
Stylus Type: elliptical
Stylus pressure: 1.5 grams

4-channel Decoder

Frequency response: 30 to 15,000 Hz each channel
Output: 0.1 volt
Transistors: 29

4-CHANNEL RECORDS

discrete

advantages

1. Each channel completely independent.
   a. No crossover between channels.
   b. Excellent front-to-back separation.

2. Each channel has frequency range of 30 Hz to 20,000 Hz.

3. Compatible with existing recording systems.
   a. Plays as 2-channel stereo on 2-channel system.
   b. Plays as monophonic on monophonic system.

4. Playing time same as for existing 2-channel stereo record.

disadvantages

1. Requires wide-frequency range phono cartridge in addition to decoder. Cartridge response to 45,000 Hz required.

2. No records available in U.S.

3. Record wear a problem. New record base material under development.

4. FM broadcasting requires FCC approval. Only being done experimentally at this time.

5. Cannot be recorded on 2-channel tape.

matrix

advantages

1. Records available now.

2. Compatible with existing recording systems.
   a. Plays as 2-channel stereo on 2-channel system.
   b. Plays as monophonic on monophonic system.

3. Plays on existing equipment with existing cartridge. Only decoder must be added.

4. Playing time of record same as for existing 2-channel stereo disc.

5. Can be broadcast by FM stations now. No FCC approval required.

6. Can be recorded on 2-channel tape.

disadvantages

1. Channels not completely independent. Front-to-rear crossover varies from 3 dB to 12 dB, depending upon playback system.

2. Record costs more than equivalent 2-channel disc.

3. Must use extra-cost logic circuit to increase channel separation.

Electro-Voice Matrix Decoder

4 CHANNEL STEREO

Scott 443 Quadrant Receiver

4-Channel Adapter

Everyone Has a System

by CHESTER H. LAWRENCE

THERE ARE SEVERAL SOURCES OF 4-CHANNEL PROGRAM MAterial available to the audio enthusiast today. They include reel-to-reel tape; 4-channel 8-track cartridge tape; and two newly-announced disc systems. (Both disc systems are described elsewhere in this issue. There's a complete study on the CBS-Sony matrix system on page 25 and another story detailing the RCA-Panasonic-JVC system on page 32.)

Unfortunately, prerecorded tapes and discs for 4-channel playback are relatively rare right now, and expensive when they are available. (By the time this article appears in print CBS matrix records are expected to be available through Columbia Records.) This is especially true of prerecorded tapes where there is a hidden cost–you get half-as-much 4-channel material on the same tape. For instance, one hour's worth of 2-channel tape used for 4-channel material will only play for 30 minutes–the tape doesn't move faster, but more tracks are used simultaneously.

Also, like so many other music lovers, you probably have an extensive library of 2-channel tapes and records, and you listen regularly to 2-channel FM stereo broadcasts. To save all of this existing material from the garbage dump, you must have a way to convert this material into 4-channel sound–enjoyable pseudo 4-channel sound (by pseudo we mean that the program material you are starting with was not originally recorded as 4 channels).

Happily, there are several different kinds of 4-channel adapters available now. But before we step into the world of 4-channel adapters, let's briefly review how 4-channel discrete tapes operate. We'll look at both reel-to-reel and 4-channel 8-track tape systems and how they work.

4-channel discrete tape systems

In Fig. 1 you can see how both reel-to-reel and 8-track 4-channel tape systems operate. We have illustrated in block-diagram form that there are four separate channels all the way from the recording studio to your listening room–from microphone to speaker. The advantages of this kind of system are obvious. The most important one is that each track on the tape can carry a completely independent channel of information. Also, by switching the field of sound around the four channels, it is possible to create unusual listening effects and an interesting moving field of sound in the listening room. However, you cannot simply take existing 4-channel program material and play it through this kind of system and come out

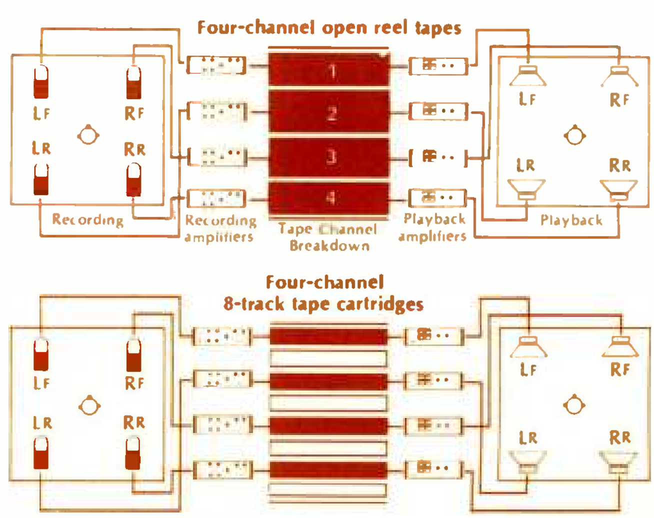
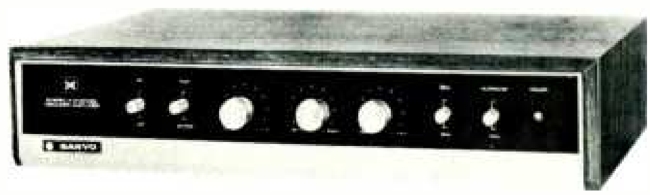


FIG. 1—DISCRETE 4-CHANNEL TAPE SYSTEMS can take either of these two forms: reel-to-reel at the top and 4-channel 8-track cartridge. Note that in reel-to-reel the complete tape is used in one pass. On the cartridge tape it takes two passes to use all the tape.

Iras Multisonic Converter

Toyo QC-1 Decoder

Pioneer QX-8000 Receiver



Sanyo DCA-1500X Decoder-Amplifier

Roundup

Here's a look at devices that turn existing 2-channel music into 4-channel surround sound

with 4-channel sound. So some kind of adapter will be needed.

DynaQuad—an early approach

One of the first 4-channel adapters to come along was the DynaQuad. What does this system do? Basically, it reproduces sounds in the rear speakers which were present during the original recording, but were hidden or lost when the recording is played through a 2-channel system. It has been called an ambience-recovery system. For the most part, these sounds are "reflected" sounds—sounds that bounced off a studio or concert-hall wall and were picked up by the recording microphones a fraction of a second after the direct sounds.

When you use a DynaQuad adapter to extract these sounds from the original recordings and fed them to two additional speaker systems located at the rear of the listening room as shown in Fig. 2. Doing this heightens stereo realism considerably, as this system does deliver a closer approximation to the sound as it was heard during the recording session.

None of the sound delivered this way are sounds that have been created artificially. They are sounds actually present during the recording and captured on the disc. Because of this, the DynaQuad system is completely compatible with existing 2-channel recordings and matrix processed records.

The great advantage of this approach is that it is inexpensive and only a minimum of additional equipment is required. Two additional speaker systems and one inexpensive (under $30) adapter. This is a good way to get introduced to 4-channel sound in your own home, but you will find the effect of this system varies from record to record and it will not produce a noticeable effect on all recordings. Therefore, you will eventually want to move on to an adapter that works with all existing 2-channel material.

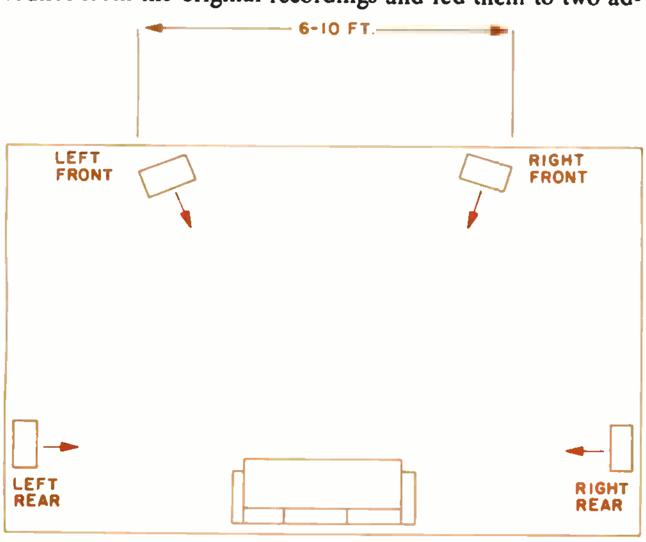


FIG. 2—SPEAKER PLACEMENT when using the DynaQuad adapter. Note that the listening position is at the rear of the room. Both rear speakers face each other with the listeners positioned between them. The front speakers are angled toward the listeners.

Matrix systems

This category of 4-channel adapters represents the major type of device in use today. Matrix simply means adding and subtracting. The purpose of a matrix system is to take apart the signals recorded in all 2-channel stereo programs, add some together, separate some, and then reassemble them into 4-channel stereo. The major effort in matrix was begun by Electro-Voice and they have just been awarded a patent covering their efforts.

When fed through a matrix circuit, ordinary 2-channel stereo signals L and R (left and right) are distributed as in Fig. 3. Also, it is possible to use the matrix while recording—but that is a different kind of story and will not be covered. in detail, here.

Using this system it is possible to get effects that are very close to those of discrete 4-channel sound. Fig. 4 shows how this is done.

Phase-shift systems

Modern 2-channel recordings already contain a lot of indirect (reverberation) sounds. If it were possible to select only these reverberation sounds and reproduce them from the rear speakers in a 4-channel system it would be possible to recreate a concert-hall effect in the home without distorting the musical properties of the original sound source.

To see what happens when this kind of system is used, see Fig. 5. Here, the sounds recorded in the L and R channels

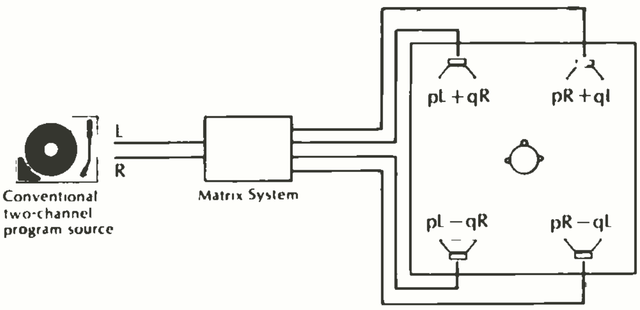


FIG. 3—THIS IS HOW MATRIX redistributes 2-channel sound to four speakers in the listening room.

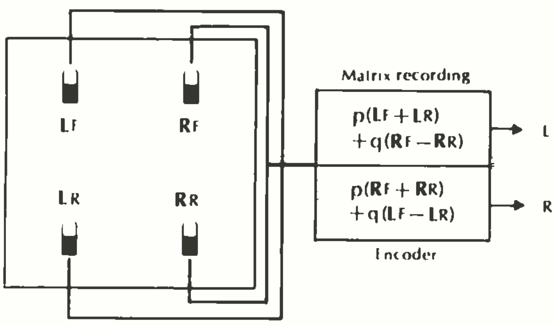


FIG. 4—AT THE RECORDING END matrix can be used to encode music being put on record. Gives close to discrete performance.

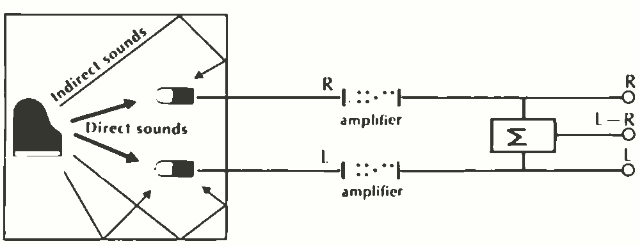


FIG. 5—DERIVED L MINUS R channel is fed to rear speakers. Phase-shift system is used to produce wall-of-reverb effect.

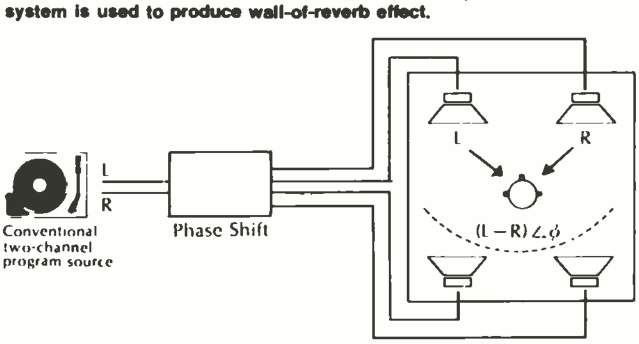
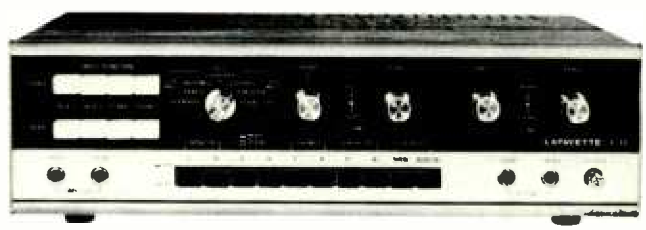


FIG. 6—PLAYBACK THROUGH PHASE-SHIFT spreads the directivity of the reverb signals as illustrated here.

Heath Stereo-4 Decoder (above)

Toshiba SC-410 Decoder (right)



Lafayette LA-44 Amplifier With Decoder (above)

Eico QA-4 Quatra-Sonic Adapter (right)

of a 2-channel stereo record contain the indirect sounds from an infinite number of directions as well as the direct sounds from the instruments. Using matrix circuitry we extract from the L and R signals, the difference signal L - R.

Now let's take this a step further. Using the L-R signal, only the reverberation sounds are separated from the 2-channel source. But now we are faced with another problem. Reverberation sounds should not be reproduced by the front pair of speaker systems. They must be fed to and reproduced by the rear pair of speakers. Also, to get a realistic reverberation effect the sounds should be spread across the rear of the room and not infinite from some particular spot.

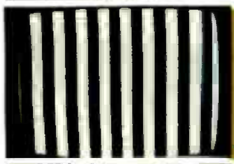
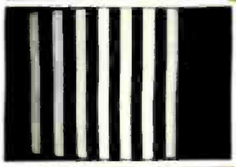
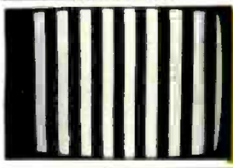
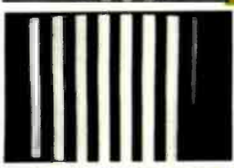
To spread the reverberation effect, the phase-shift system introduces a 90° shift in phase between the left rear and right rear speakers. This creates an unfixed positioning sensation so the listener can no longer tell exactly where the sound is coming from. Fig. 6 shows how this works in the listening room.

Other systems are more correctly called synthesisers—they manufacture a psuedo 4-channel effect and can be adjusted by the listener to produce the mix and balance of sounds he desires. The great advantage of all of these systems is that they enable you to play your existing 2-channel program material through your four-channel system and come up with an effect that sounds like 4-channel discrete. In time discrete will probably be the only way to go. But for now adapters are a must. R-E

Kwik-Fix™ picture and waveform charts

Forest H. Belt & Associates*

SCREEN SYMPTOMS AS GUIDES — WHERE TO CHECK FIRST

SYMPTOM PIC	DESCRIPTION	VOLTAGE	WAVEFORM	PART
	Color normal (for reference)			
	Color cut off, but one setting of threshold control lets color through			C1 shorted C2 shorted C2 leaky
	Color blocked off completely			R3, R4, R7, R8, R10, R11, R12, R13, C3, C4, C7, Q2
	Too much color at mid-setting of threshold control			C2 leaky
	Color weak			R3, R11, R12, R13, C7, Q1
	Color too high, then missing altogether as threshold control turned clockwise			R3 low
	Weak or no color; ringing in bars			R7 high R8 high
	No confetti at all, except possibly near mid-setting of threshold control			R4 open R5 open, low R6 open, low
	Confetti flashing on and off at some critical threshold setting			C6 open
	Can't cut confetti off with threshold control			C5 leaky C5 shorted Q2 shorted

NOTES FOR SYMPTOM GUIDE:
Use this guide to help you find which key voltage to check first, or to guide you to the causes of symptoms that don't have voltage clues. (There are no waveform clues in these stages.)
Study the screen, with no station, for action of the KILLER THRESHOLD control. Study the screen, with color bars, for action of the ACC control.

The most helpful clues to the cause of whatever symptoms you see are found at the key test points listed opposite them.
Make whatever voltage measurements are indicated.
Use the Voltage Guide to analyze those measurements.
For a quick check, test or substitute the parts listed as most likely to cause the symptoms you see.

The Stages

The color killer in any color chassis stops the bandpass amplifier section from operating whenever no color signal is present. If left operating, the bandpass stages inject their own noise into the black-and-white signal. The confetti, as it is called, becomes particularly noticeable on the screen when a station signal is weak enough to leave snow.

The turning-off is passive; the turning-on, active. That is, left to itself, the third bandpass amplifier—the stage (not shown) this killer acts on—stays biased off. Nothing, noise or signal, gets past. A color signal reaching the acc/killer detector stage (also not shown) makes the killer voltage change to forward bias for the bandpass stage. Chroma signals can get through to the color demodulators. With only a monochrome signal, the killer allows the bandpass stage to turn off.

The acc/killer detector, which precedes the acc amplifier shown here, does the sensing. Field-effect transistor Q1 transfers the color/no-color indication to the color killer transistor, Q2. At the same time, the fet amplifies whatever effect color-signal *strength* has on the acc/killer detector, and passes that effect on to a control stage in the automatic color control (acc) system. Chroma levels are thus evened out.

Signal Behavior

These stages handle no signal in the usual sense. They deal with *changes* in dc levels. The dc shifts may occur suddenly or very gradually. Either one, however, gives a "signal" nature to conditions in the stage, and operation can be described somewhat in that way.

Two kinds of dc shift occur. One, for automatic chroma control, is a gradual up-or-down variation of the dc voltage applied to the gate of fet Q1. The variations can be fairly rapid if signal strength varies rapidly for some reason. But usually acc effects can be considered slow variations.

The voltage change caused by acc action is amplified by the fet. A connection from the drain terminal goes to an acc control transistor (sometimes also a fet) which in turn usually controls gain in the first bandpass amp.

The other "signal" in these stages is the sudden shift when a program changes from monochrome to color. A frequent example: color commercials interspersed in a black-and-white movie. The change in voltage is abrupt, the equivalent of one half-cycle at some fairly high frequency.

Capacitor C1 bypasses any chroma-sideband signal that accidently gets through the acc/killer detector stage. The dc should be reasonably "pure" so the fet senses only legitimate dc shifts. The R1-C2 network may look familiar, being similar to the anti-hunt network in horizontal afc systems. It serves a like purpose here, damping overshoot or ringing that might upset fet operation.

Capacitor C3 keeps the fet source element at rf (and af) ground, and decouples the supply resistances. Capacitor C4 shunts to ground any rf or ringing signals that reach the drain circuit of the fet.

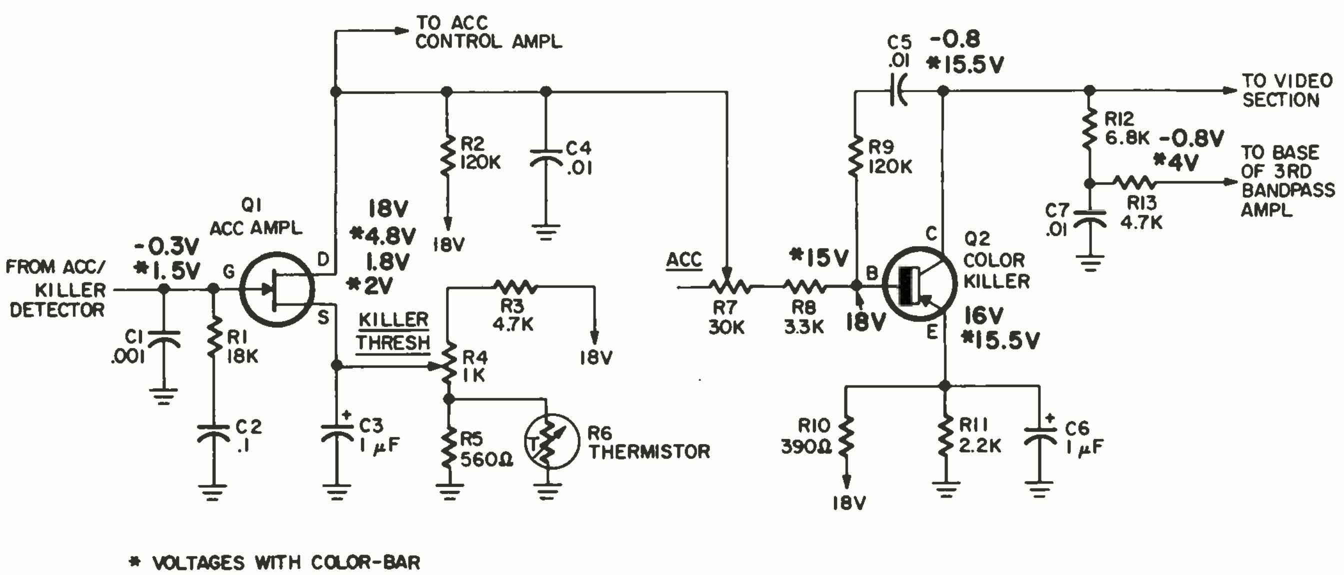
Shifts of dc level in the output circuit of Q1 are coupled to the base of Q2 by R8 and acc control R7. Emitter capacitor C6 decouples and bypasses, keeping the emitter of Q2 at "signal" ground. Network C5-R9 feeds a little "signal" back from the collector of Q2 to the base, again damping any "hunting" characteristic and killing any tendency of the stage to be shock-excited into oscillation. Capacitor C7 mainly decouples the output circuit of Q2 from the bandpass amp it controls. so no chroma signal works its way back to upset killer operation.

DC Distribution

Operating dc voltages for these stages bear no oddities. The gate of Q1 gets bias from the acc/killer detector (not shown), and varies with operation of that stage.

The source of Q1 is biased from an 18-volt dc supply line. R3-R4-R5-R6 make up the divider, with R4 adjustable to set the operating point of Q1. You adjust the pot to keep Q1 cut off until the gate exceeds a certain level of positive voltage Thermistor R6 stabilizes the fet bias for any temperature variations.

The drain of Q1 gets operating power from the 18-volt dc line through R2. (text is continued on page 42)



* VOLTAGES WITH COLOR-BAR SIGNAL APPLIED TO RECEIVER. OTHERS WITH NO SIGNAL TO RECEIVER.

DC VOLTAGES AS GUIDES						
Voltage change	**to zero**	**very low**	**low**	**slightly low**	**slightly high**	**high**
Q1 source Normal *1.8V 2.0V	C3 shorted	R3 open R4 open	R3 high	C1 shorted C2 shorted C3 leaky C4 leaky	R5 high R6 high	R2 low R4 open R5 open R6 open
Q1 gate Normal *–0.3V 1.5V	C1 shorted C3 shorted C4 leaky R3 open R4 open	C1 leaky C2 shorted	R3 high R7 open R8 open	R1 low C2 leaky C3 leaky	R5 high R6 high	R2 low R3 low R4 open R5 open R6 open
Q1 drain Normal *18V 4.8V		C3 shorted	R10 open*	R2 high* C5 leaky*	C2 leaky	R1 open R3 low R4 open C1 leaky C2 leaky C2 open
Q2 base Normal *18V 15V			R10 open* R11 low, shorted C6 leaky C6 shorted	C5 leaky*	C1 leaky C1 shorted C2 shorted R3 very low R4 open	
Q2 emitter Normal *16V 15.5V	R10 open* R11 shorted C6 shorted		R11 low C6 leaky		R10 low*	
Q2 collector Normal *–0.8V 15.5V	R3 very low R4 open R7 open R8 open R10 open R11 open C1 leaky C2 shorted C6 shorted	(fluctuates when C6 open)	R7 high R8 high R11 low C6 leaky		C5 leaky*	
Point A Normal *–0.8V 4V	R3 very low R4 open R7 open R8 open R10 open R11 shorted R12 open R13 open C1 leaky C2 shorted C6 shorted	(fluctuates when C6 open) C7 shorted	R7 high R8 high R11 low R12 low R13 low C6 leaky C7 leaky		R12 low R13 low C5 leaky*	

NOTES:
**no-signal*
Use this guide to help you pinpoint the faulty part.
With no station signal, turn KILLER THRESHOLD full counterclockwise (ccw). Then turn it clockwise (cw) till confetti or colored snow is blocked out of raster. If you can't tell when colored snow stops, just set KILLER THRESHOLD at midrange.
Feed signal from keyed-rainbow color-bar generator into receiver. Set COLOR control of receiver two-thirds up; set generator color knob fully clockwise.
Turn ACC control full ccw. Then turn it cw till color level on screen stops changing. If that point isn't discernible, set ACC at midrange.
Measure each of the seven key voltages with your vtvm or fetvom, both with signal and without.
For each, move across to the column that describes whatever incorrectness you find in that voltage.
Read which parts might cause that alteration.
Finally, notice which parts are also named as possible causes of other voltage changes you find.
Test those parts individually for the defect described.

R8 and acc control R7 connect the base of Q2 back to the drain of Q1 and through R2 to the 18-volt supply. But dc voltage on the base depends mostly on base-emitter resistance of transistor Q2 in series with the R8-R7-R2 return path.

The emitter is divider-fed. R10 and R11 form the divider, across the 18-volt dc line. The collector supply path isn't shown in this schematic, being mainly in the video section. R12 and R13 form a dc path to the bandpass amplifier this killer acts on, but they are not a supply path for Q2.

Signal and Control Effects

Operation in these stages varies widely with signal level, with control settings, and with whether station signal is present or not. In fact, sensing and handling the presence of signal is the only reason for these stages.

KILLER THRESHOLD control R4 varies the bias at the source terminal of fet Q1. The object is to set the level at which gate voltage allows Q1 out of pinchoff. That determines the color/no-color operating point for both stages.

ACC control R7 does not, as it might seem, control how much dc voltage is applied from the drain of Q1 to the base of Q2. Just the opposite. It affects the acc voltage applied to the control amplifier (not shown) and sets the "normal" operating level of the first (or whichever is controlled) bandpass amplifier. The ACC control has no significant effect on killer action.

Signal and no-signal voltages are listed on the diagram. They represent average conditions with the KILLER THRESHOLD pot set to kill confetti in the snowy (no-station) raster of a normally operating receiver.

Quick Troubleshooting

With no signals, your scope is useless. Your fetvom or other electronic voltmeter gives you the best clues. A good procedure:

(1) No station. Measure gate voltage of Q1. Then apply color-bar signal. Voltage at gate should change considerably in positive direction.
(2) No station. Measure change of voltage at Q1 source as you rotate KILLER THRESHOLD. Voltage should vary widely.
(3) No station. Measure change of voltage at Q1 drain as you rotate KILLER THRESHOLD. Voltage should at some point vary sharply, not gradually.
(4) Set KILLER THRESHOLD at midpoint. Still measuring at Q1 drain, note change of voltage as you apply color bar signal. Voltage should alter considerably.
(5) Repeat (3) and (4) but measuring at base of Q2. Results should be similar.
(6) Repeat (3) and (4) but measuring at collector of Q2. Results should be similar.

This procedure, coupled with analysis of incorrect voltages by the Voltage Guide, should uncover the trouble quickly and easily.

Waveforms as Guides

Because these stages operate mainly on dc voltages and on the effects of changing dc voltages, there are normally no signal waveforms in the stages. Therefore no waveform clues are possible. **R-E**

add-on agc for pa system

Resistor-diode network in a PA amplifier channel is the easy way to add automatic gain control

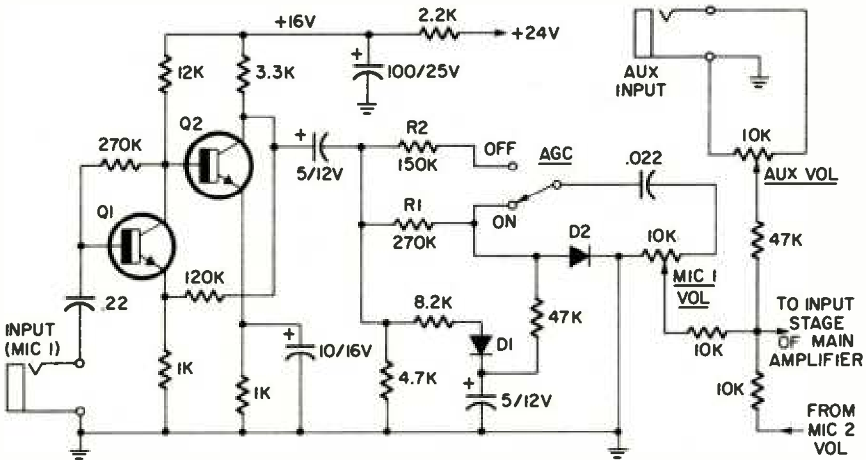
Automatic gain control is a useful feature in a PA system. It keeps volume constant as the speaker moves closer to or away from the mike, compensates for the voice levels of various speakers and permits the amplifier to be operated close to the feedback level without breaking into a howl if the speaker raises his voice.

The novel agc circuit shown here was used in a PA system described by Mr. George Hughes in *Electronics Australia.* It is one of two identical microphone preamp channels in the amplifier. When agc is being used, resistor R1 and diode D2 form a variable voltage divider across the signal path from the output of Q2. Diode D2 is the variable element in the divider. Its impedance varies with the level of a signal-derived dc bias applied to it.

The signal output from Q2 also appears across a 4700-ohm resistor and is rectified by D1 to develop the positive control voltage for D2.

When the amplified mike signal is high enough, D1 conducts and forward-biases D2, lowering its impedance and the signal voltage developed across it. This controlled signal is fed to the following stage in the main amplifier. (If you build this circuit, feed its signal into your amplifier at a high-level point such as radio, crystal phono or auxiliary input.) When the agc circuit is not needed, R2, selected to match the attenuation at agc threshold level, is cut into the circuit so there is no need for a major change in the volume setting.

The agc circuit begins operating when a signal of about 8 mV is fed into the mike input jack. Agc threshold is constant for all settings of the mike volume control. Best results are obtained by setting the volume control just below the feedback level. Any increase in mike input signal is leveled off before feedback develops. At the same time, the volume is held constant if the speaker drops his voice or turns away from the mike. **R-E**



Q1 = BC109, BC149, 2N2926, SK3020, ECG123A
Q2 = BC108, BC148, 2N1566, SK3020, ECG123A
D1, D2 = BA100, 1N914, OR EQUAL

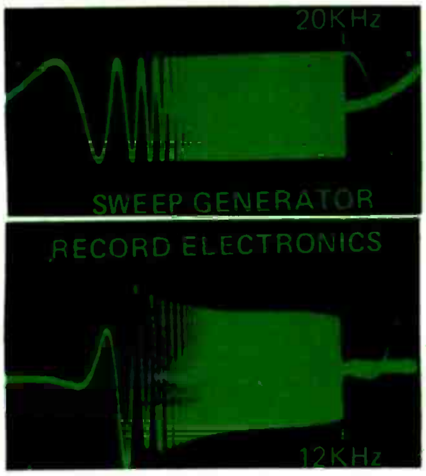


Fig. 1

R-E tests cassette tapes

Sweep audio generator and a storage scope enable us to produce a waveform that is a measure of recording tape response

by JOE SHANE

HOW DO YOU TEST BLANK CASSETTE magnetic recording tape frequency response and get meaningful results?

You can try a listening panel, but no matter how sharp the panel's ears, the results of listening tests are subjective. So we used a tape-testing system devised by the Maxell Corporation. We feel it is a good way to check frequency response, although it offers no measure of distortion or noise. And at times these factors can be more important than response.

We start off with a Hewlett-Packard model 141B Dual Trace Storage Scope and a Hewlett-Packard model 3300A Function Generator with a model 3305A Sweep Plug-in. The generator produces a logarithmic sweep from 20 to 20,000 Hz. The sweep time is approximately 0.7 second.

For a tape deck we used a TEAC model A-23 cassette deck that had been biased for TDK SD tape. Incidentally, bias variation to cover all of the tapes commonly available is no more than 10% and this range of adjustment is available in just about any cassette recorder. It is a service adjustment and should only be made by a qualified technician.

The two waveforms in Fig. 1 are our starting point. The top waveform is the output of the signal generator. The bottom waveform shows how this signal looks after it has gone through the record electronics in the TEAC deck. Note that it now cuts off at 12,000 Hz, the top limit of the deck electronics.

With the equipment on hand we went out and purchased a variety of cassette tapes and ran the same tests on 26 different brands. The results of these tests are on the next two pages. Here's how it was done.

The sweep generator output signal is fed to the tape deck and recorded on a fresh sample of blank cassette tape. Then the cassette is rewound and the recorded signal is played back and displayed on the scope. The scope is switched to storage—this freezes the image—and we take a Polaroid picture of the waveform. We have made no attempt to judge the tapes ourselves, but are simply presenting the waveforms and letting you, our readers, draw your own conclusions from the photographs.

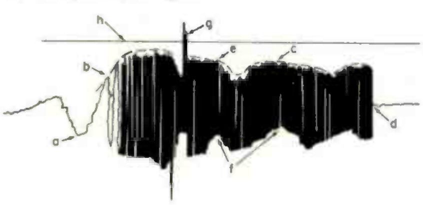
However, to help you interpret the waveforms you will have to refer to Fig. 2 at the bottom of this page. It explains what to look for.

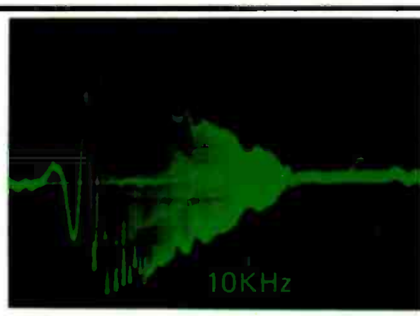
If we had optimized the bias setting of the tape recorder for each tape, before we tested it, some of the waveforms might have been improved somewhat, but remember, we're only talking about a 10% variation.

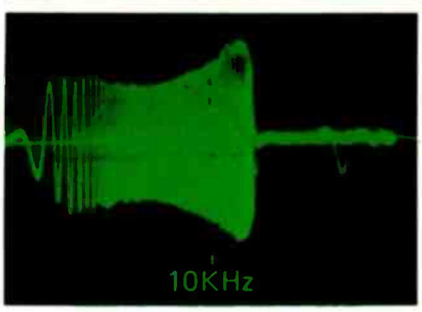
No matter what recorder or what tape you decide upon using there are several points to observe to get the best possible performance. First, decide on a tape (brand and type) and always use that tape. This will permit you to become familiar with one tape's characteristics and abilities. Also, you can now get the record bias of your recorder optimized for the tape you are using.

Now take a look at the waveforms at the bottom of this page. The one in Fig. 3 is typical of what we found when

Fig. 2—THIS DIAGRAM SHOWS information that can be derived from the scope trace.
a. Superimposed fluctuations indicate irregularity in tape travel usually due to wobbling cassette hub.
b. Response curve (dashed line) can be clearly read.
c. Superimposed rough edge denotes noise level.
d. Exact upper limit of tape deck—usually not a function of the tape.
e. Outer envelope contour denotes equalization characteristic.
f. Large cutout of edge shows dropout.
g. High peak slice indicates bind in cassette or tape travel.
h. When increased levels are used to test for tape saturation visible flats appear in different frequency ranges.







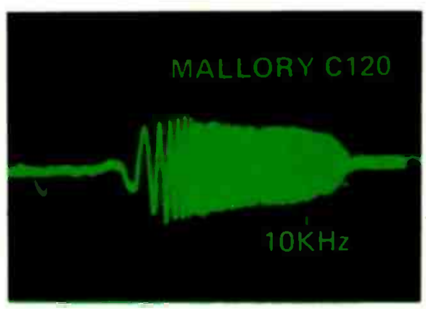


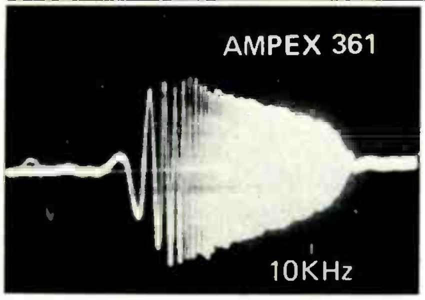
FIG. 3—(left) TYPICAL WAVEFORM of "white-box" tape. We tested several samples and found similar poor performance. We show only one example here.
FIG. 4—(center bottom) SIGNAL PLAYBACK when using chromium-dioxide tape in recorder biased for standard tape. Note exaggerated high-frequency response.
FIG. 5—(below) C120 TAPE has lower signal output than C60 tape. Other characteristics remain similar. Lower output is caused by thinner oxide coating on tape.

we tried several "white-box" cassettes. Low prices—but low quality too. While we tested several different "white box" tapes they all had about the same performance so we are showing only one waveform here.

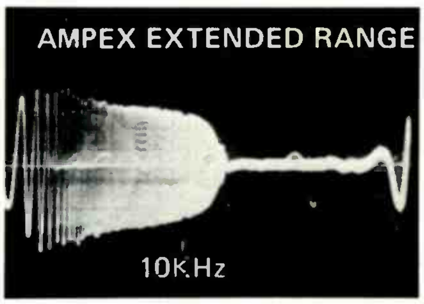
In Fig. 4 is an unlabelled waveform. It shows what happens when you use chromium dioxide tape in a recorder that is biased for conventional tape. Note the accentuation of the high-frequencies. Some readers may find this a good way to improve high-frequency response of an inexpensive recorder. But when played back on a quality deck the high-frequency boost would probably be undesirable.

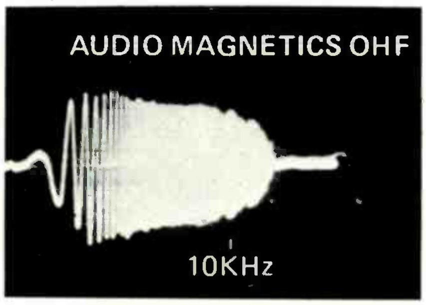
The last waveform (Fig. 5), labelled Mallory 120, is typical of all 120-minute cassette tapes. The waveform is very similar to the same manufacturer's 60-minute cassettes, but because the oxide layer on the tape is thinner on the tape in the 120-minute cassettes, the output signal level is also lower, by about 40%. This is directly related to the thickness of the oxide coating on the tape. The more oxide the more signal.

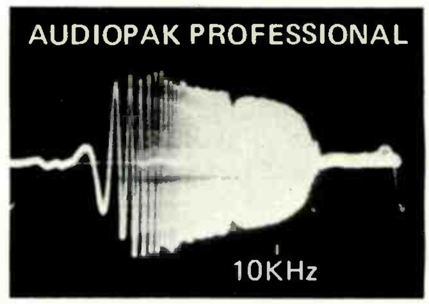
Here are some numbers to illustrate this point. You can expect a C60 (60-minute cassette) to use 0.5-mil tape with a 0.2-mil oxide coating. By contrast, a C90 cassette (90-minute cassette)

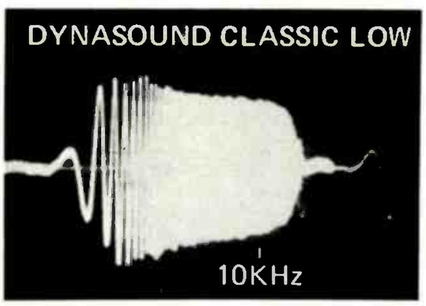


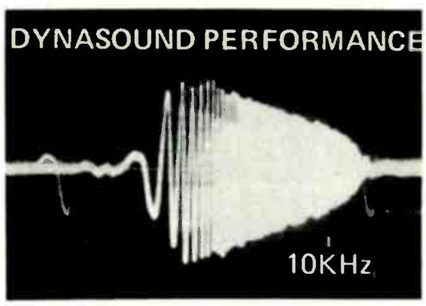
Here are actual Polaroid photographs of tapes we tested using the method and equipment described in this article. All tapes were purchased locally over the counter in electronics parts stores, department stores, record shops, and photography stores. The brand and type of each tape is in-

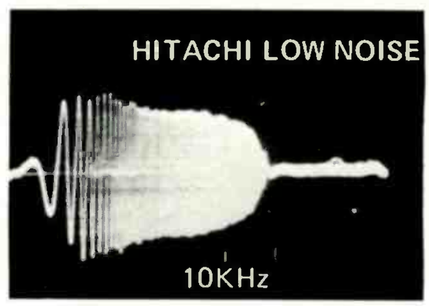


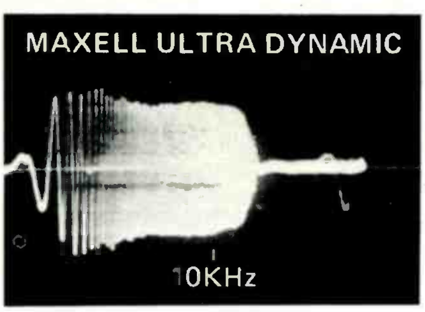


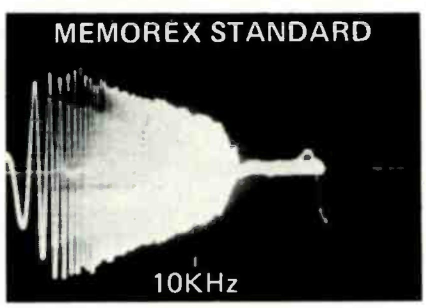


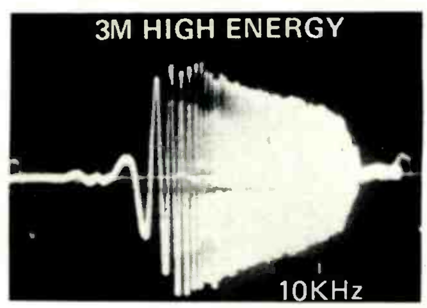


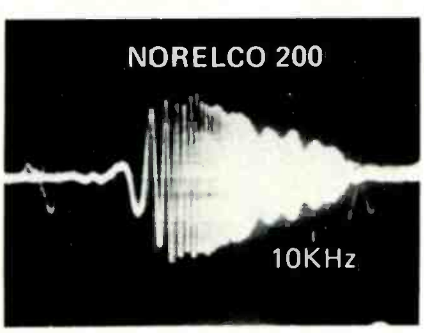


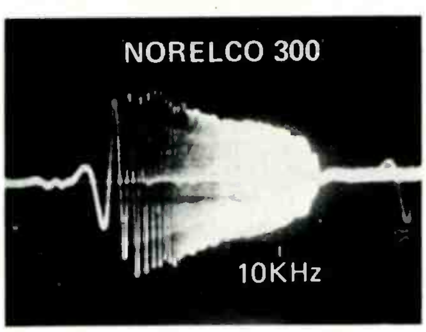


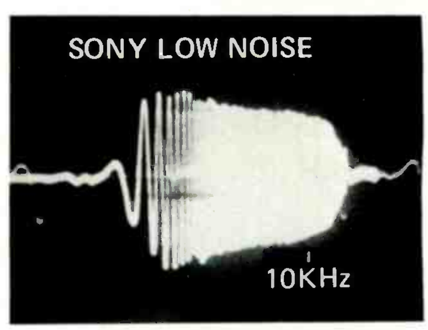












uses 0.3-mil tape and a 0.15-mil oxide layer. C120 tapes (120-minute cassettes) use 0.24-mil tape with 0.12-mil oxide.

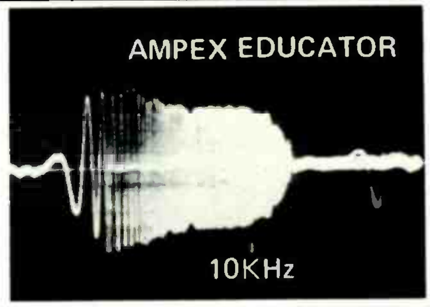
To get the best possible results from any cassette tape, always run it through your recorder once in each direction (fast forward, then rewind) before using it. This will loosen up the factory-wound tape and insure smooth playing with minimum wow and flutter. When fresh the tape is wound tighter than it ever will be while you use it.

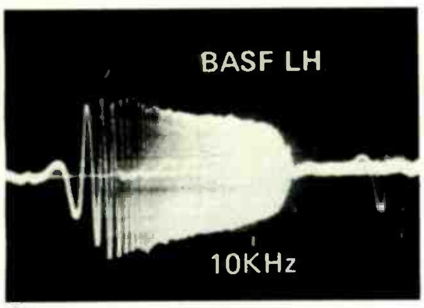
Next, remember not to use the first ten or fifteen seconds of tape at each end of the reel. This also goes for the last ten or fifteen seconds of tape. This keeps you from using the part of the tape that tends to stretch and wrinkle because of the strains placed on it when it is played.

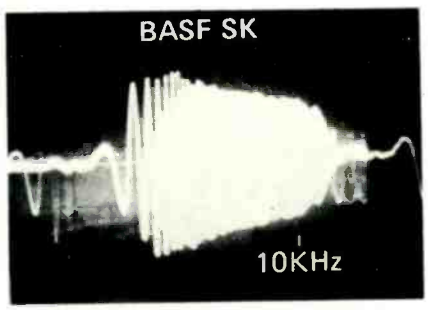
Another point that is critical for all tape recorders and especially for the narrow track cassette machines is to keep the tape heads clean. Make it a practice to run a cleaning tape through the recorder every ten or twenty hours of use and about once a month use a cotton swab with an appropriate cleaner directly on the heads.

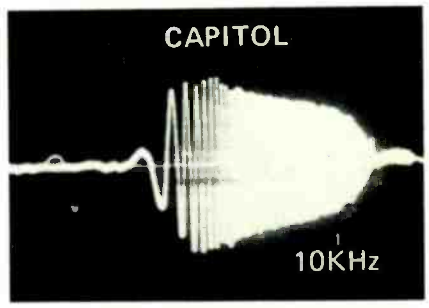
Lastly, don't forget to clean the rubber pinch roller that presses against the capstan. Use plain alcohol here, again with a cotton swab. **R-E**

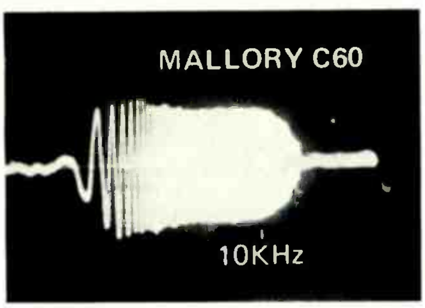
dicated on the waveform. All tapes tested were C60 (60-minute cassettes). The taller the waveform, the higher the level of playback signal. Other details of evaluating the photos are shown in Fig. 2. Keep in mind that optimizing bias will improve performance.

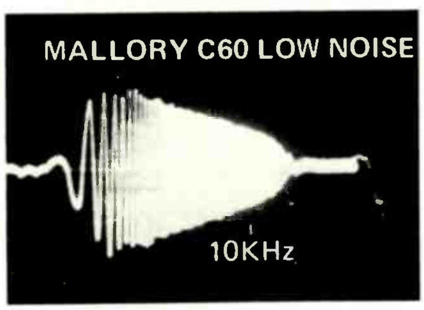


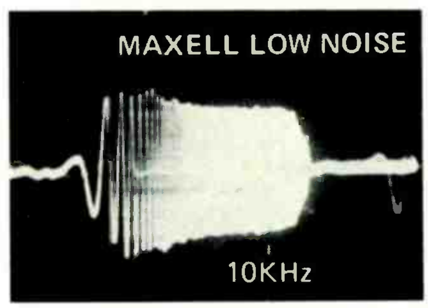


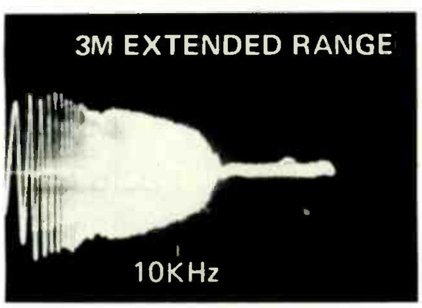


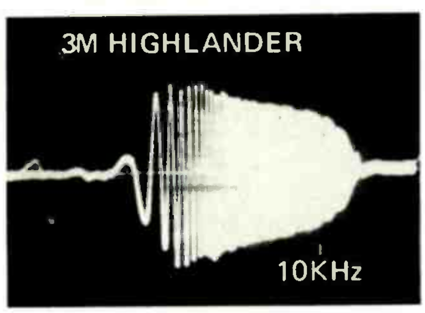


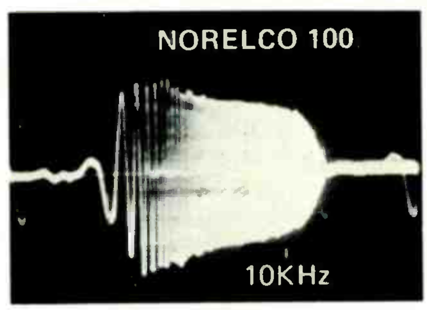


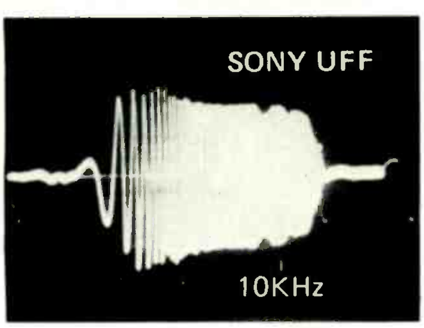


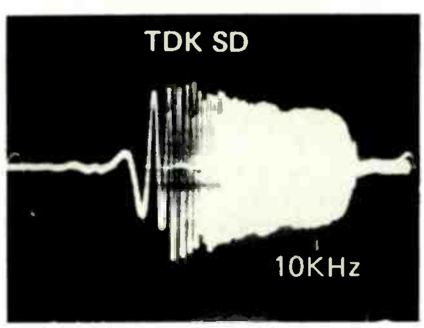


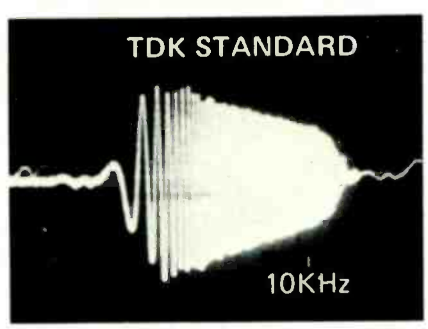


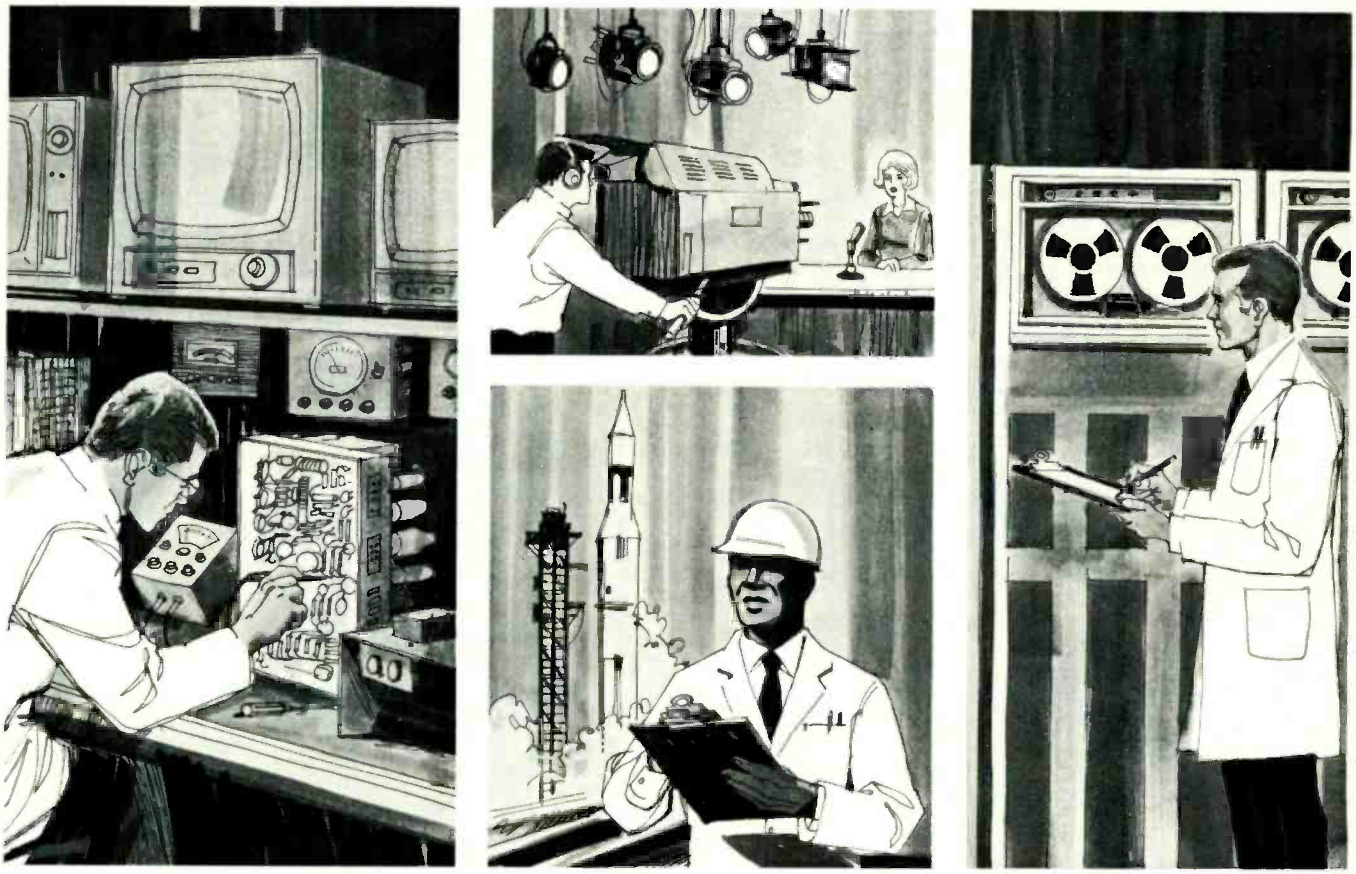




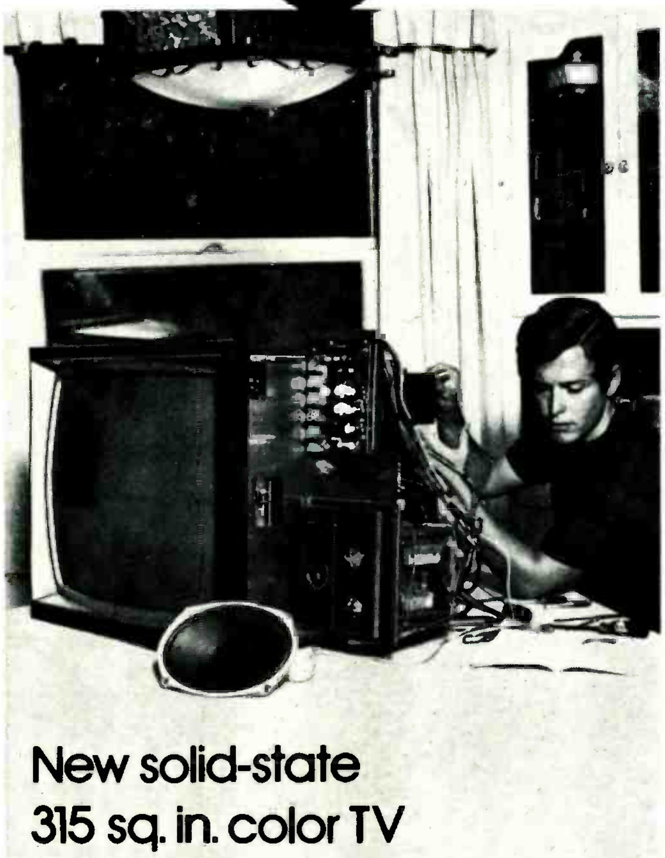








begin at home.



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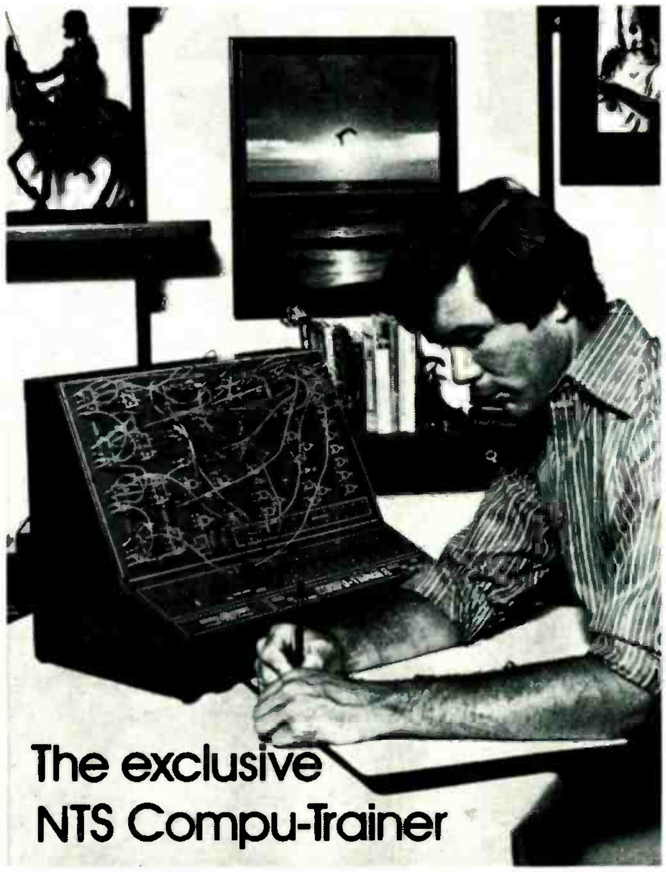

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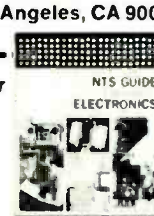

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STEREO

how to design your own solid-state audio amplifier

Class AB power amplifiers

by MANNIE HOROWITZ*

THE QUANTITY OF POWER THAT CAN BE delivered by a Class-A amplifier is extremely limited. A transistor can dissipate a specific amount of power. Should the transistor conduct current over the entire cycle, as well as when it is idling, a considerable amount of power is wasted just keeping the device operating at its predetermined quiescent bias. This is the state of affairs in Class-A operation.

On the other hand, Class-B power amplifiers are biased so that no collector current flows when the transistor is idling. The transistor does not conduct until the applied signal is of such magnitude and polarity as to put the device into its active region. NPN transistors, for example, do not conduct until the signal applied to the base relative to the emitter, is positive and greater in magnitude than the 0.6 or 0.7 volt necessary to turn on the base-emitter junction.

Even though the amount of power dissipation in Class-B remains identical to its capabilities in Class-A, in Class-B the amplifier will dissipate this power only when conducting useful audio currents. The portion of power wasted in maintaining the Class-A bias is applied here to enable the Class-B amplifiers to deliver more useful signal output.

Only one half of a purely ac sinusoidal cycle will turn on a Class-B biased transistor. To reproduce the alternate half of the cycle, the circuit must use a second transistor to conduct during this latter portion of the cycle. Two transistors are required to reproduce a full cycle in Class-B-biased amplifier circuits.

Class-B statistics

A push-pull Class-B amplifier circuit is shown in Fig. 1 using two npn transistors. Should a sinewave be fed to the input, the various waveshapes shown can be found at the specific points in the circuit when they are measured with respect to ground. The dots next to the ends of the input transformer windings

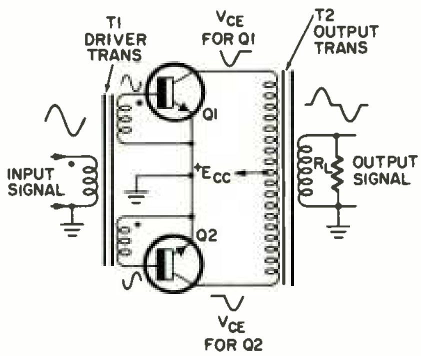


FIG. 1—TRANSFORMER-COUPLED Class-B push-pull circuit. Significant waveshapes are shown.

indicate that the corresponding leads or terminals are identical in polarity with respect to those at the unmarked ends. The base of Q1 is in phase with respect to its emitter as is the "hot" lead of the input signal with respect to ground. Establishing the proper status for push-pull operation, the polarity at Q2's base is 180° out of phase with that at Q1's base.

During the first half cycle, Q1's base is positive with respect to the emitter, so this transistor conducts. Q1 does not conduct during the second half cycle for during this interval, the base-emitter junction is reversed in polarity. The collector voltage is, as shown, for the voltage across the transistor and the upper half of the transformer winding is reduced as the transistor goes into conduction.

The second half of the cycle turns Q2 on; for only then does the signal bias that base positive with respect to the emitter. The waveform of the output voltage at the bottom of the output transformer with respect to the center tap, as well as across the transistor, is as shown. The voltage across the entire primary is relatively sinusoidal, as is the output signal across the load R_L. Ideally, the output signal is a magnified version, power-wise, of the input signal.

As discussed for the Class-A amplifier, the two transistors see the actual load R_L reflected as a resistor, R_L', into the *entire* primary winding of the output transformer T2. $R_L' = R_L(N_p/N_s)^2$ is an equation describing the relationship. In this formula, N_p is the number of turns in the *entire* primary winding and N_s is the number of turns in the secondary. Either one of the transistors sees a resistance, R_L'', across *one half* of the transformer winding. Since the number of turns each transistor sees is $N_p/2$, $R_L'' = R_L(\frac{N_p}{2}/N_s)^2 = (R_L/4)(N_p/N_s)^2$. Comparing the two equations, we arrive at the important conclusion that R_L'' is equal to $\frac{1}{4}R_L'$ or that the ac load seen by either *one* transistor appearing across *half* the primary winding of the transformer, is equal to one-fourth that seen by *both* transistors across the *entire* transformer.

Each transistor delivers power to the load. To determine the power delivered by two transistors, we need only determine the power one transistor delivers and multiply this number by two.

Using one transistor, draw the P_{CEM} maximum power dissipation hyperbola discussed last time, on the collector characteristic curves of the transistor. As was our previous practice, we omit the actual transistor curves to avoid cluttering the drawing. Assuming half the primary winding of T2 has zero resistance, the dc load line, defined by the equation $V_{CE} = E_{CC} - I_C R_P$, is a vertical line up from the E_{CC} voltage point on the V_{CE} axis. R_P in the equation is the resistance of ½ of the primary winding of transformer T2.

The ac load resistance is $R_L'' = (R_L/4)(N_p/N_s)^2$. Assume that at its maximum, the load line is tangent to the P_{CEM} curve. (We will deviate from the concept of not working above the P_{CEM} curve later on. Here, we assume the load line cannot cross this hyperbola.)

If a sinusoidal signal is at the input, a half cycle of voltage and current appears at the output. For the maximum output, the collector to emitter voltage will swing from E_{CC} to zero and the

*Chief Project Engineer, EICO Electronic Instrument Co. Inc.

collector current will swing from its I_{CM} maximum to zero. As the rms values of a half sinewave is the peak voltage or current divided by two, the signal power delivered to the ac load, R_L'', is

$$P_{R_L''} = \left(\frac{I_{CM}}{2}\right)\left(\frac{E_{CC}}{2}\right) = \frac{E_{CC}^2}{4R_L''} = \frac{I_{CM}^2 R_L''}{4} \quad (1)$$

This equation is valid irregardless of where the ac load line is with respect to the P_{CEM} hyperbola. The maximum power is dissipated by the transistor at the instant the swing is at the center of travel, or

$$P_C\,(\text{max}) = \left(\frac{I_{CM}}{2}\right)\left(\frac{E_{CC}}{2}\right) \quad (2)$$

This equation is also independent of the P_{CEM} curve. It should be emphasized that P_C(max) is not the average power the transistor will dissipate. It is the power the transistor will dissipate only at the instant the swing is at $I_{CM}/2$ and $E_{CC}/2$. This is the maximum power it will dissipate at any point in the swing. If the load line is tangent to the maximum allowable power dissipation hyperbola, P_C(max) is equal to P_{CEM}. The power dissipated when averaged over the entire cycle is less than P_C(max) for it is P_C(max) for but two instants in the half cycle as it swings on the load line.

Comparing equations 1 and 2, we note that the transistor can deliver as much power as the maximum instantaneous power it will dissipate in the half cycle. This is double the power the same transistor can deliver in the Class-A mode of operation.

The average or dc current in a half sinewave of collector current is I_{CM}/π. This was discussed in the article on rectification. The power supply must provide this dc current. It must provide $E_{CC}(I_{CM}/\pi)$ watts to the transistor. Comparing this with the power delivered to the load, the percent efficiency of the circuit is $100P_{R_L''}/P(\text{supply}) = 100\pi/4 = 78.5\%$—a decided improvement over the Class-A case.

The transistor dissipates power during ½ the cycle only for it does not conduct during the alternate half cycle. Over a complete cycle, one transistor of the push-pull pair will dissipate

$$P_{trans}(\text{for 1 cycle}) = 0.068E_{CC}^2/R_L'' \text{ watts} \quad (3)$$

if the signal swings the output from zero to its E_{CC} maximum limit. The average power the device will dissipate over the cycle, is higher if the swing is less than the maximum. Should the transistor deliver about 40% of the $P_{R_L''}$ in equation 1, it will dissipate more power than it will dissipate with any other size of signal swing. The power it will dissipate is

$$P_M\,(\text{av}) = V_{CC}^2/\pi^2 R_L'' \text{ watts} \quad (4)$$

if the power it delivers to the load is 40% of the maximum. Comparing this with equation 2, the transistor can deliver about 2½ times the power it may dissipate.

Averaged over a complete cycle, the transistor may dissipate P_{CEM} watts. It will cross the P_{CEM} hyperbola and yet be within the power dissipation rating of the transistor when the dissipation is averaged over the 360°. This differs from the Class-A case for here the idling and average power over the cycle were at P_{CEM} when the transistor was biased for minimum distortion. As the power during idling (and hence the average during the cycle) was not permitted to exceed P_{CEM}, the load line was not permitted above the maximum power dissipation hyperbola.

Class-B design procedure

Assume you want to design a 60-watt push-pull amplifier which will drive an 8-ohm speaker system. How would you proceed to specify the output transistors and transformer? Use the circuit in Fig. 1.

If the two transistors are to deliver 60 watts, each one must be capable of delivering half the power or 30 watts to the load. If the transformer is 25% efficient, the transistors must deliver 30 watts + 25% of 30 watts = 37.5 watts to the primary of half the output transformer. Add about 10% to compensate for losses due to saturation voltage and leakage current, so that the circuit should be designed to be capable of providing about 42 watts.

A good power transistor for this application is the 2N3055. The maximum collector current that can safely flow through this transistor is 10 amperes.

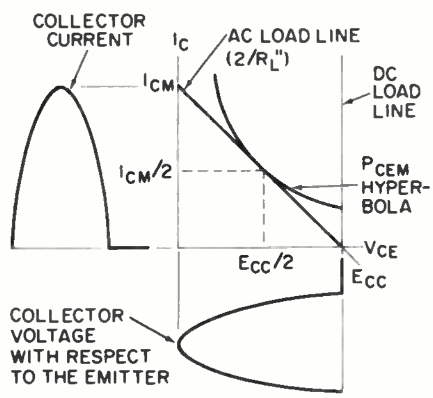


FIG. 2—PLOT OF LOAD lines for Class-B amplifier. A sinusoidal input and output signal is assumed.

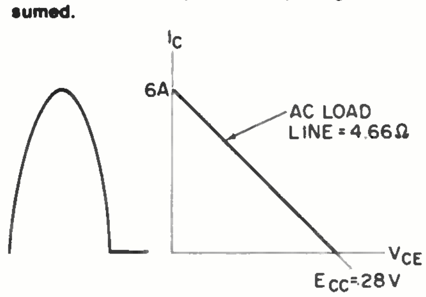


FIG. 3—CURVES FOR CLASS-B design procedure.

Adding some leeway, use 6 amperes as the maximum collector current. As the rms current of the half sinewave (see Fig. 3) is 6/2 = 3 amperes, the load the transistor must see at the primary of the transformer is:

$$R_L'' = P_{R_L''}/I_{rms}^2 = 42/9 = 4.66 \text{ ohms}$$

The supply voltage, from equation 1, is:

$$E_{CC} = (4R_L''P_{R_L''})^{\frac{1}{2}} = (4 \times 4.66 \times 42)^{\frac{1}{2}} = 28 \text{ volts}$$

Maximum power is dissipated by the transistor when the power delivered to the load is about 40% of 42 watts, or 16.8 watts. When delivering this power, the transistor dissipates V_{CC}^2/π^2R_L'' watts = 783/(9.9)4.66 = 17 watts. The 2N3055 can easily cope with this power dissipation requirement.

(It is interesting to stop for a moment and note several things here. For the full swing, the transistor will dissipate $0.068V_{CC}^2/R_L''$ = (0.068) (783)/4.66 = 11.4 watts. This is less than the power dissipated when 40% of the maximum power is delivered to the load.

(The power a transistor will dissipate is equal to the power taken from the supply less the power delivered to the load. The power furnished by the supply can be calculated as follows. Based on equation 1, the square of the collector current swing is $I_C^2(40\%) = 4P_{R_L''}(40\%)/R_L''$ for the case where the output is 40% of maximum. Hence, $I_C^2(40\%)$ = 4(16.8 watts)/4.66 ohms = 14.4 amperes². The current is then $I_C(40\%) = \sqrt{14.4}$ = 3.79 Amperes. The power from the supply is $E_{CC}(I_C(40\%)/\pi)$ = 28(3.79/3.14) = 33.9 watts. Subtract the 16.8 watts delivered to the output at 40% of the maximum output power from the 33.9 watts supplied by the power source, and the transistor must dissipate 17.1 watts. This is very close to the 17 watts solution determined from the V_{CC}^2/π^2R_L'' equation above. This alternate method is presented to indicate a logical procedure used to determine the transistor power dissipation at any portion of the maximum power the device can deliver, rather than being required to memorize a nebulous formula.)

Since the impedance across one-half the primary of the output transformer is 4.66 ohms, the impedance from collector to collector, across the entire primary, is 4 x 4.66 ohms, or 18.64 ohms. The impedance ratio of the entire primary to the secondary is 18.64 ohms: 8 ohms —2.33:1. The turns ratio is the square root of the impedance ratio, or 1.51:1

Turning to Class-AB

A typical set of collector characteristic curves are in Fig. 4, for the 2N3055. Notice that they are not evenly spaced. Should the collector-current swing the full 10 amperes for the half cycle, the

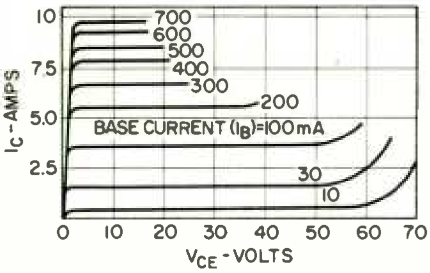


FIG. 4—TYPICAL OUTPUT characteristics of power transistors. Courtesy RCA

current gain differs at different points of the cycle. For example, at the point the in cycle where 2 amperes collector current is required, the base current at the input is about 40 ma. At the 4 ampere collector current point in the cycle, the base current is about 120 ma, while for 6 amperes, it is about 250 mA. In the portion of the output curve where there is a 2-ampere collector current rise from 2 to 4 amperes, the equivalent base current increase about 120 – 40 mA = 80 mA, while for the same 2-ampere collector current increment from 4 to 6 amperes, the equivalent base current increase 250 – 120 ma = 130 ma. Even though the increase in collector current remains at 2 amperes in both cases, the base current drive required was greater at higher collector currents. This information could, of course, have been derived from the beta curves which show that beta varies considerably with collector current. The a-c and d-c current gain is nonlinear producing distortion.

Another curve, shown in Fig. 5, is a

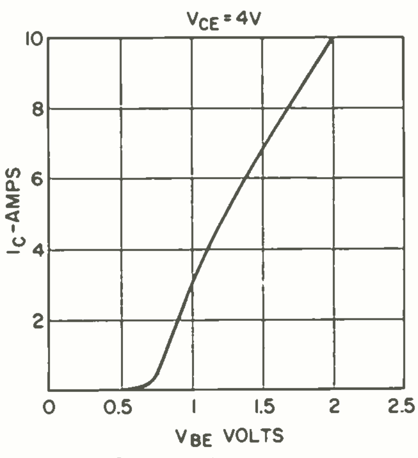


FIG. 5—TYPICAL TRANSFER characteristics of power transistors. Courtesy RCA

plot of the collector current against the base-emitter voltage. You may recognize this as a transconductance curve, where the definition of transconductance is not unlike that applied to the JFET. Notice that this curve, after the first 0.6 or 0.7 volts is a relatively straight line. The slope of this line is the a-c transconductance. It is equal to $\Delta I_C/\Delta V_{BE}$, where the Δ indicates a change or difference. The a-c transconductance is relatively constant with changes in collector current. Should the half cycle of 10 ampere collector current be at the output, the required input base-emitter voltage at the 2 ampere collector current point in the cycle is 0.9 volts, at the 4 ampere point it is 1.1 volt, and at 6 amperes it is 1.3 volts. While the collector current increase is in increments of 2 amperes, the base to emitter voltage increase in one case is 1.1 volts – 0.9 volts = 0.2 volts and in the second case it is 1.3 volts – 1.1 volts = 0.2 volts. Hence equal changes in base emitter voltages produce equal changes in collector current. This is a linear situation favorable to the cause of low distortion.

Good power amplifiers are driven from low impedance voltage sources where transconductance is the controlling factor, rather than high impedance current sources where the varying beta determines the relatively distorted output.

In Fig. 6-a, we apply half a sine wave of voltage to the input between the base and emitter. The collector current at the output appears next to the I_C axis. Note that there are portions in the cycle where there is little or no output current. This is known as the crossover region. For the two transistor push-pull circuit in Fig. 1, the output across the load, R_L, would appear as in Fig. 6-b rather than be perfectly sinusoidal. This signal has a considerable amount of odd harmonic distortion and intermodulation distortion. Even worse,

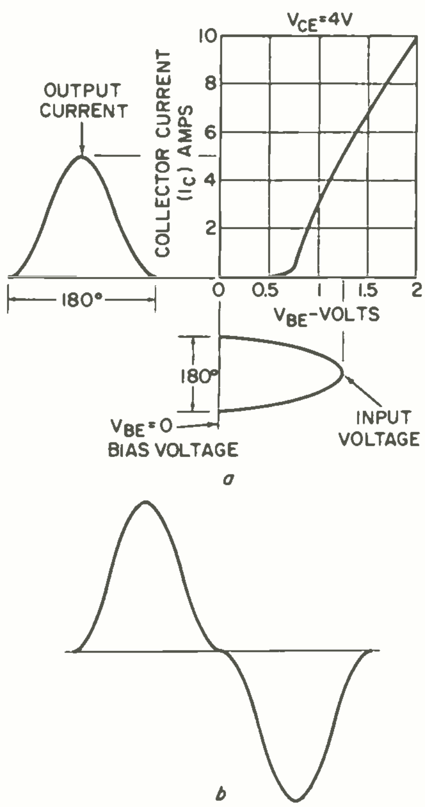


FIG. 6-a—COLLECTOR CURRENT due to half a sinewave input. b.—COLLECTOR CURRENT as it appears for a full cycle. Note crossover distortion. Courtesy RCA

in conjunction with transformer and speaker inductance, this abrupt crossover can cause sharp peaks in the circuit which can damage or destroy the transistor.

Crossover distortion can be minimized if the transistor is biased so that it is always conducting some minimal amount of collector current. A normal procedure to determine the minimum base-emitter voltage for this type of operation is to extend the straight line of the curve to the V_{BE} axis. The curve in Fig. 5 crosses this axis at 0.75 volts. The transistor should be biased at this voltage. It may be true that some power will be dissipated due to the idling collector current (about 40 mA at 0.75 volts), but the reduction in crossover distortion is well worth this minor expenditure of power. Some manufacturers cause the transistors to idle at much higher current to assure that the collector current will never be completely cut off. This type of biasing puts the transistor into what is referred to as Class-AB operation.

A drawing of the output current when the transistor is biased at 0.75 volts is shown in Fig. 7. There is no por-

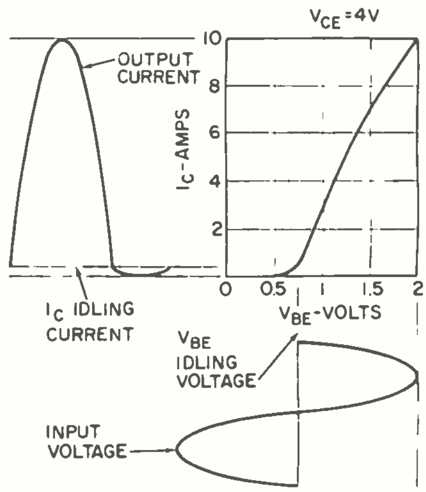


FIG. 7—CURVES WHEN TRANSISTOR is biased for Class AB operation. Courtesy RCA

tion of the half cycle during which there is an absence of collector current flow. The distortion is relatively low when compared to the Class-B mode of operation. The output over the full cycle is a relatively good sine wave.

Should the circuit in Fig. 1 be biased for Class-AB operation, it could take the form shown in Fig. 8. The bias voltage is developed across R_X, which is applied between the bases and emitters of the two transistors. R_B and R_X form a voltage divider with E_{BB} as the source of the base bias supply voltage. The quiescent base current can be determined using Thevenin's equivalent circuit procedures described in an earlier article. Do not forget to include the dc resistance of the driver transformer's

(continued on page 85)

TECHNICAL TOPICS

Introducing the ESD—a brand-new component with a myriad of applications in electronics—and more

by ROBERT F. SCOTT
TECHNICAL EDITOR

THIS MONTH I'M GOING TO TAKE MOST of your time to discuss something really new and interesting—haven't decided whether it is a device or component—and I think you'll find its concepts and applications exciting. It is still in its horse-and-buggy stage but appears to be the answer to many problems. I'm talking about the ESD (*e*nergy *s*torage *d*evice) made by Gould Ionics. It is an *electrochemical capacitor* with quite a few unique features. Among those of greatest interest to electronics engineers and experimenters are:

Very high capacitance—Values are rated in *farads*, not in μF or pF as are conventional types. Currently made in 0.01, 0.1, 0.5, 1.0, 5 and 50 farad units.

Very high capacitive density—The 50-farad unit occupies less than 0.33 cu. in. Density averages 160 farads per cubic inch.

Very high leakage resistance ($\cong 10^{10}$ ohms)—Retains more than 97% of its initial charge after 16 months of storage.

Very low leakage current—Typically less than 1 pA. A particularly useful factor when charging current is a few microamps or less and discharge current is in milliamperes.

Stores large amounts of charge at low voltages.—A 50-farad unit stores up to 25 coulombs at 0.5 volt.

ESD cells can be paralleled or series-connected.—Follow conventional capacitor and battery arrangements for greater voltage and higher current capability.

Low equivalent series resistance (R_{es}).—R_{es} is inversely proportional to the diameter of the device—less than 1 ohm for a 5-farad, 1-inch diameter device and less than 10 ohms for a similar device 0.5 inch in diameter. The R_{es} is the sole factor limiting the ability of the ESD to transfer its charge to a load.

The ESD is composed of chemically stable compressed powders and there is no danger of damaging or destroying adjacent components due to leakage. Shelf-life is said to be indefinite, even when stored under random temperatures ranging from -65°C to +140°C. It is a sturdy component, not prone to catastrophic failure. It takes large amounts of energy to destroy an ESD used outside its ratings.

When used as a power source, it has a low power density when compared with batteries. Further, both its maximum voltage and current per cell (500 mV and 1 mA) are much lower than most other electromotive cells. ESD's can be connected in series, parallel and series-parallel combinations for the desired current and voltage ratings.

Figure 1-a shows the symbol the manufacturer uses for the ESD. Figure 1-b is the constant-current discharge curve for a typical ESD. When used purely as a capacitor, the current-time characteristic capacitance is

$C = I_t/V$, where V is 500 mV.

When used as an energy source, ESD's can be operated at up to 625 mV per cell for an increase in energy storage capability of approximately ten times or t1 + t2.

For example, a 5-farad, 10-cell ESD can provide current for time *t* as determined by the current drain. For a 1-volt drop (from 5 to 4 volts) a 100-mA drain can be sustained for about 50 seconds. With a 1-mA drain it would take about 5000 seconds for the charge to

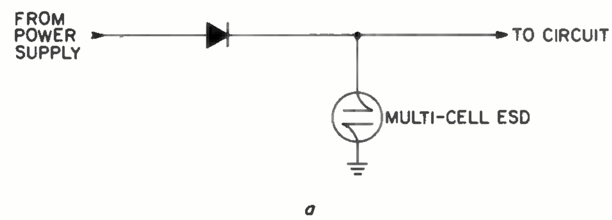


FIG. 1-a—THE ESD (energy storage device) has a symbol representing its dual functions as a massive filter capacitor (rated in farads) and as a low-capacity storage battery.

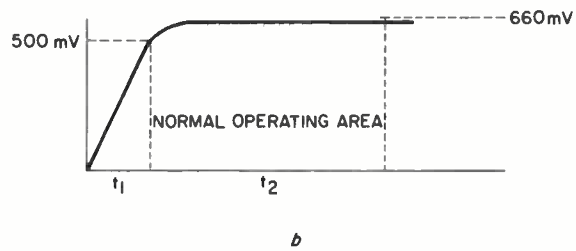


FIG. 1-b—TIME CURVE for the ESD when discharged at a constant rate. The normal charge is to 500 mV. Charging to 625 mV increases the operating range by a factor of at least ten times.

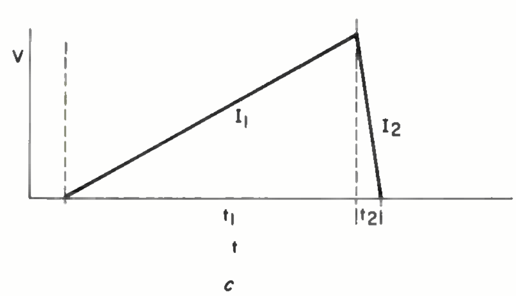


FIG. 1-c—RAPID RECYCLING OF ESD TIMER uses the charge and discharge times of the device. Its low current rating prevents the use of a short-circuit discharge device.

drop 1 volt. The same ESD charged to 6.25 volts would have a power increase of at least ten times. This allows an increase in current or time or a reduction in device size.

Applications

Source of standby power in cases where loss of primary power can be either dangerous or extremely inconvenient. For example, in a crystal-controlled digital clock, a simple circuit like that in Fig. 1-a might be used to supply the oscillator and counters so they won't lose step during power interruptions. The same applies to memory systems in computers.

An excellent decoupling device for use when large numbers of circuits are operated from a common power supply.

Pulse-power source to minimize overall power drain in devices with low-current power sources which must have an occasional low duty-cycle, high-current output. A typical example might be a remote weather station or flood-warning system powered by solar cells. Power is stored slowly over relatively long periods and then pertinent information is telemetered out in one short burst of energy.

In timing circuits, the charge-storage capability and low leakage-current make the ESD an excellent current-time integrator whose performance is limited only by the characteristics of the external circuit components. Fig. 1-b shows the time versus constant-current charge/discharge curve for the ESD. Note that regardless of the charging current, time *t* is linearly proportional to voltage. Due to the low voltage at which a charge can be stored in an ESD, the device can be charged from a voltage source through a resistor that holds the current constant.

Since time equals KV (where K is a constant and V is voltage), *time can be set as accurately as voltage can be measured.* Although some ESD's show capacitance increases up to 0.1% per degree C, the voltage/time repeatability is better than 0.1% when temperature is held constant.

For indefinite life, the maximum charge and discharge currents of an ESD should be limited to 1 mA although occasional higher currents can be tolerated.

In most electronic timers, a capacitor is charged to a given voltage level and then discharged rapidly through a short circuit to reset for the next timed cycle. This method is not particularly suited to this new device. For example, a 0.5 F, 1-inch diameter ESD—when shorted—has an R-C time-constant of about 0.5 second (R_{es} is less than 1 ohm) and takes around 3.5 seconds to discharge to 0.1% of its initial charged value. When discharged through a 500-ohm resistor—to limit current to 1 mA at 0.5 volt—the R-C time-constant is 250 seconds and the period required to discharge to 0.1% is 1750 seconds; *nearly 30 minutes.*

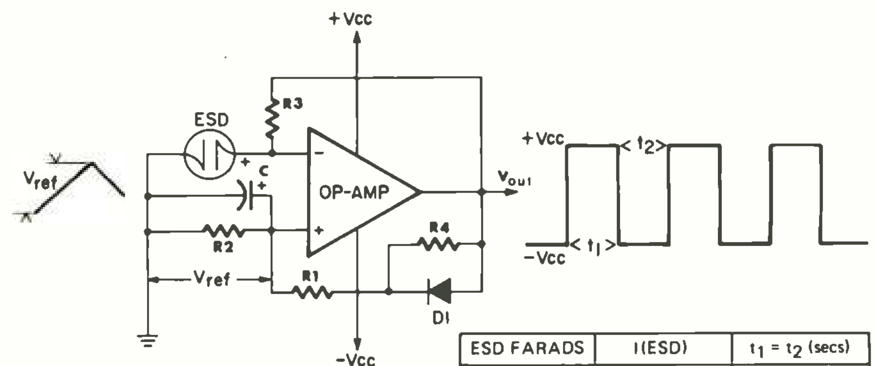
However, when timing is based on the R-C time-constant—the time in seconds required for the voltage across the charging capacitor to rise to 63% of the applied voltage or to lose 63% of its charged voltage—the long discharge-time required by the ESD may still be acceptable. For example, when charging current is limited to 10 μA, the charge time is 25,000 seconds. When the discharge current is limited to 1 mA, reset time is 250 seconds, only 1% of the timed interval and quite acceptable in many applications.

When a more rapid reset time is needed, the timed period may be made equal to the *sum* of the *charge and discharge* times. In this case, the circuit is held in the required state as long as the ESD is charged *above zero* (see Fig. 1-c). In this type of design, the ESD is completely discharged and the time delay before the next period begins is a function of the system's logic speed.

Figure 2 shows how the ESD, an op-amp and a few components can be used to make a free-running multivibrator with periods ranging from a few seconds to several *million* seconds. When power is first applied to the circuit (with the ESD fully discharged) the op-amp output V_{out} will be positive. Diode D1 is forward-biased so voltage V_{ref} (greater than zero and less than 500 mV) appears at the non-inverting input.

The ESD then charges from V_{out} (positive) through R3 at a constant-current rate I_{ESD}. Maximum I_{ESD} is a 1 mA and circuit values should be adjusted so $(V_{out} - V_{ref}/2)/R3$ is less than 1 mA. When the voltage across the ESD—appearing at the inverting input—is more positive than V_{ref}, V_{out} changes from positive to negative. This reverse-biases D1 and the voltage at the non-inverting input drops to zero. The ESD is then discharged from the negative V_{out} through R3. When the voltage across the ESD becomes more negative than zero, the op-amp again switches state—going from negative to positive (the starting condition) and the cycle repeats.

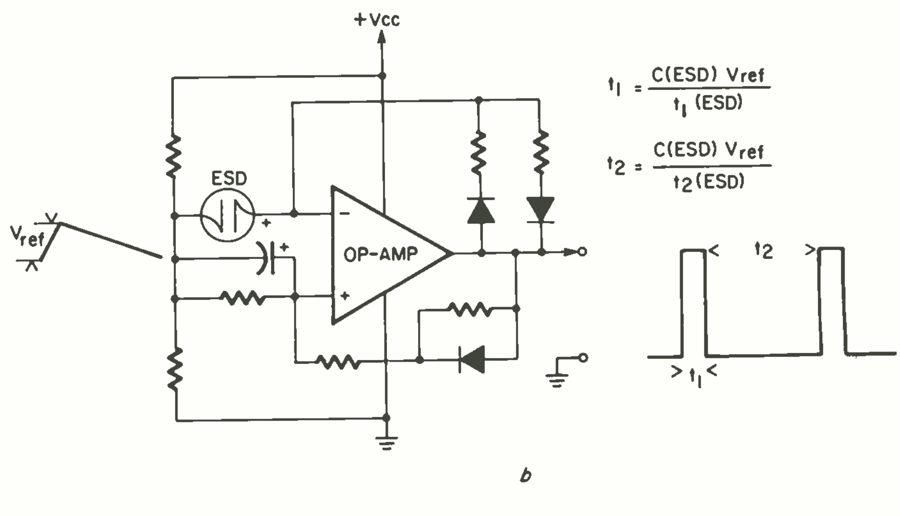
Time t1 equals
$C(R2/R1 + R2) \times R3(V_{out} - V_{D1}/V_{out} - V_{ref}/2)$
and *approximately* equal $C(R\text{-}2/R1 + R2)R3$. And, if V_{ref} equals 500 mV, *t* =



$$t_1 = t_2 = \frac{C(ESD)\ V_{ref}}{I_1\ (ESD)}$$

ESD FARADS	I(ESD)	$t_1 = t_2$ (secs)
0.01	1mA	5
0.50	100μA	1,500
50	10μA	2,500,000

a



$$t_1 = \frac{C(ESD)\ V_{ref}}{I_1\ (ESD)}$$

$$t_2 = \frac{C(ESD)\ V_{ref}}{I_2\ (ESD)}$$

b

FIG. 2—MULTIVIBRATOR USES AN ESD to drive an op-amp flip-flop with periods up to several million seconds. Circuit in Fig. 2-a provides symmetrical output and needs two power supplies. Fig. 2-b needs only one supply and has a variable space-mark ratio.

$CV_{ref}/I_{ESD(max)}$. Thus, t1 is 5 seconds when V_{ref} is 500 mV, C is 0.01 farad and I_{ESD} is 1 mA. When using the same ESD and setting I_{ESD} at 10 μA the time increases to 500 seconds. By using higher ESD values and charging currents around 10 μA, times up to 2½ million seconds can be reliably produced.

The circuit in Fig. 2-a provides symmetrical output (t1 = t2). Figure 2-b incorporates changes to permit the op-amp to operate from a single power supply and to provide asymmetrical output. The ratio between t1 and t2 can be as much as 100,000:1 with either t1 or t2 being the greater, depending on the input bias current of the op-amp.

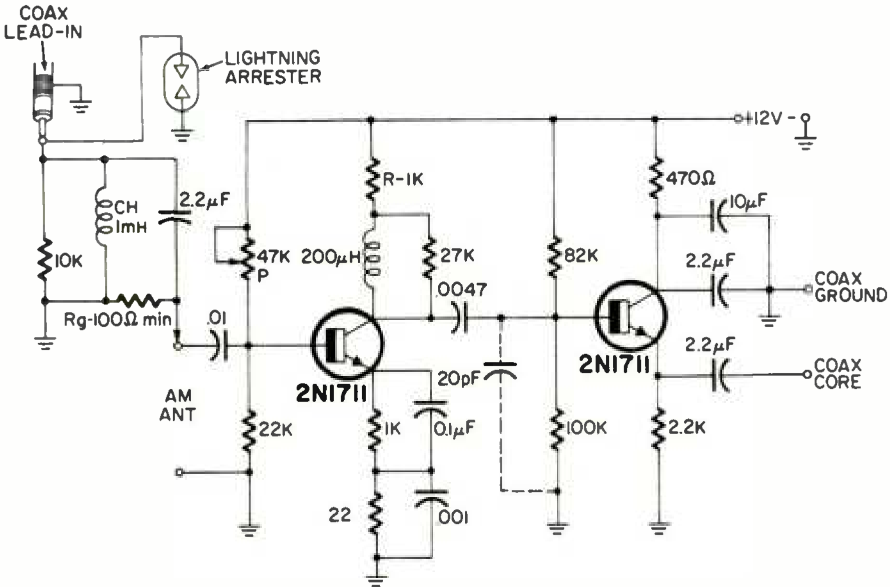


FIG. 3 (above)—BROADBAND BOOSTER for broadcast and shortwave receivers that can use more sensitivity.

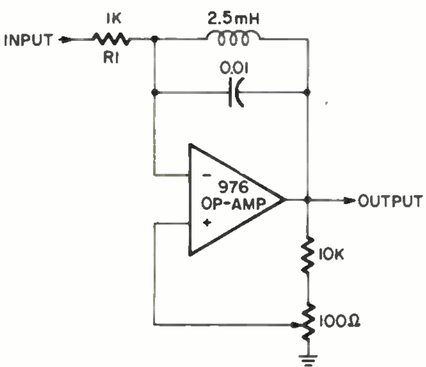
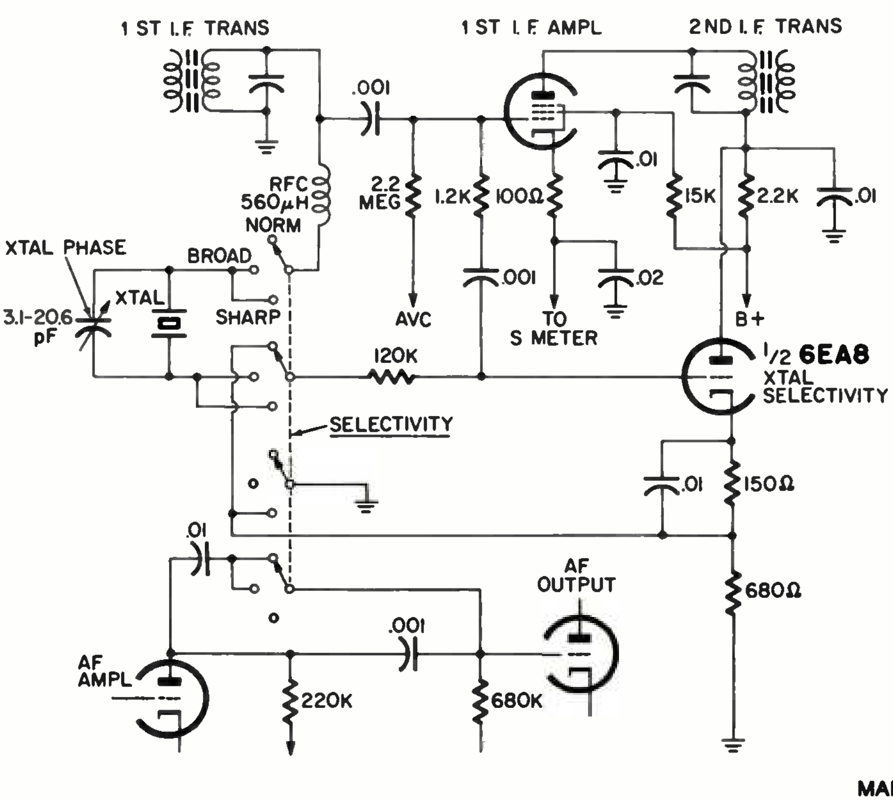


FIG. 4 (left)—IC Q-MULTIPLIER uses tuned circuit between output and inverting input for selective regeneration.

FIG. 5 (below)—VARIABLE SELECTIVITY in Hallicrafters SX-133 receiver is provided by Q-multiplier around the crystal.



At its present state of development the ESD can be compared to the point-contact transistor of 1948. Thus it is not a component you can rush out and purchase over the counter at your friendly parts dealer. You have to order them from the manufacturer: Gould Ionics Inc., P.O. Box 1377, Canoga Park, Calif. 91304. The eight types covering six capacitance values are $30.00 each and the minimum order is three pieces. Before ordering, I suggest writing to Gould Ionics for copies of Bulletins 70107, 70818, 71304 and 71324.

The "more" on the blurb refers to a broadband signal booster for frequencies ranging from below the broadcast band to well up in the shortwave bands. The circuit in Fig. 3 is one of several for different frequency bands described in *Le Haut Parleur*. It should be just the thing for BCB and shortwave DX'ers whose receivers are not as sensitive as they would like them to be. It works best into receivers with antenna input impedances between 100 and 500 ohms. With the circuit values shown, the gain is flat from around 150 kHz to 30 MHz.

A Q-multiplier is a scheme of using positive feedback (regeneration) to increase the effective Q of a L-C network. They are used in active filters in lab test gear and are fairly common.

The circuit in Fig. 4 was described by Richard C. Gerdes in *Electronics* magazine. The parallel-tuned L-C network (resonant at 33 kHz in this case) is in a feedback network between the output and inverting input of an op-amp. Circuit selectivity is shaped by the potentiometer.

Possibly the most unusual use of a Q-multiplier thus far is in shaping the response of the simple crystal filter in the Hallicrafters SX-133 communications receiver as in Fig. 5. The crystal filter is by-passed and full-fidelity response is available for AM reception when the SELECTIVITY switch is in the NORMAL position. In the BROAD position, the crystal is inserted in series with the input to the first i.f. amplifier. The triode section of the 6EA8 acts as the Q-multiplier. Multiplier gain is limited by degeneration across the 680-ohm cathode resistor. The SHARP position of the switch shorts out the 680-ohm resistor; increasing multiplier gain and sharpening i.f. selectivity. A fourth section of the switch decreases the coupling capacitance between the audio stages. This peaks the audio response for best CW reception while eliminating the possibility of audio howl. **R-E**

LAST MONTH WE REACHED THE POINT OF testing electrolytics with a scope—moving the vertical input probe along the B+ line as filter capacitors were bridged with good ones to note their effect on ripple and hash.

There is one, and only one, exception to this rule. You will find a fairly high ripple on the input filter capacitor. This is normal, because the dc hasn't gone all the way through the whole filter as yet. Actual ripple voltage here will vary, depending on the design. However, at the filter output, you should never have more than about 1.5 volts p/p ripple, and this for tube-type circuits. Solid-state circuits should have practically zero ripple. Transistors are much more sensitive to hum than tubes are.

Insufficient filtering

There is one other place where you could run into problems. This is in the cheaper sets where the complaint is often "I've got a light-colored bar floating up and down in the picture" Checking the original electrolytics on a capacitor tester shows that they are all in the ballpark. Yet the scope shows you a peculiar "writhing" ripple waveform on the *output* of the filter!

This, in several cases, turns out to be insufficient filter capacitance in the original design! The cure is obvious; add more capacitance to the circuit. Shunt another electrolytic across the output filter until you have reduced the ripple to a level where it won't cause the light-bar symptom. I have had to add as much as 100 μF of extra filtering in some sets!

Intermittent electrolytics

This discussion wouldn't be complete without mentioning the most annoying fault found in electrolytic capacitors—the intermittent! It is the cause of the infuriating problem where the set has all sorts of symptoms, yet the instant you touch anything in the circuit with a test-prod (even a scope probe!) it goes pow! and starts to work perfectly again! In most cases, it will keep right on working, no matter how you hammer on it, etc. Once it is turned off and allowed to cool, the same problem comes back. (In the worst cases, it won't come back at all—that is, until after you have taken the thing home again! There it usually cuts out no later than the next day, and you've got a call-back.)

This type of problem is caused by an intermittently-opening electrolytic capacitor. When you bridge a good capacitor across one of these, the resulting surge of voltage seems to weld the bad contact, and the capacitor seems perfectly good again.

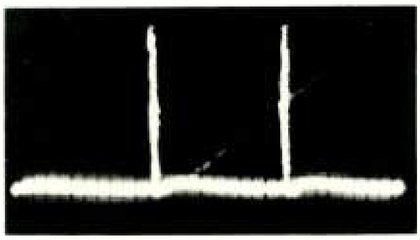


FIG. 10—VERTICAL-FREQUENCY spike found on dc power lines cancelled true vertical sync pulse.

The problem here is identifying the bad one. You can have very similar symptoms with bad solder joints or bad PC board conductors. However, when you see the trouble, check carefully to see if it looks like "open-filter" trouble. (Hum-bars, bending, feedback, etc.) There is one way to check. Turn the set off, and *then* clip the scope across the suspected unit or circuit. Now turn the set back on. If you see any sign of signal or ripple on the dc power supply, that's it. You can then *intentionally* "trigger" it back on, by touching it with a voltmeter probe, etc. If the "signal" disappears, OK. Replace the filter capacitors. You can also use this method with a substitute capacitor. Turn the set off and hook your bridging capacitor across the circuit, then turn it on again.

The weirdos

High power-factor or odd troubles inside an electrolytic capacitor can cause some strange and wonderful symptoms, especially in color TV's. In one well-remembered case, the set had absolutely no vertical sync. Everything else worked beautifully, and the composite sync waveform at the sync-separator plate *looked* fine. After checking all the things that would normally cause this, the scope was used on the power-supply lines. You can see the result in Fig. 10: a high-amplitude, very sharp spike, 60 Hz, coming from the vertical output stage! This was getting into the sync-separator tube's dc plate supply, with exactly the right frequency and phase to literally "punch out" the vertical sync, leaving the horizontal sync untouched! A closer look at that composite-sync waveform showed that there was no vertical sync in it after all! Replacing one of the big electrolytics in the filter system cured it.

The backward feedback case

If you had a color TV, and you could see a small resistor between two sections of an electrolytic, burning up, you'd naturally suspect that the electrolytic on the load-side of the resistor was shorted, wouldn't you? Yet an ohmmeter check here showed a very high resistance—no short at all. Replacing the resistor, it promptly burnt up again.

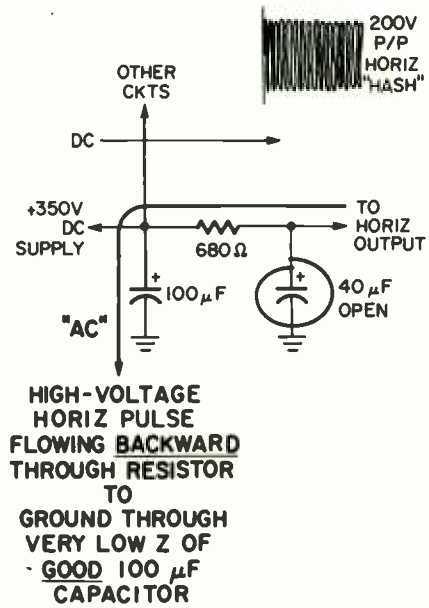


FIG. 11—OPEN OUTPUT ELECTROLYTIC makes impedance to ground very high. So pulses flow backward through resistor, burning it up. See text for details of this case.

The scope showed why. The circuit is in Fig. 11 (RCA CTC 35). When we put the scope on the load end of the resistor, we found a very high horizontal-frequency pulse voltage! The 40-μF section of the electrolytic was open. The only explanation I could find for the odd reaction was that the 100-μF electrolytic on the line side of the resistor was good. This offered a very low impedance to the high-frequency horizontal pulses. So they flowed backward through the little (680-ohm) resistor, actually overriding the 400 volts of B+, and made the resistor overheat and burn up. I do know this; when we replaced the capacitor and the resistor, it worked!

This is an excellent example of the type of reaction you can get when a big electrolytic capacitor opens. You'll find parts burning up, but there will be no direct short-circuit on the load side to account for it! In such cases, get out the scope and check for high-amplitude *pulses*.

Electrolytic coupling capacitors

In a great many solid-state circuits you'll find electrolytic capacitors used as

Part II—Faulty electrolytics can cause some weird effects. Here is the dope on some of them.

BY EUGENE CUNNINGHAM

A ONE-FARAD ELECTROLYTIC CAPACITOR provides a whopping amount of filtering and is a mighty handful that you can't expect to find in a transistor radio or recorder.

coupling capacitors. This is mostly in audio amplifiers, but you will run into them in TV circuits as well. These are very small, and tend to be low-voltage types.

Once again your scope is the best "weapon" to find the trouble. Coupling capacitors, especially, are easy. Just feed in a test signal, and look on both sides of the capacitor for the signal. If you have signals on the input, and none on the output, it's open.

When used in TV circuits, such as vertical oscillators, sync, agc, etc., you may find distortion on the output side of the capacitor. Check the waveforms shown on the schematic to see if this is normal. If you see signal clipping on the output, this could indicate excessive leakage through the capacitor, causing the transistor to be improperly biased and clipping.

Tantalum electrolytics

In the very small capacitors used in TV circuits, you may find some that are different. If they are very very small, they will probably be one of the newer type electrolytics, made of tantalum. They are generally found in circuits such as TV vertical oscillators, etc., or any application where the actual capacitance of the electrolytic must be held to tight tolerances. If one of these is defective, replace it with an exact duplicate. If the capacitor is used in a "timing circuit" like a sweep oscillator, actual capacitance is important. (Some of these things can be confused with silicon diodes, they are so small!)

Replacing electrolytics

For some reason, a lot of men have trouble replacing electrolytic capacitors! There is absolutely no reason for it. An electrolytic capacitor of any kind is about the easiest part to find replacements for! (Aside from the critical tantalum types just mentioned). A lot of technicians will complain "I can't find an exact duplicate for this ________" (multiple-section electrolytic).

The reason for this can be summed up in one word—tolerance. There is no part in a set which has a greater tolerance than an electrolytic capacitor! When we're looking for a replacement for any multiple-unit capacitor, we need only two things: One, a **minimum capacitance** (which is the value given for the original unit) and a **minimum voltage rating** (the working voltage of the original). **If our proposed replacement meets or exceeds both of these ratings, we have a suitable replacement.**

Electrolytic capacitors for filtering and bypassing are made with very wide tolerance. This is a one-way tolerance, however. Check the fine print on any new replacement electrolytic in your stock and you may see figures like this: +150%/-10%! If this is a 100-μF capacitor, it means that it can be as high as 250 μF or as low as 90 μF and still be in the ballpark!

Why so dag-bone liberal with us? Because. What do we need for filtering purposes? Enough capacitance to get the dc power supply lines down to the desired "zero impedance". So it doesn't make any difference if the capacitor is *bigger* than the original, but it shouldn't be smaller. (Reason for this: the engineer that designed the set probably used the very least amount of capacitance he could get by with! When we make replacements, we are under no such restrictions!) Of course, we must equal or exceed the working-voltage rating of the original. If it was a 300-volt unit, we can use a 450-volt unit.

We can sum up the whole bit in three words; **Always Go Up.** After observing this rule, all you need to do is be sure that your proposed replacement has the same mounting as the original. This applies only to the "twist-lug" mounting; these can have either 3 or 4 lugs, and it's best to match, although you can always use the mounting plate supplied with the replacement. If the capacitor is an insulated-can tubular type, it can be clamped to the apron of the chassis.

To select a suitable replacement for any multiple unit, look through the catalogs of the makers. There's a trick you can use here: if the original had three big capacitors at a high working voltage and one low-voltage section, you can use a 3-section high voltage unit, and replace the low-voltage section with a separate tubular type. These are so small that they can be tucked away anywhere in the chassis.

There's only one definite no-no in replacing electrolytics. If you find one section of a multiple bad, always replace the whole unit. **Do not** disconnect one section and hook a tubular across it! Worse than this, **do not** simply bridge a separate unit across the open original and leave it in circuit! Whatever happened to one section of the original to make it go bad is still in there, and it may affect the remaining good sections. So take it out completely.

Electrolytics in solid state

If you're on my side of the generation gap, the sheer size of some of the electrolytic capacitors you find in modern solid-state power supplies will amaze you. You'll find tremendous values in very small cans. I remember hearing a radio engineer give a talk, when I was a boy (and that's a while back!). He was describing a radio he'd built for his own use. He said proudly "And, do you know, I've got over 2,000-μF in it!" We all gasped, of course. At that time, the average total capacitance in a set was about 8-μF.

Not too long ago, I worked on a big transistor amplifier. The output filter capacitor alone was 8,500 μF. (Two units, 4,250-μF each). This one capacitor had more capacitance than a thousand radios, "back in the good old days." Wheeee! **R-E**

HARD-CORE SERVICING

If 8-track auto tape players drive you up a wall don't miss Joe Carr's article in the April issue. There's a complete set of case histories of actual repair jobs.

Incorrect Use Of Semiconductors

Many semiconductors can be used for purposes other than those the manufacturer expects them to be used for—and in many cases, they can be used very satisfactorily in such applications. Some of these "incorrect" uses are popular—others are rather obscure, but still very useful. Some odd uses are almost necessary, since other devices to accomplish the desired purpose are either not available or are too expensive for general use.

But some of these applications are not recommended by the manufacturer, either because he sells other devices better suited to the task, or because the application may be unreliable or may even damage the device. But let's take a look at these applications; many are very useful to the engineer, technician or home experimenter in his design, construction and repair work.

by PAUL FRANSON

Use semiconductors wrong?

We must distinguish between serious and truly useful odd applications, and interesting but often impractical tricks. For example, the technique of using a forward-biased diode as a voltage reference is well known, valuable, and widely applied. But using a conventional diode or transistor as a photocell is of little practical use, even though it's a good item with which to impress unsophisticated newcomers.

Why then, do experimenters and sometimes manufacturers use transistors as diodes, for example? Why not just use a diode instead?

There are a number of reasons why this technique is useful. One is that it simplifies stock requirements, and can reduce prices through quantity purchases. One bin full of a popular plastic-encapsulated silicon transistor such as the 2N3903, for example, can provide not only audio, dc and rf amplifiers and switches, but also high-frequency small-signal diodes, Zener diodes, low-temperature-coefficient voltage references, tuning varactors, and even noise generator diodes! And in many cases, these devices have excellent characteristics, which a designer can learn thoroughly and exploit often. Many pieces of equipment manufactured by relatively small companies contain parts used for this reason.

And not only are the parts cheaper because of the price breaks. A plastic transistor can be bought new in single quantity for 21¢ (2N5172 or MPS5172). Even the cheapest varactors and Zener diodes are considerably more expensive.

Some parts are more readily available than others, too. Plastic transistors with known characteristics are available everywhere; more exotic parts are not. This often makes emergency repairs possible in remote areas of the USA, or abroad, and at inconvenient times. It can also permit immediate building of interesting projects without the long wait and hassle of ordering "special parts" (anything other than a TV repair component, that is). It is also possible to obtain superior, or at least different, characteristics, by using parts in this manner. For example, constant-current diodes are available for currents from about 0.22 to 5 milliamperes. But it is possible to select a conventional FET to give higher or lower currents (and an FET can cost less than fifty cents, while a constant-current diode is more like $4.50).

There are often disadvantages to using components in unconventional ways. When you buy a 6.2-volt, ±5% Zener, you pretty well know what you have (if you use it at the correct current and temperature). But a transistor emitter-base junction used as a Zener might have a value of 5 volts, or it might be 8 volts. Only checking will tell. And its knee or noise characteristics might not be as good as those of a Zener specified and tested for these characteristics.

With these considerations behind us, let's look at some "incorrect" uses to see if they might be useful to you.

Diodes as voltage references

The usual definition of a perfect diode is a device with zero impedance in the forward direction, and infinite impedance in the reverse direction. No practical diodes meet these criteria, of course, and the variations from the ideal provide interesting and valuable applications.

A forward-biased silicon diode has a voltage drop of about 0.7 volt at moderate currents (Fig. 1) and a germanium diode has a similar drop of about 0.3 volt. This property can be exceedingly valuable.

Zener diodes make good references at voltages above 3, but aren't really useful for much lower voltages. But forward-biased diodes provide reasonably good references as low as 0.3 volt, and combinations of diodes can provide many intermediate voltages. As an example, Fig. 2 shows a replacement for the one battery, a flashlight cell, used in many otherwise line-operated voltohmmeters. The two diodes in series provide 1.4 volts, about the same voltage as a new cell.

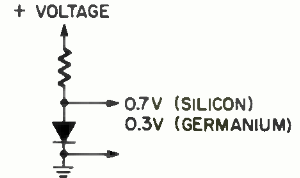


FIG. 1—FORWARD VOLTAGE of germanium or silicon diode makes a low-voltage reference.

The ZERO ADJUST potentiometer can compensate for any slight variation.

The major problem with forward-biased diodes as references is that they really aren't very good references. Though it's considerably better than that across a resistor, the voltage across a diode does vary with current

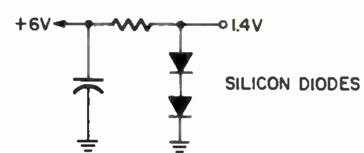


FIG. 2—SIMPLE REPLACEMENT for the 1.5-volt flashlight cell used in an ohmmeter.

(Fig. 3), so the current should be kept relatively constant (unless the varying voltage is useful, as it is in some types of compensating circuits).

Conventional silicon diodes can also be used as voltage regulators, or Zeners, by connecting them as a conventional regulator (Figure 4). Here the regulating voltage is the diode's breakdown voltage, which will be above the diode's rated PIV. For example, a good diode with a PIV rating of 50 volts will have a breakdown above 50 volts. How high above is the question, and it can be found only by trying it out as shown. Be sure to limit the power dissipated by the diode to a reasonable value, say 200 milliwatts for glass diodes, 500 milliwatts for 1-ampere rectifiers. Unfortunately, the regulating characteristics

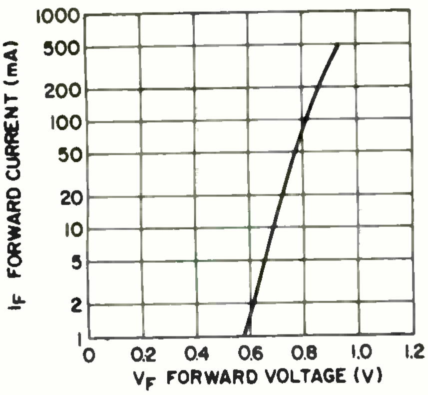


FIG. 3—FORWARD VOLTAGE MEASURED against current for the 1N695 silicon rectifier.

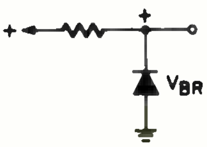


FIG. 4—CONVENTIONAL DIODE becomes a substitute for a high-voltage Zener diode.

of many diodes aren't too great, but this scheme is useful in some applications.

Temperature compensation

Another valuable property of the nonideal silicon diodes we use is that the forward voltage drop depends on temperature in a most useful way. For a constant current, the voltage drops 2.2 millivolts for each degree Celsius (centigrade) in temperature. Thus, it has a *negative TC* (temperature coefficient).

Conveniently enough, conventional regulator (Zener) diodes with breakdown voltages over about 5 or 6 volts have *positive* temperature coefficients. An example is the 1N5236, a 7.5-volt Zener with a TC of +4.5 millivolts/degree. As shown in Fig. 5, two forward-biased silicon diodes in series with this reverse-biased Zener provide a composite temperature coefficient of only [+4.5 + 2(-2.2)] or 0.1 millivolt/degree. This very respectable characteristic would be useful for regulating a vfo, for example. But don't forget to keep the current almost constant!

Of course, since the three diodes

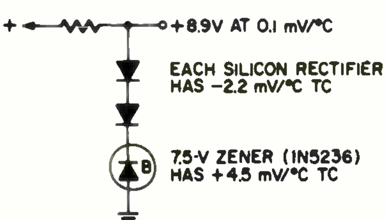


FIG. 5—TEMPERATURE COMPENSATION with two forward-biased silicons and one Zener.

are in series, the resulting reference voltage is above the Zener voltage. It is [7.5 + 2(0.7)] or 8.9 volts, close to the 9-volt standard of many designs.

The diode as a thermistor

The same temperature coefficient makes a silicon diode an excellent "thermistor." This property is widely used in compensating power amplifiers to reduce distortion and prevent thermal runaway with high power output.

The temperature coefficient is also valuable in electronic thermometers for remote temperature readings. A bridge circuit should be used for best results.

Another property of diodes that is possibly useful in thermometers or temperature compensation is the reverse leakage current, which typically doubles for each 10° C rise in temperature. This phenomenon is probably not as useful as the forward-voltage change.

The diode as photosensor

It's long been known that semiconductors are light-sensitive. This property has proved valuable in photodiodes and phototransistors. The same effect caused mysterious circuit malfunctions when germanium and silicon diodes were first used. Circuits would operate properly when sealed in their cases, but act peculiar when opened for servicing. The cause, as you might expect, was that light reaching the semiconductor junction changed its characteristics. Manufacturers soon learned to coat the devices with opaque paint or seal them in black plastic or metal instead of clear plastic or glass.

What this is leading up to is that painted glass diodes can be used as photodiodes by scraping off the paint. As you might expect, the device may be a good photodiode or it may be a poor one, depending on its construction. Consequently, this use, unlike the preceding ones, must be considered more a gimmick than a serious application.

Unusual uses for the Zener

The regulator diode is usually called a Zener, even though, strictly speaking, only diodes with breakdown voltages under about 6 volts are Zeners. Others are *avalanche regulators*. They have many conventional uses, and a few unusual ones as well. For example, since a Zener can be thought of as simply a conventional diode with known breakdown characteristics, it can be used much like any other diode below its breakdown voltage. An obvious example would be forward biased as temperature compensation for another Zener (but this scheme is likely to appeal most to those possessing an unusually bountiful supply of Zeners).

The Zener as noise source

More practically, Zener diodes often make excellent white-noise sources. White noise, the rushing sound evenly distributed across the spectrum, is very useful in electronic musical instruments and in test instruments. It can also mask other noises, a use that may prove a godsend in small apartments with thin walls.

A Zener generates white noise when it is reverse biased, the way Zeners are normally used. This can be a nuisance in most circuits, since the noise must be filtered out. Fortunately, however, the greatest noise appears when the diode voltage is sitting right on the knee, where the Zener is normally not operated. It's easy to encourage operation on the knee, however, for maximum noise. Simply use a large series resistor to insure low current flow. The circuit is shown in Fig. 6. It's easiest to adjust while

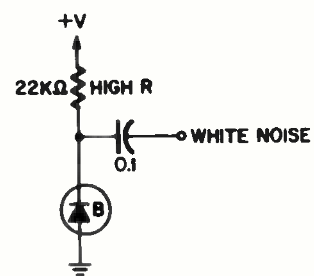


FIG. 6—WHITE NOISE SOURCE from Zener.

looking at the output on an oscilloscope or while listening to it with an amplifier or headphones.

The Zener as a varactor

Voltage-variable-capacitance (vvc) diodes, otherwise known as tuning diodes, varactors, Epicaps or Varicaps, are popular in afc circuits, and in automatic and manual tuning of radios and TV sets. Most vvc's have relatively low capacitance—say under 100 picofarads—as is desirable in the application they are intended for. But if you need a high-capacitance vvc, say over 500 pF, the conventional vvc isn't much help. Here again the Zener is useful. For example, the 3.9-volt 1N5228 typically has a capacitance of 700 pF at 3.8 volts (just before breakdown). A problem here is the small bias voltage necessary for the high capacitance. It limits the signal across the diode to less than half the value, which is inadequate for many applications.

Zener "capacitance" diodes also have relatively low Q and, often, insufficient capacitance ratio for many applications. In spite of this, Zeners as capacitance diodes should prove useful in some circuits.

Transistor applications

One of the great attractions of the transistor is that it is a three-terminal device, making it easy to control and to isolate its input from its output. The tunnel diode can amplify, oscillate and switch, much as a transistor can—even better in some cases—but it has only two terminals, making it difficult to use in many practical circuits.

Yet the transistor has many uses when it is treated as a two-terminal device (as a *diode*, in the common usage*). Since there are three terminals, there are three possible connections, and each can be reverse or forward biased. Oddly enough, all are useful, though some are considerably more so than others. Let's look at the devices, using the popular and inexpensive 2N3903 plastic-encapsulated npn silicon transistor as an example.

Diodes and varactors

A conventional transistor can be thought of as two back-to-back diodes, with a common anode (the base) for npn transistors, and common cathode for pnp. This is shown in Fig. 7. This

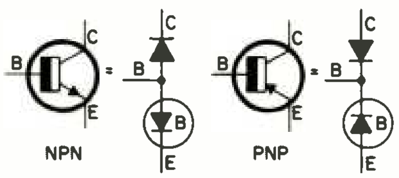


FIG. 7—TRANSISTOR DIODE equivalents reveal some interesting possible applications.

analogy is valid except for one case, the collector-emitter connection with collector positive (npn). More on that later.

The collector-base diode of a typical 2N3903 appears to be a conventional diode with a PIV of 40 volts, low leakage, and good high-frequency characteristics. As such, it can be used the same way a similar diode can be used, including taking advantage of the 0.7-volt forward drop when forward biased (base more positive).

In the reverse-biased mode, the C-B junction makes an excellent varactor (VVC), and one with fairly predictable characteristics, since C_{cb} (or C_{ob}) is usually specified on its data sheet, sometimes even in a curve (Fig. 8). This VVC generally has reasonably good high-frequency characteristics, but relatively low capacitance and tuning ratio, since it's not designed for this use.

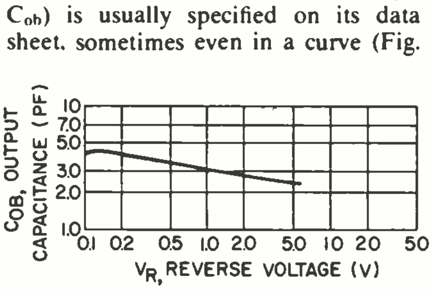


FIG. 8—TYPICAL C_{ob} curve of transistor.

A transistor Zener

The base-emitter diode of the 2N3903 and most other small silicon transistors looks like a Zener diode with a breakdown voltage in the 5 to 9-volt range. The voltage seems to be relatively consistent in a given device type, and can be measured easily, as outlined above. The voltage is always above the rated BV_{EBO} or V_{EB}. These "Zeners" often have excellent knees and are excellent regulators. Transistor Zeners can be used the same way as conventional Zeners within their power limitations (Fig. 9). For the 2N3903 type, the maximum dissipation is 310 milliwatts at 25°C ambient temperature.

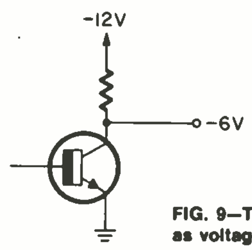


FIG. 9—TRANSISTOR as voltage reference.

This B-E diode proved especially useful to me at a small company where I worked. We produced a number of high-frequency (3 to 30 MHz) dual receivers for radio astronomy. The problem was to match the sensitivities of the receivers at a given frequency. We decided to do that with a wide-band noise source. A conventional diode was tried in a noise generator much like those popular with vhf experimenters, but the noise was inadequate. Then a Zener was tried, but it was erratic. Finally a cheap plastic transistor (a 2N4125) was used as a "Zener" noise generator with excellent results. It drew little current, operated to well above 100 megahertz, and produced plenty of smooth white noise; so much, in fact, that it had to be severely attenuated for use with the receivers, which have sensitivities under 0.25 μV.

Low TC reference

The final set of terminals of a transistor is the collector and emitter. Here two junctions are involved rather than one, as in the applications just discussed. If the terminals are connected with the collector negative with respect to the emitter, it is equivalent to a Zener (BE) in series with a forward-biased diode (BC). Remembering the discussion of temperature coefficients, we find that this means we have a low-temperature-coefficient reference, since the TC's of the "Zener" and diode are opposite. In fact, the two junctions are in such intimate contact that they track very well with temperature changes, better than separate devices ever could.

Latching-voltage oscillator

The final two-terminal use of a transistor cannot be explained in terms of series diodes. This is the collector-emitter connection with the collector positive. This, of course, is the way in which the most common device breakdown rating, BV_{CEO}, is specified. The BV_{CEO} is the maximum voltage that should be applied to a device under any circumstances. It doesn't tell what happens above this voltage, and there's probably no reason it should. However, some manufacturers specify LV_{CEO}, *latching* voltage, instead of BV_{CEO}. This is in recognition of an odd property of transistors: they latch into conduction under certain circumstances. If a planar transistor is connected as shown in Fig. 10, with enough limiting resistance to

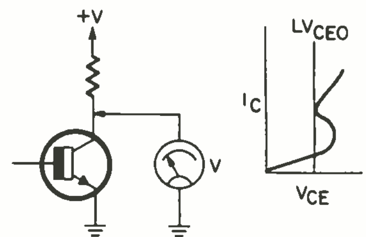


FIG. 10—LATCHING CHARACTERISTICS make relaxation oscillations a possibility.

prevent device damage, and the voltage is slowly increased above the rated BV_{CEO}, the voltmeter reading will rise, peak, then drop back to a stable state (as long as current is limited). If the voltage supply continues to increase, eventually the voltmeter indication will start to rise again, eventually excess current will flow, and the device will destroy itself.

This latching phenomenon can be used in a relaxation oscillator similar to one made with a neon bulb. Its circuit is shown in Fig. 11. The voltage rises as

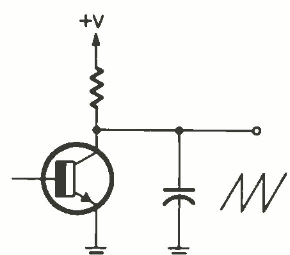


FIG. 11—A RELAXATION OSCILLATOR. An interesting but impractical application.

the capacitor charges, suddenly drops as the transistor conducts, then repeats its cycle. The same property is used in the so-called three-layer diode, or bilateral trigger, used in SCR and triac motor speed controls. It is a symmetrical transistor with similar characteristics in each polarity. Only two terminals are

*Another definition of a diode is a *single-junction* device. However, this includes unijunction transistors and excludes four-layer diodes. Confusing, no?

needed, hence the name.

The transistor relaxation oscillator is interesting, but not really too useful. Transistors aren't made to be used in this way, and tend to give up unless they are treated very carefully. This is one case when a device intended for the use is clearly preferable.

A double-diode

For low voltages (below the breakdown voltage of the emitter-base junction), the transistor simply looks like two back-to-back diodes, and can be so used in full-wave detectors and rectifiers or other circuits where no dc bias is applied. If it were, the transistor might act like a transistor.

The SCR as a 4LD

One of those interesting devices that never caught on is the four-layer diode (4LD), or Shockley diode (not Schottky diode; that's a hot-carrier diode). The 4LD is a voltage-controlled switch. It is off (doesn't conduct) until the voltage across it rises to a critical value (the breakover point;, then latches into conduction with only a small voltage drop (about 1 volt). The only way to switch the 4LD out of conduction is to reduce current through it to below the holding current, which is generally about 1 mA. This is usually done by breaking the circuit.

Four-layer diodes can be used in overload circuits and in other ways, but many experimenters hesitate to try them out because they are expensive (around $3.50). It turns out, however, that a silicon-controlled rectifier acts just like a four-layer diode if you ignore its gate. This is especially attractive because low-voltage SCR's, the best for use as 4LD's, are inexpensive.

The breakover voltage can be determined much as for a Zener voltage (Fig. 12). Simply increase the voltage

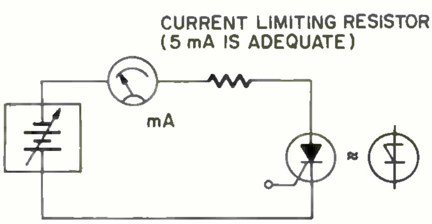


FIG. 12—SCR AS FOUR-LAYER DIODE. Gate of silicon-controlled rectifier is open.

across a 4LD (through a current-limiting resistor) until current starts flowing. Then the supply voltage is equal to the 4LD breakover voltage if the supply is relatively stiff.

Constant-current diodes

Zener diodes, which provide a constant voltage with changes in load current, are exceedingly useful and justifiably popular. Their dual is the current-regulating diode (CRD), which provides a constant current with changes in input

FIG. 13—CONSTANT-CURRENT DIODE, the opposite number to the well known Zener.

voltage or load resistance. The symbol for the CRD is shown in Fig. 13.

A constant-current diode is useful in supplying a constant current to a Zener reference, and in other parts of a power supply. It can also be used as a current source in a differential amplifier and in sawtooth-wave generators. One especially interesting application is an ohmmeter with an uncrowded, linear scale. Its schematic is shown in Fig. 14.

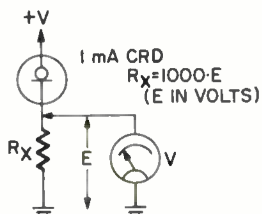


FIG. 14—LINEAR SCALE OHMMETER uses a constant-current diode and a voltmeter.

If a 1-mA CRD is placed in series with a voltage source and an unknown resistor, the voltage across the resistor will be equal to the resistance times the current (1 mA, or 0.001 ampere). Thus the resistance in ohms will be 1000 times the voltage. Maximum resistance will be limited by the rated operating voltage of the CRD, typically 100.

If you use this circuit, be sure to disconnect the voltmeter when changing resistors. Also start all measurements with the meter range switch above 100 volts to avoid meter damage.

There are many other uses for the CRD, but so far it hasn't found widespread use, as the Zener has. As a consequence, prices are still high ($4.50 apiece) and the current range available is limited, about 0.22 to 4.7 mA. Fortunately, an inexpensive field-effect transistor can be used instead. In fact, the CRD is nothing but an FET with an internal connection between the gate and the source. We can therefore make a CRD by simply shorting the two terminals externally (Fig. 15). This FET

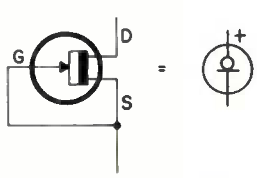


FIG. 15—FIELD EFFECT TRANSISTOR becomes a CCD by shorting its gate to source.

now acts like a CRD with its drain the positive terminal and the source/gate the negative terminal. The regulating current of the device, the I_P, is then equal to the I_{DSS} (zero-voltage drain current) of the FET. The I_{DSS} can be found in the device specifications. Normally, a range is provided, such as 2 to 8 mA, and it is necessary to select an FET if a specific value is needed. The selection can be made by connecting the FET/CRD in series with a voltage supply and a milliammeter. This selection process explains part of the cost of a CRD; you may have to try quite a few to find the right value.

If an adjustable current source is needed, a FET can also be used. Simply place a resistor between the gate and source (Fig. 16). The combination acts

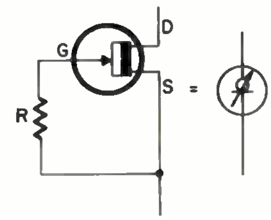


FIG. 16—ADJUSTABLE CCD can be made by FET with a resistance between gate and source.

like a variable CRD that can provide current values below the I_{dss}.

Conclusion

This article has discussed a number of semiconductor components that can be used in unusual ways. Many of the applications are very valuable. But take care that device ratings are not exceeded by the unconventional applications! And, if parameters are critical, a device specified for the use may be better. **R-E**

The service technician will be here tomorrow. Meantime he recommends you keep the shaking, kicking and pounding on the set to a minimum.

R-E's Service Clinic

diagnosis and the methods thereof

The first step in any repair job is to analyze the fault

JACK DARR
SERVICE EDITOR

LET US NOW TAKE A SHORT RIDE ON my favorite hobby-horse—diagnosis, and how she is did. At any moment now, someone will jump up and yell "But you said that a while ago!". True, I did. And I'll keep on saying it until you (and I) can remember it. In any job, the *diagnosis* is the most important part.

Frankly, the mass of the mail I get in the Service Clinic is from men who have problems in diagnosis. (To be embarrassingly truthful, most of the times I get stuck on a problem in the Test Lab, it's from the same cause!) So let's see if we can simplify the basic approach. If we use the scientific method, we'll get better results.

This is really simple. The first thing to do is "State the problem". There are two steps to this—Examination and Identification. In other words, turn the thing on and see just what it is doing or not doing. From the results of this, we get our first bit of data. This tells us what section of the set to look into. When we find that we have a certain problem, as shown by the symptoms, then we go to the final step. This is Elimination, and it's the longest one.

As we all know too well, there is no such thing as a problem in electronic equipment with only one possible cause! There may be one somewhere, but I haven't found it. So, the answer to our question "What's causing . . . . . .?" is *always a multiple choice!* We must check out all possible answers, to be sure.

There's your Basic Method. Take the first two steps, identify the nature and probable location of the fault. Then make out a mental list of the circuits, parts, etc. that could cause it. Now, we patiently, calmly and impartially test each one of these. Somewhere along the line, we'll find the one we're looking for. Notice the last word in there—"Impartially".

That's the key word! The most valuable asset we can have during diagnosis is a completely *Open Mind.* We know that there is a faulty part in there somewhere—what difference does it make which one it is? None at all.

However, here is one of the most troublesome things that can happen to you. (It is also one of the most common, as I can testify from years of doing it!) It's surprising how contrary the human mind can be. In far too many instances, we make up our mind that a certain thing is causing the trouble. Then, we make tests, not to locate the real cause, but to verify our first guess! (And at this point, without much data, that's all it is—a guess!)

We have become *partial* to a certain answer, not impartial. This ruins our scientific objective approach to the whole problem. So when you run into a problem, the first thing to do is "cool it". Sit there and look at it, and note what it is actually doing.

From this point, you make up that list of possible causes. Then, you slowly, carefully and methodically check them out until you find the bad part. This list *must* be based on a thorough knowledge of how the circuit works. If you do NOT have this, let the thing alone until you can dig out a book and read up on it. Sitting there and "poking at it" with a voltmeter will get you nowhere fast!

I've seen this happen. In fact, I do it myself far too often. When I work out a job in the Test Lab, I make detailed notes of every test made, the reason for it, and the results. When I run into troubles, I can always go back over the notes and see where I went wrong. In every case, I find that somewhere in there I "froze" on a mistaken diagnosis, and then started looking for evidence to "make me be right," instead of really trying to find out what was wrong.

You can try it yourself. Get a clipboard and some paper, and start writing down each step you take, and the reasons, and the results. Even if it does nothing but keep you from repeating yourself, it's worth while. Don't overlook the simple things, either. (I worked on a very "complicated problem" for at least an hour, only to find out that the reason I had no signal-output from the stage was due to zero screen-grid voltage on the tube!)

There's one more common problem; the complaint that "I've checked everything in that circuit and it still doesn't work!" There are two possible answers; One, you *haven't checked everything*, and Two: the trouble isn't in that circuit at all! Go and look for things which could *affect* this circuit. Example: all dc voltages, the tubes, ca-

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

If you're really stuck, write us. We'll do our best to help you. Don't forget to enclose a stamped, self-addressed envelope. Write: Service Editor, Radio-Electronics, 200 Park Ave. South, New York 10003.

pacitors, transformers, are ok in a band-pass amplifier, but you can't get a color signal through it. The trouble turns out to be a high negative voltage on the grid, cutting the tube off; the color-killer is the section at fault!

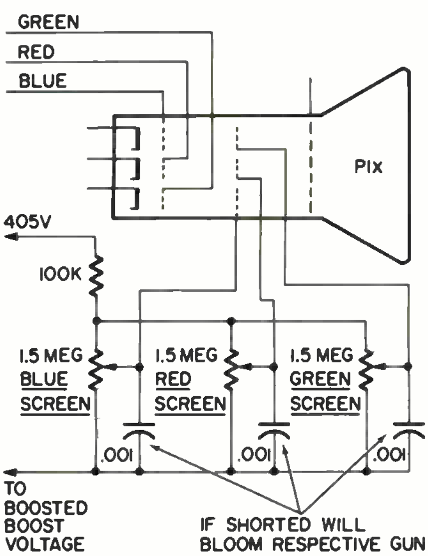
Other problems can have much more "complex answers", but this just means that our list of "possibles" is that much longer. For a good example, there are a great many things that could cause the cathode current of a horizontal output tube in a color set to run far above normal. All you have to do is make your little list and patiently eliminate them one at a time, and you'll find it. Just for fun, take a piece of paper, and make out this list. Then, look at it, and see how many actual cases you can remember where something *you have left out* was causing it! When you get through, pin the list up over your bench. **R-E**

Reader Questions

RED BLOOM; NO FOCUS?

I can't get good focus in a Sylvania DO-9 chassis, even with the core of the focus coil all the way out. However, it seems that the blue and green focus pretty well, but the red doesn't. Checking with a magnifying glass shows that the red dots are much bigger than the others.

The focus voltage on pin 9 varies from 4,000 to 5,000 volts, with hv of 25 kV. Grid and cathode voltages on the pix tube look ok; about equal on all guns. Does this look like a bad picture tube?—J.A., Dallas, Tex.



Not necessarily. There are a couple of things which can cause this symptom. Doublecheck; turn off the red screen and see if there are clear scanning-lines on the blue-green raster, or either one by itself. Then recheck the red raster all by itself. If you can't see the scanning lines now, then you *do* have a red bloom problem in this color set.

Sylvania's "Troubleshooting schematic", a part of which is shown in the diagram. Shows one possible cause for a single-color bloom; a shorted bypass capacitor across its screen control. If the capacitor were only leaky, it might account for the slight bloom you have on the red.

I *think* your focus-voltage variation, with the hv you have, is normal. Focus voltage should be about 20% of the existing hv. The 5,000-volt maximum you can reach should be enough to get good focus with 25 kV of hv. If you can focus *any one* raster, of course, then the focus voltage itself is ok.

BAD TRANSISTORS

I'm trying to fix a KRACO Stereo tape player. Do you have a schematic for this, or know where I can get one? It has two blown 2SB487 transistors (power outputs) and I can't find them listed either! What is a replacement?—T.K., Ohio.

Sorry; nothing at all in my files on "KRACO". You have an orphan. However, I did eventually locate a listing on a 2SB481 transistor, which is the same as the 2SB487. HEP-642 Motorola, RCA SK-3052, GE-30, or Sylvania ECG-131. Be sure to check the little emitter resistors, which will probably be about 1.0 ohm each. If the original transistors shorted, these probably burnt up.

(continued on page 68)

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READER QUESTIONS
(continued from page 63)

HORIZONTAL INSTABILITY

The horizontal oscillator in this Zenith 25MC33 chassis is very unstable. Horizontal hold range is very small. Blanking bar sometimes locks in the center of the screen. I hear a frying in the flyback, at times. Vertical sync very good.—J.B., Elmhurst, N.Y.

Short out the afc. If this lets the horizontal oscillator run on-frequency (that is, make a single, floating picture) the oscillator itself is ok. Since you have good vertical sync, this shouldn't be in the sync-separator.

So, the most likely cause here would be a defective dual-diode in the horizontal afc. Try a new one; this is the quickest way.

HORIZONTAL SHRINKAGE

I've got a peculiar problem! One of my best customers brought in a little Emerson transistor portable TV, a 120771 chassis. It's got a "thermal shrink" of the raster, just like a weak horizontal output tube! The only trouble is, no tube! All solid-state!

This is the one which uses a GTO (Gate-Turn Off) horizontal output device. About 15 minutes after it's turned on, the raster shrinks in about an inch from each side. I've read the current to the GTO, and it's quite a bit high. In other words, the thing is taking too much current, but the narrow raster shows that the yoke isn't getting enough current. I'm baffled! What the heck is this?—S.P., New York.

If your drive signal shows ok, and voltages, etc are up to normal in the first few minutes of operation, I believe you'll find that this is due to a *leaky* GTO Gate Turnoff Switch. Due to the circuit connection, this is effectively in shunt with the yoke. So, you're trying to draw normal yoke current, plus the leakage current, and you wind up with a narrow raster.

The Exact replacement for this is an Emerson Part No. 815157. However, a good high-voltage, high-current silicon power transistor, in a TO-3 case, will replace it! (A power transistor, after all IS a "turn-off switch".) Delco DS-502 or Motorola HEP-740 can be used as replacements; check the current to make sure. 680 MA is normal.

SAFETY PRECAUTIONS CRACKED PIX TUBE

I have an odd problem. This 21-inch color tube has arced, apparently between the 2nd anode and the degaussing-coil shield. It cracked the bell of the tube! (The customer says he fell asleep while watching it, so he doesn't know how long the arcing went on.) Anyhow, now the thing has a crack all around the 2nd anode button, 6" in diameter, but it seems to still have vacuum!

I'm afraid to take it out, for fear that it will implode and wreck the chassis. How can I release the vacuum to play safe? Tube has no dud value.—J.M. Orlando, Fla.

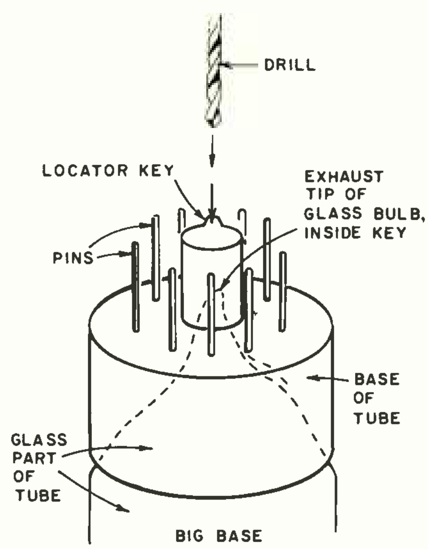


Fig. 1

You're right; play it safe! Try this: take the back off the set, and lay it face-down on a cushion. Now, get an old quilt, and pack it inside the cabinet, all around the bell of the tube. Leave the neck sticking out, but wrap the quilt up around it pretty well, tying with string if necessary. Now, carefully take the pix tube socket off.

If this is one of the "big-base" round tubes, carefully drill a ⅛ inch hole right through the center of the locator key on the base (Fig. 1). This will hit the exhaust tip of the bulb, and you'll hear a loud hisssss when it breaks. This will let air in slowly and the tube will then be safe.

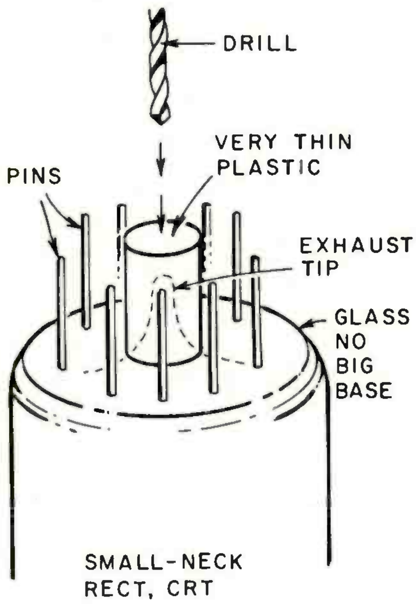


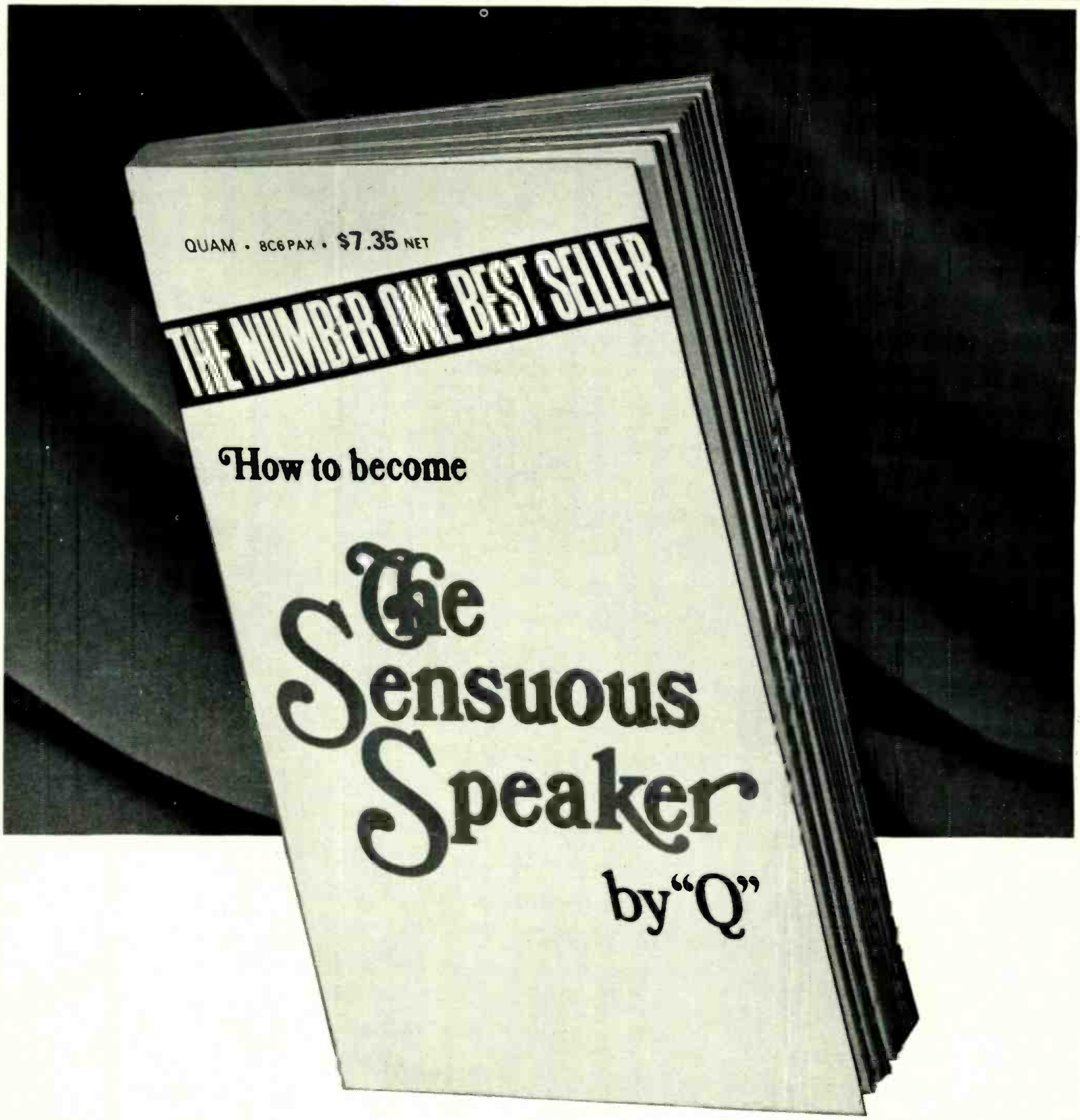
Fig. 2

If it's one of the new rectangulars, with the small base, you can crush the locator pin with a pair of gas pliers. This is very thin plastic. The chances are that you'll break the exhaust tip when you do this. If not, you'll be able to see it, and you can snap it off with the pliers. Fig. 2 shows how it looks. You might not have much vacuum left, but it never hurts to play it safe.

RECORDING DISTORTION

I've got two little Motorola GP-20GW cassette tape-recorders with the same problem. They play back perfectly, but they record with a terrific distortion. The sound comes through, but there's a low-frequency hum or buzz recorded with it! I've tried two or three different mikes, and tried to check the bias, but no luck. What is this?—J.G., Mena, Ark.

Keep on trying mikes! You haven't got the right one yet! Suggestion; get the original microphone, and try it. If you try to use this particular machine with a very high-impedance mike, such as a ceramic crystal, etc., it will oscillate! This is causing the distortion. (No bias on this unit; it uses dc bias for record and erase!) Original mike is a low-impedance dynamic. **R-E**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DIGITAL CLOCK, *AMG.* Available in 12- and 24-hour models, these solid-state clocks use bright red neon readouts rated

200,000 hours life (22+ years). Instrumentation quality TTL logic components include 15 IC's, 4 transistors, 7 diodes, fiberglass printed circuit boards. Built-in, rechargeable battery "holds" time in the circuit during power line failures of up to five minutes. The 24-hour clock has a bright red neon light, flashing for 30 seconds every ten minutes as a Station-Ident call reminder for hams. Disable switch provided. 12-hour clock, $93.00; 24-hour clock, $99.00.—**AeroMetric General, Inc.,** 155 Franklin St., Dayton, Ohio 45402.

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DIGITAL LAMP CLOCK, *model #770.* This *Colorama Tele-Vision* clock comes in the "new" colors, avocado, poppy, charcoal brown and white. Big numerals, comforting dual lighting, plastic case, height 4-¼ in., width 7 in., depth 3-¾ in., weight 3 lbs. Self-starting electric, 110-120 V, 60

Hz. $17.00.—**Pennwood Numechron Co., Tymeter Electronics,** 7249 Frankstown Ave., Pittsburgh, Pa. 15208.

Circle 32 on reader service card

DOLBY NOISE REDUCTION UNITS, *models AN-180, AN-80, and AN-50.* Three different Dolby system noise reduction units designed for recording applications. The *AN-180* is a simultaneous record-playback control center with microphone and line

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preamplifiers and the Dolby recording and playback circuitry. The *AN-80* has all features of the first model, but input mixing is omitted and only one Dolby circuit is available for each channel instead of two. Does not record and playback at the same time. The *AN-50* is more compact than the *AN-80* but has essentially the same performance. It is intended for use with cassette equipment. *AN-180* is $289.50; *AN-80* is $129.50; and the *AN-50* is $49.50.—**TEAC Corp. of America,** 2000 Colorado Ave., Santa Monica, Calif. 90404.

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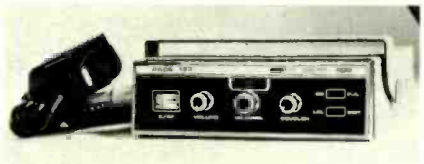
TWO-WAY RADIO, *model = 123.* 23 channel Citizens Band two-way radio operates from positive or negative voltage source, has both transmit and receive indicator lights to guide nighttime operation, a precision meter in front panel to give relative signal strength of incoming signals and indicate modulation output. Double-conversion receiver with a series gate noise limiter; a local/distance function enables the operator to use the full designated sensitivity of 0.4-µV when operating away from city and auto rf noises. $129.95.—**Pace Communications, div. Pathcom, Inc.,** 24049 South Frampton Ave., Harbor City, Calif. 90710.



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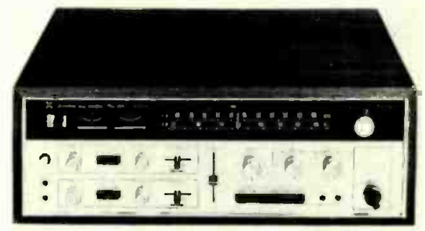
AM/FM RECEIVER, *model QR6500.* Combines receiver with synthesizer for converting standard two-channel stereo sources to four; a decoder for reproducing all compatibly encoded matrixed 4-channel sources; facilities for handling discrete 4-channel sources, such as open-reel and cartridge tapes; and complete set of controls and accessory circuits for all modes and functions. Includes four power-output amplifiers. Amplifier section delivers 280 watts IHF music power (50 watts of continuous power at 4 ohms in each channel, 37 watts at 8 ohms). Frequency response is 20 to 30,000 Hz ±1 dB and distortion at rated output less than 0.5%, either intermodulation or total harmonic. $679.95.—**Sansui Electronics Corp.,** 32-17-61st St., Woodside, N.Y. 11377.



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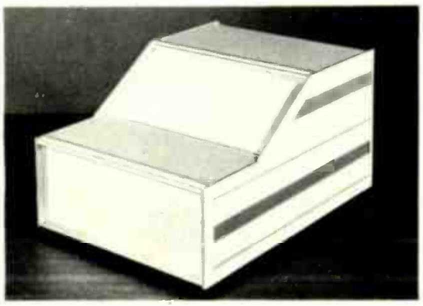
TRANSFER TUNER SPRAY KIT, *Slim-Jim.* Smaller size and shape for service calls, fits conveniently in a shirt pocket or service caddy. The *Slim-Jim* is designed to be refillable. Buy economy, bench-size cans of electronic chemicals and use to refill the *Slim-Jim* which operates in a

Circle 62 on reader service card

piggy-back fashion, takes 30 seconds, and fills completely to service six to ten tuners each time, depending on how dirty the tuners are. Kits are available with two bench-size cans of *Tun-O-Wash, Kit #1;* *Tun-O-Wash and Tun-O-Brite, Kit #;* or *Tun-O-Wash and Tun-O-Foam, Kit #3.* Each kit also has two *Slim-Jim* size cans ready to be filled. *Kit #1* is $6.98; *Kit #2* is $8.24; *Kit #3* is $8.24.—**Chemtronics, Inc.**, 1260 Ralph Ave., B'klyn., N.Y. 11236.

Circle 36 on reader service card

INSTRUMENT CASE, *Slant-Front,* is used primarily with a mounted keyboard and is a variation of a standard case from off-the-shelf components. Concealed fastenings are used to assemble this aluminum case accented with glare-free, suede-type color finishes of your choice, on the top, bottom,



and side feature strips. Standard 8-¾ in. height with width and depth infinitely variable, determined only by individual specifications. Special chassis fabrication, silk screening and piercing for control panels or keyboards are available.—**Buckeye Stamping Co.**, 555 Marion Road, Columbus, Ohio 43207.

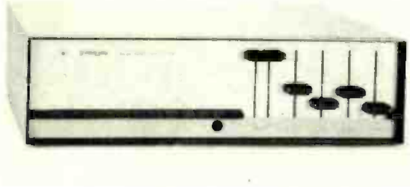
Circle 37 on reader service card

COLOR PICTURE TUBE BRIGHTENER, *model W27,* for 90°color picture tubes. Parallel isolation repairs heater cathode shorts. Original 6.3-volt heater supply is

boosted to 8.5 volts to brighten picture and extend useful picture tube life. $11.50.—**Workman Electronic Products Inc.**, Box 3828, Sarasota, Fla. 33578.

Circle 38 on reader service card

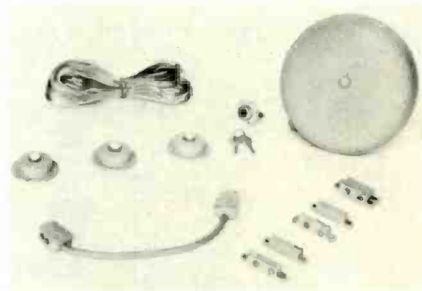
STEREO CONTROL UNIT, *Radford SC-24,* is a transistor stereophonic pre-amplifier control unit that may be used with any power amplifier. Mains input 110V, 120V, 130V, 220V, 230V, 240V, 50-60 Hz. Dis-



tortion less than 0.01% at 1V rms output level. Suitable for shelf mounting. $345.00.—**Audionics, Inc.**, 8600 N.E. Sandy Blvd., Portland, Ore. 97220.

Circle 39 on reader service card

BURGLAR-FIRE ALARM SYSTEM, *the Watchdog Too.* Do-it-yourself system comes complete with an eight inch diameter bell that delivers loud, sharp warning



signals when activated by solid state control circuitry; three sets of foolproof UL approved weatherproof switches; three UL

Circle 63 on reader service card

Circle 64 on reader service card

approved fire sensors; on-off key switch; door cord; 100 feet of plastic-coated wire; mounting hardware; outside entrance decals; clearly illustrated installation drawings. Designed for small business or homeowner, for offices, service stations, boats, mobile homes, etc., the *Watch-guard Too* operates on a single 12 volt dc battery. $59.95. Catalog available for 25¢.—**Crime Detection Systems, Inc.,** P.O. Box 790, Pearland, Texas, 77581.

Circle 40 on reader service card

STEREO AMPLIFIER, *model D-150.* This dual-channel stereo amplifier has these specifications: 150 watts rms both channels at rated distortion with 8-ohm speakers (typically 100 watts per channel at 8

ohms, 180 watts per channel at 4 ohms); frequency response ±0.1 dB, 20 to 20,000 Hz at 1 watt; distortion IM less than 0.05%, 0.01 watt to 75 watts, harmonic less than 0.05% at 75 watts; separation better than 90 dB, 20 to 20,000 Hz. $399 without panel, $429 with panel; (walnut cabinet $33.00).—**Crown International,** Box 1000, Elkhart, Indiana 46514. **R-E**

Circle 41 on reader service card

new lit

All booklets, catalogs, charts, data sheets and other literature listed here with a Reader Service number are free for the asking. Turn to the Reader Service card on page 103 and circle the numbers of the items you want. Then mail the postage-paid card.

ELECTRONIC PROJECTS CATALOG, *No. 800/13, 1972.* More than 350 do-it-yourself projects described, including color TV, electronic organs, ham radio gear, service and test instruments, kitchen appliances, table-top road racing layout, modular electronic workshops for youngsters, AM/FM/FM-Stereo receiver, garbage compactor, microwave oven, remote control garage door openers, intercom systems, digital depth sounder, automotive equipment, oscilloscope. Fully illustrated.—**Heath Co.,** Benton Harbor, Mich. 49022.

Circle 100 on reader service card

ITU FREQUENCY LISTS, *6th Edition, 1971.* Frequency lists and callbooks published by the International Telecommunications Union, the world-wide treaty registration center for all radio stations and frequencies. Computerized lists of the hundreds of thousands of radio stations are updated quarterly. Typical lists and prices are: *List of Ship Stations,* $5.25; *List of Coast Stations,* $6.60; *List of Fixed Stations,* $22.00; *List of Broadcasting Stations Operating Below 5950 kHz,* $11.50; *Alphabetical List of Call Signs,* $7.70. The *ITU Frequency List* itself, with every radio station, emission, power, antenna pattern, termination, hours of operation, who owns and operates, etc., covering half a million stations in 4 volumes with a Preface, $285.00.—**Gilfer Associates, Inc.,** Box 239, Park Ridge, N.J. 07656.

ELECTRONIC BURGLAR & FIRE ALARMS, *# A-107.* Brochure showing plug-in installation of alarm system in different spots in the household. Also describes detector-transmitters, receiver-alarms, and accessories for protection devices.—**Functional Devices, Inc.,** P.O. Box 368, Russiaville, Indiana 46979.

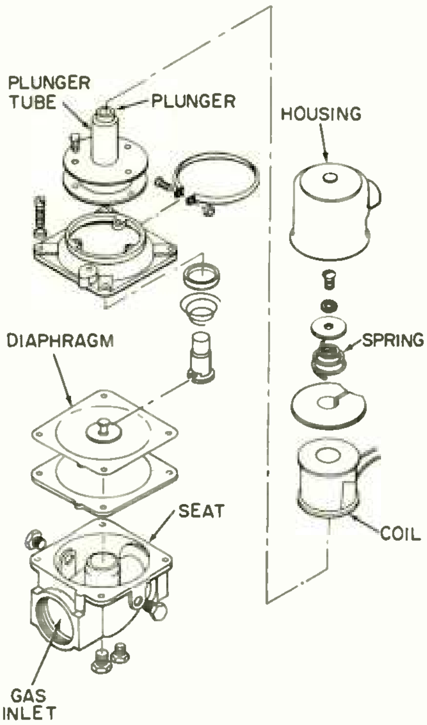
Circle 43 on reader service card

PRECISION TUNER SERVICE ADOPTS NEW NAME. With purchase of entire tuner parts line from Colman Electronics, plus the addition of two extra lines of repair services—i.f.-subchassis and 8-track car stereos and tape decks—the company has taken the new name, PTS ELECTRONICS, INC., as more appropriate to an industrial supplier. PTS Electronics remains at Box 272, 5233 Highway 37 S., Bloomington, Ind. 47401. **R-E**

Circle 65 on reader service card

APPLIANCE CLINIC
(continued from page 22)

much trouble. Fig. 2 shows a typical direct-operated valve of this type. The coil and working parts will be enclosed in a housing, held in place by screws. If you take one of these apart, remember "where everything goes", and in what order!



Any dirt that is jamming the operating parts of the valve can be cleaned out. Polish tightly-fitting parts, such as rods, until they're very smooth and shiny. If the valve was leaking, check the valve and seat for small particles of dirt which is keeping the valve from seating tightly.

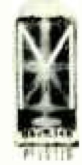
As a general rule, you shouldn't use too much lubricant on these things. If any, use one of the silicone oils or greases. There is also a spray-can product, available from refrigeration-supply houses, which actually leaves a very thin film of Teflon on the surfaces!

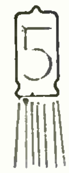
Never use excessive oil or grease. It will tend to make the valve jam sooner than it would. Apply it very sparingly if at all.

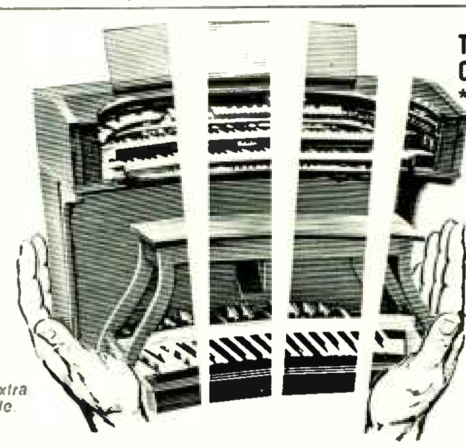
When you get it back together, check it very carefully for quick, positive shutoff, and full opening. If it will not work properly, replace it! Don't take chances; if it isn't working *perfectly*, throw it out. **R-E**

ELECTRONIC IGNITION?

Facts & Fallacies Of Electronic Ignition appears next month. This article explodes the myths of what electronic ignition can and can't do for your car.



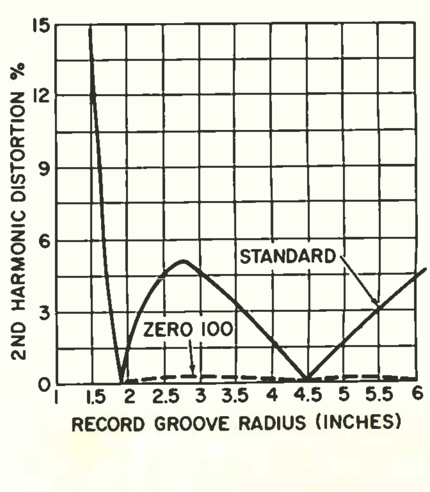




Garrard Zero 100 Automatic Turntable

Circle 60 on reader service card

LATERAL TRACKING ERROR AND ITS resulting distortion is a well studied phenomenon with mathematical analysis going back thirty years. The geometry of a conventional finite length tone arm requires that the angle between the cartridge axis and the tangent to the record groove (the tracking angle) change as the tone arm travels across the record surface. As will be explained, this tracking error can lead to considerable playback distortion. Garrard has developed the Zero 100 Automatic Turntable, with a tone arm geometry that virtually eliminates it. Fig. 1 (below) graphs the distortion of the Garrard system due to this source as compared to a conventional system. Combined with the turntable's other features the tone-arm system makes this



equipment report

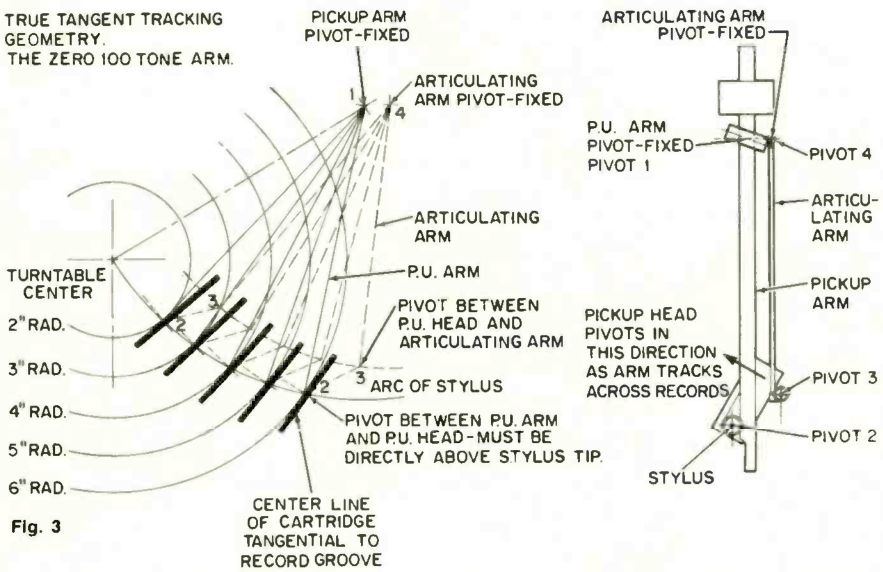


Fig. 3

disc-handler second to none as a complement to the first-rate audio equipment so common in these days of the solid-state revolution.

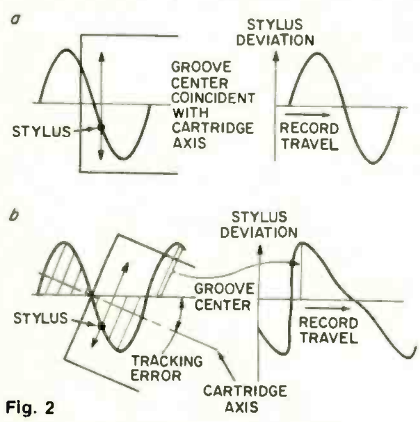


Fig. 2

Rigid mathematical analysis of tracking distortion depends on such mathematical niceties as Bessel functions which some readers may recall as basic to frequency modulation principles. However, Fig. 2 dramatically demonstrates how tracking distortion is produced. Exaggerated stylus movement is used to show the zero-error condition (above). Since the lateral stylus movement is in line with the disk's center hole (along its raduis), the stylus exactly traces the recorded sine wave groove modulation and no distortion results.

(continued on page 84)

Grantham's New Program in

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next month

APRIL 1972

- **Add-On Electronics For Your Car**
  Electronic ignition, tach-dwell meters, rpm limiters, and many other add-on electronic devices that make your car run better are described.

- **Facts And Fallacies Of Electronic Ignition**
  The truth about electronic ignition—what it really can and can't do for your car.

- **Automotive 8-Track Tape Player Repairs**
  Case histories of actual service experiences.

- **Programmed Course In the Staar Cassette System**
  Step-by-step tour of how this popular car-cassette-tape system operates.

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channel playback. It is also fully reproduced but without location in two-channel stereo playback. In monophonic playback it reproducces at a somewhat attenuated level. CBS advises recording engineers to avoid placing soloists in the back center of the recording area, corresponding to the rear two channels. In playback through a two-channel stereo system an SQ record plays in precisely the same manner as a regular stereo record, with its four channels emanating from the two loudspeakers of the stereo outfit. The left front channel is heard in the left loudspeaker, the right front channel is heard in the right loudspeaker. The *center sounds* are precisely and sharply centered, while the back channels are spread appropriately between the two loudspeakers. An all-around panned sound travels back and forth between the loudspeakers. The overall effect is that you are playing a first-rate two-channel stereo record.

SQ, says CBS, offers "full" right-to-left separation of both the front and rear channels, separation said to be as great as any you get from a typical good stereo system. A recent Sony ad plugging SQ stated that the separation was "40 db or so." This separation is said to be "concentrated where psychoacoustic research has shown it is most necessary–side-to-side."

Front-to-back ratio

Front-to-back separation in the SQ format is 3 dB. This is considered by many to be less than adequate. However, CBS defends this parameter by stating that according to the newly-established psychoacoustic principle of "front source dominance," the ear tends to ignore that rear channel information which duplicates information in the front channels–i.e., the front-channel elements which leak through to the rear because of lesser separation contribute only to the *total volume* we sense in the room, and do not contribute to a sense of *directionality*.

Henry Akiya, product manager for Sony Corp. of America, told us that use of the firm's SQD-1000 or SQA-200 decoders which use a *straight* logic circuit, enhance front-back separation by up to 6 dB. Further, he noted, there are other possible combinations of decoding parameters–to effect even greater front-back separation. Akiya said it was possible, for instance, to develop a decoder using *wave-matching* logic. By so doing, it would be possible to obtain infinite separation between the front and back pairs of channels, and up to 20 dB separation between the two front and two back channels. This overcomes one prime objection to the SQ system.

Dispensing with both forms of logic circuitry, and with a slight reduction of separation between the front and back pairs of channels, Akiya said it was possible to create a decoder that would obtain up to 7 dB separation between front and back channels.

Sony claims that a pure matrix decoder–even the matrix at the heart of SQ–can't reproduce a solo instrument without a softer, phantom soloist in other channels. But by adding a logic circuit, these phantom signals can be diminished or eliminated, sharpening the sense of the soloist's position, making him stand out more clearly.

Another claim for the SQ system is total omnidirectionality. No matter where a musician sits when being recorded in the 360-degree quadraphonic circle, he will be heard in playback at exactly the same volume as if he were sitting up front. This holds whether playing an SQ record in 4-channel, or playing it on a regular two-channel stereo system without an SQ decoder.

(continued on page 95)

EQUIPMENT REPORT

(continued from page 77)

The actual situation is a bit more complicated than depicted here since the cartridge is velocity sensitive. The groove velocity is equal to the angular velocity times the radius so the farther away from the record center the greater is the tangential velocity of the groove relative to the stylus. The tracking error becomes less significant as the tangential velocity increases, leading to the conclusion that the second order distortion at the cartridge terminal is proportional to the tracking error divided by the radius of the groove being traced. In other words, a tracking error of 4 degrees at a groove radius of 4 inches produces the same distortion as a tracking error of 3 degrees at a 3-inch radius. A conventional arm is designed so it overhangs the record center allowing the tracking error to pass through zero twice during arm travel, helping to keep the distortion to manageable proportions.

Garrard has conquered the tracking problem by using a two-piece construction consisting of a main arm and an articulated arm. This geometry pivots the cartridge with respect to the main arm to keep the cartridge tangential to the groove as in Fig. 3. Although the system does deviate minutely from zero tracking error, the distortion produced is entirely negligible when added to other distortion sources such as tracing distortion (due to the inability of the stylus to precisely follow the groove contour). A listening test proves to bring new life to many records, noticeably reducing distortion on the inner grooves.

We've covered the turntable's headline feature, so let's move on to the others. A lightweight turntable is driven by a magnetically shielded synchronous motor which is rapidly started with a 4 pole induction section. The 33⅓ and 45 rpm speeds are mechanically variable over a ±3% range. Two stroboscope bands are visible through a window, with only one producing a stationary pattern at the selected speed. The variable speed control surrounds the speed and record size selector. A rotating spindle is provided for the ultimate in single play operation. Wow and flutter are specified as less than .1% and .05% respectively.

Tone-arm tracking force is adjusted with a sliding weight which is first put in the zero position and then the isolated counterweight positioned for arm balance. The sliding weight is then adjusted for the desired tracking force. A weight movement of 1⅛ inches changes the force by only one gram, permitting precise setting. The tone-arm system includes a unique magnetic anti-skating scheme. A magnetic shield is

slid between two ceramic magnets; one mounted on the fixed gimbal surround and the other on the rotating arm gimbal. The skating force is adjusted by sliding the shield so the indicator corresponds to the previously adjusted tracking force. Two scales with tracking force markings are calibrated for conical and elliptical styli. All frictional forces have been kept very low, which is probably the reason that Garrard has succeeded with a design using an articulated arm with its four pivots, while previous similar attempts have failed. The cartridge mount has two tilt positions to produce a 15-degree vertical tracking angle at a height of either one record for single play operation, or at a height of three records which is halfway up the six record stack permitted in automatic play. Cartridge installation is facilitated by a plastic gauge with cross hairs used to position the stylus directly below the main arm cartridge pivot. The tone arm may be locked to a spring loaded stanchion offering protection against accidental arm damage.

The $189.50 Zero 100 consumes 9 watts, measures 14¾" wide by 13¼" deep by 6¾" high and weighs in at 11½ pounds.

Offering simple set-up and flawless performance, this automatic turntable should satisfy the most sophisticated audiophile. **R-E**

SOLID-STATE DESIGN

(continued from page 52)

secondary winding in series with the base circuit.

The design procedure in all other facets is identical to that described for Class-B operation. A 10% factor was added there for contingencies such as saturation voltage and leakage current. Perhaps in Class AB, this factor should be increased to 15% or 20%.

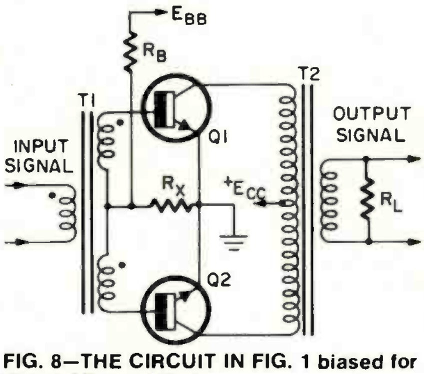

FIG. 8—THE CIRCUIT IN FIG. 1 biased for Class AB operation.

Only one type of push-pull circuit is described here—using transformers. It was used only for convenience sake. Modern designs negate the need for this type of component at the input or at the output. **R-E**

new books

RCA RECEIVING TUBE MANUAL, Technical Series RC-28. RCA Electronic Components, Harrison, N.J. 07029. 784 pages, 5½ x 8 in. Softcover, optional price $2.50.

A tube manual notably bigger than the preceding edition is a surprise in this age of semiconductors. The new RC-28 is more than 100 pages larger than its predecessor, and describes more than 1600 tube types. New material includes data on more than 190 industrial tubes, as well as 75 new entertainment-type receiving tubes. Data—in chart form—on RCA picture tubes is also supplied.

The 101-page, five-chapter introduction is still the best short text on receiving tubes available to the technician. Some 80 pages are devoted to a listing of discontinued and replacement-only tube types, including terminal diagram listings cross-referenced by type number and base diagram.

The "regular departments" (application guide, resistance-coupled data, etc.) appear as usual or in expanded form.—*FS*

ADMIRAL MONOCHROME TV SERVICE MANUAL, by Homer L. Davidson, 160 pp.; MAGNAVOX MONOCHROME TV SERVICE MANUAL, by Jay Shane, 160 pp.; JAPANESE COLOR TV SERVICE MANUAL No. 2 (Panasonic, Hitachi, Delmonico), by Stan Prentiss, 176 pp.; RCA COLOR TV SERVICE MANUAL No. 2, by Stan Prentiss, 176 pp. Tab Books, Blue Ridge Summit, Pa. 17214. All 8½ x 11 in. Vinyl cover, $7.95 ea., softcover, $4.95 ea.

Four of the latest additions to the Tab line of servicing/schematic manuals for black-and-white and color TV sets. Each gives the vital service data on the specific brands it covers. Useful for service technicians and hobbyists with "clients" among their friends.

JACK DARR'S SERVICE CLINIC, No. 2. Tab Books, Blue Ridge Summit, Pa. 17214. 5 5/16 x 8½ in., 176 pp. Softcover, $3.95.

Picking up where No. 1 left off, this volume contains material selected as the best and most timely service data published during the past three years. The ten chapters cover service techniques, antennas and reception problems, color crt's, rf, agc, and sync, sweep systems, power supply and control circuits, test equipment and testing, stereo, audio and other devices. Jack Darr's beguiling style lends its magic touch to the serious work of diagnosis and repair. The book is full of diagrams and photos to bring out the points the text makes.

STEREO IN YOUR HOME, by Walter G. Salm. Vertex Books by Auerbach Publishers, 1101 State Road, Princeton, N.J. 08540. 5 11/16 x 8½ in. 231 pp. Hardcover, $8.95.

This handy guide for the layman and do-it-yourselfer reviews many of the developments in stereo since its popularization, and offers tips on how to install a system, make recordings, evaluate equipment and sound systems, and what to look for in buying equipment. Discusses how stereo and tape recorders work, how commercial recordings are made, how FM and TV antennas can be used in your stereo system. Includes an examination of 4-channel stereo as well as eight-track cartridges. Complete with photos, charts and diagrams to make things clear. R-E

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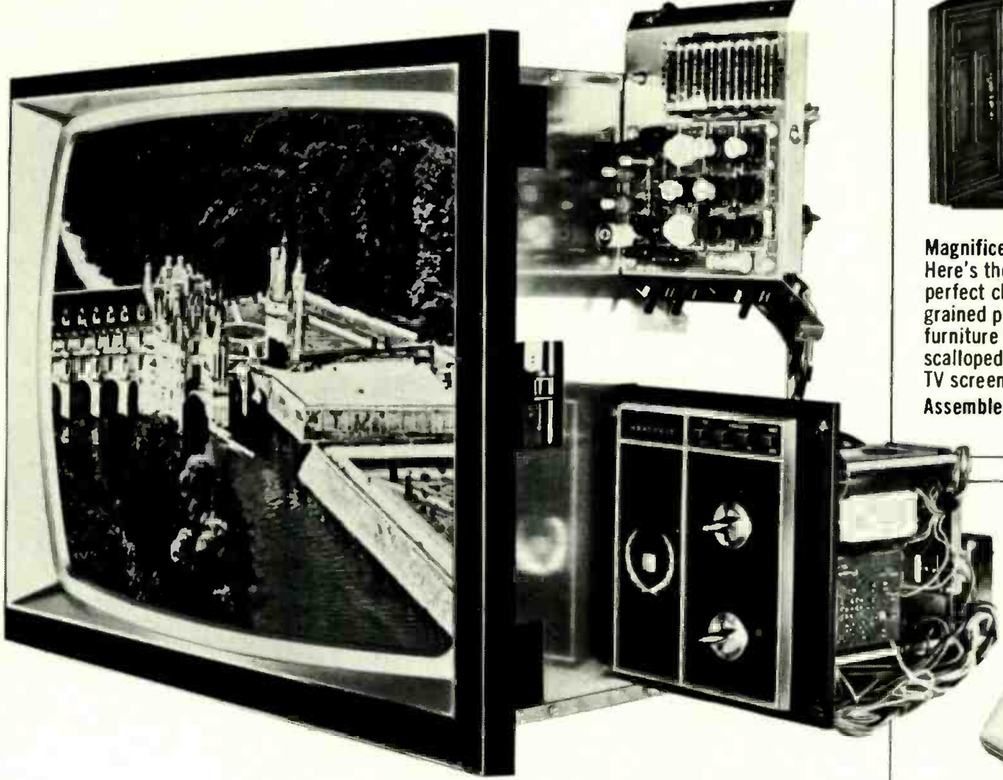
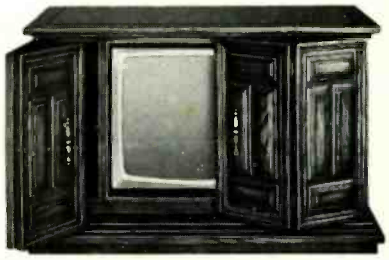
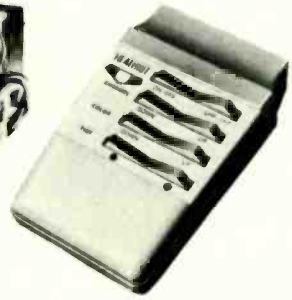




Magnificent Mediterranean Console. Here's the finest TV cabinet we offer, a perfect choice for a GR-900. Has deep-grained pecan veneers on hand-rubbed furniture grade hardwood solids. Two scalloped double-hinged doors hide the TV screen when not in use.

Assembled GRA-405-25, 100 lbs. **179.95***



Wireless Remote for your GR-900. The ultimate in armchair viewing. Gives you eight-function across-the-room control of on/off, three preset volume levels, power tuning (up or down), color, tint, UHF/VHF channel selection. Also activates Custom Wall Mount doors.

Kit GRA-900-6, 6 lbs. **79.95***

New Custom Wall Mount. Touch a button on the frame or on your Heathkit Remote Control unit and the folding tambour doors open to reveal your color TV. Kit includes everything needed to build your Heathkit GR-371MX or GR-900 into a wall.

Kit GRA-402-25, walnut finish, 50 lbs. **114.95***

Kit GRA-407-25, unfinished, 50 lbs. **109.95***

The new Heathkit GR-900 25V Color TV has UHF/VHF detent tuning & varactor UHF tuner, angular tint control – more features than any other color TV kit! Better performance than any other set.

UHF/VHF detent power tuning. Push a button and you scan the channels in either direction with detent action locking in on VHF channels 2-13 and any 12 preselected UHF stations. A pushbutton selects either UHF or VHF mode, and a lighted dial indicates tuner position. And you can have full remote-control selection too for just a few dollars more.

New voltage-controlled varactor UHF tuner and specially designed VHF tuner with MOS Field Effect Transistor contribute to better fringe-area reception, increased sensitivity.

New angular tint control. A switch now gives you either "normal" or "wide angle" color demodulation to reduce tint and flesh tone change when changing stations and when programs change. Other deluxe features include "instant on" operation with override for conventional on/off operation; automatic fine tuning; adjustable tone control, and an output for playing TV audio through your stereo hi/fi system.

Exclusive Heath MTX-5 ultra-rectangular tube. It's the largest color screen you can buy anywhere, with a full 25 inch meas. diag., 315 sq. in. viewing area. You see virtually everything the station transmits, in the corners and at the sides. The specially etched face plate cuts glare, and reflection, increases contrast without sacrificing brightness, and each dot is projected through a matrix screen to stand out crisply against a solid black background.

Modular solid-state circuitry. Plug-in circuit boards and plug-in transistors make assembly, adjustment and servicing easy. There are 46 transistors, 57 diodes and four ICs – making this one of the most reliable sets we've ever designed.

Other features include automatic chroma control, adjustable video peaking, adjustable noise limiting and gated AGC.

Exclusive Heath self-service built-ins. Your Heathkit GR-900 includes built-in dot generator, tilt-out convergence panel for set-up and periodic adjustments. A handy volt-ohm meter included in the circuitry helps you check your work during assembly, and can be used in conjunction with the manual for any servicing. Like all Heathkit color TVs, the GR-900 gives you complete installation flexibility. There are four beautiful Heath cabinets to choose from plus the new built-in electronic wall mount with hide-away tambour doors. Or you can custom install your GR-900. We think you'll agree, the GR-900 is truly the most impressive color receiver we've ever offered.

Kit GR-900, TV less cabinet, 125 lbs. **599.95***

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New AR-1500 stereo receiver 379.95*

Successor to the famed Heathkit AR-15, with impressive improvements in every critical area. 180 watts Dynamic Music Power, 90 watts per channel, 8 ohm load. Less than 0.2% IM and 0.25% harmonic distortion. Greater than 90 dB FM selectivity and 1.8 uV sensitivity. Vastly superior AM, too. It's the talk of the audio world. Order yours now.

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Now, a digital multimeter that meets lab specs at a low, low kit price! 3½ digits for 100 uV resolution on 200 mV range; 1V on 1000V; 5 DC ranges (100 uV—1000V, either polarity); 5 AC ranges (100 uV—500V); 10 current ranges (100 nA—2A AC or DC); 6 resistance ranges (0.1 ohm—20 megohms.) DC calibrator supplied for 0.2% accuracy without external equipment. Can be lab calibrated to 0.1%. Don't miss this outstanding instrument value.

Kit IM-102, 9 lbs. 229.95*

New 10 MHz triggered scope 229.95*

A 5" triggered sweep scope at a low kit price you can't afford to pass up. AC—10 MHz response, calibrated attenuator, 50 ns sweep rate with magnification, AC-DC coupling, 50 mV sensitivity. One of the outstanding scope values on the market. Order one for your ham shack, shop, lab or classroom, today.

Kit IO-103, 37 lbs. 229.95*

The better-than-ever '72 Heathkit Catalog has the world's largest selection of fun-to-build, money-saving electronic kits...including color TV, stereo/hi-fi, organs, home appliances, engine tune-up tools, radio control, portables, shortwave, marine gear, metal locator, instruments, hundreds more. If you don't have this catalog, you've missed seeing over 50 new kits, introduced since the last edition. Send today for your free copy.

New...Heathkit solid-state 100 MHz counter...only 269.95*

With the IB-1101, Heath closes the price gap in high frequency counters. Till now, "low cost" counters were confined pretty much to the 15 MHz range. Instruments above that range were complex, costly, and often more counter than you could ever use. Now, with the IB-1101, you have a truly low-cost counter in kit form with 1 Hz to 100 MHz capability and a list of features to rival counters costing much more. Compare for yourself.

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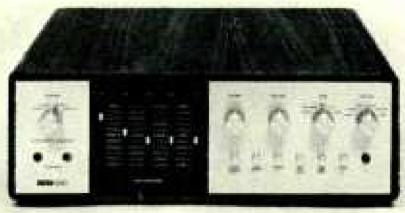
Circle 100 on reader service card

equipment report

Harman-Kardon "Citation Eleven" Preamplifier



Circle 96 on reader service card

HARMAN-KARDON'S CITATION ELEVEN—preamplifier is a companion to their outstanding Citation Twelve power amplifier, reviewed previously (**Radio-Electronics**, January 1971). However, the preamp is designed to operate with virtually any basic power amplifier, solid-state or tube-type. The Citation Eleven is available only as a wired unit, whereas the Citation Twelve can be purchased in either wired or kit form. A kit version of the "Eleven" would no doubt be complex, but it would be an interesting, money-saving challenge for the experienced kit builder. We hope Harman-Kardon decides to make it available some day.

The preamp is big (16 1/16" x 4¾" x 12"), heavy (20 pounds) and impressive looking, both front and back. The front is a thick, brushed aluminum panel with an imposing array of controls of three types—knobs, pushbuttons, and sliders. The back bristles with more audio jacks than we've ever seen on one piece of "home" equipment—24 in all, plus four ac outlets (three switched, one unswitched). In addition, there is a special receptacle (with matching plug and cable supplied) and terminal strips for speaker connections (more on this, later).

The Citation Eleven's most distinctive feature is its use of "audio equalizers" instead of conventional bass and treble controls. Five smoothly sliding equalizers cover the audio spectrum, with control midpoints at 60, 320, 1000, 5000, and 12,000 Hz. Each slider provides up to 12 dB of cut or boost. Used properly, these controls offer a much broader and more satisfactory range of adjustment to the reproduced sound than ordinary tone controls can provide. Used improperly, they can create some astounding sounds! A pushbutton switch is provided to switch the audio equalizers completely out of the circuit, for comparing the equalized and non-equalized response, or for assuring absolutely flat reproduction.

Another interesting feature is the Citation's speaker switching function. Many all-in-one amplifiers and receivers provide switching of the power amplifier outputs between two or more sets of speakers and/or stereophones, but separate preamps do not usually incorporate such control, for the obvious reason that the output lines simply aren't there to control. Thus, the separate preamp, one reason for which is to gain more sophisticated control, actually deprives the user of the ability to switch speakers. This is overcome in the Citation Eleven by building in a complete speaker switching/stereophone terminal, with input and output connections feeding the power amplifiers to the speakers or two attenuated phone jacks on the front panel. This switching network is completely isolated from the main preamp circuitry and its use is, of course, optional. We used it and liked it, and found the stereophone level just right; no ear-splitting blast when switching from speakers to phones.

Getting back to the business end of the preamp, we find six pairs of inputs: two low level PHONO inputs, a TUNER input, and three AUX inputs. Two of the latter—AUX 1 and AUX 2—have normal sensitivity (150-mV input for 2 volts output), suitable for interfacing with most high-level, equalized outputs from tape recorders, tuners, etc. AUX 3 is attenuated so that twice the signal—300-mV for 2 volts output—is required. This is done to accommodate inputs with what would otherwise be excessive gain. The six inputs are selected by a rotary switch.

Other front panel controls are: LEVEL and BALANCE controls, a MODE selector (stereo, reverse stereo, mono, left and right), and six pushbuttons—from left to right, the audio equalizer bypass switch; two (yes, two!) tape monitor switches, to permit comparison of recorded vs input signals from either of two recorders; a high-cut filter that provides a cut of -8 dB at 10,000 Hz, with a 6-dB-per-octave slope; a subsonic filter that gives a -12 dB attenuation at 15 Hz, with a 6-dB-per-octave slope; and the main power switch.

Two sets of main output jacks are provided, for feeding two power amplifiers or a power amplifier and a tape recorder. Outputs are low impedance, allowing long cable runs to the power amp, if necessary.

Harman-Kardon's engineers obviously had the serious recordist in mind when they designed the Citation's tape input and monitoring functions. Two completely separate sets of tape recorder outputs, plus the previously mentioned two sets of tape monitor in-

(continued on page 94)

EQUIPMENT REPORT
(continued from page 93)

puts are provided. The tape outputs are unaffected by the front panel controls. If it is desired to take advantage of the tone-modifying characteristics of the audio equalizers and/or filters, the extra pair of main outputs can be fed to a recorder.

So much for controls, inputs, outputs and the like. Now, how does it perform? We lived with the Citation duo, for several weeks, showing it off to friends (alienating wife, children, and dog in the process), and trying every conceivable operating situation. We even rigged up two 3-head reel-to-reel recorders, to experience the button-pusher's delight—alternately monitoring two recorders. We taped reel-to-reel and cassettes simultaneously. We tried taping from the main output jacks, to take advantage of the audio equalizers, which we used to "doctor" the signal to the recorder, to overcome deficiencies in the response of the input signal or the recorder itself.

After this extended in-use test, we concluded that the Citation Eleven fulfills all its intended functions superbly. At first, the audio equalizers took a little getting used to. Frankly, we were never one to diddle with tone controls very much, but we found the audio equalizers something else again. After a little practice we found we could achieve just the right tonal balance without the obvious sensation that somebody turned the bass (or treble) up (or down). Consequently, we rarely play a record or tape through the Citation without making some adjustment to one or more of the equalizers. And the recordings never sounded better.

The filters

The sub-sonic and high-frequency filters performed their intended functions beautifully, with almost no effect on the program material.

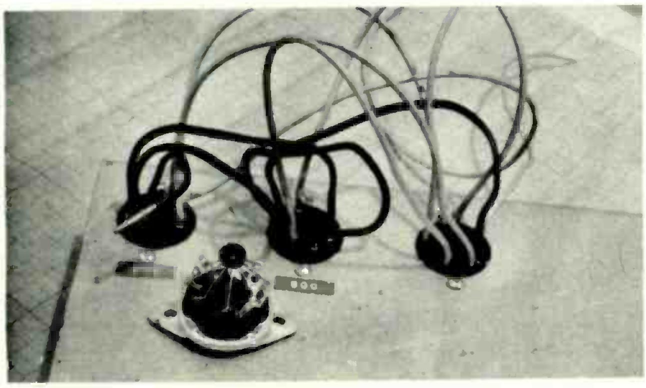
Of course, the Citation Eleven isn't perfect. The little deficiencies in a piece of high-quality audio gear aren't usually noticed at first. But we'd object to the excessively high sensitivity of the phono inputs, requiring caution when switching from a high-level input, lest speakers and windows be shattered. Too much of a good thing, at least with the several cartridges we tried. Some convenient means of backing off a bit, to adjust the levels of the phono inputs to the high-level inputs, would be welcomed. Also, for us old-fashioned folks who like to fool around with center channels, a derived L+R output, with its own level control, as the old Citation I had, would be nice. We recall, also, that the Citation I—still, in our opinion, one of the most flexible, versatile preamps ever made—had some other nice touches, like a phase reversing switch, which come in handy now and then.

Finally, on units like this we'd like to see more practical and convenient means for flush-mounting in custom cabinets. The preamp is ostensibly designed for either flush mounting or installation in its optional walnut cabinet, but no really practical way of anchoring the unit in a panel is provided, except for four tapped holes on the bottom plate which are useable only if the underneath of the supporting shelf is accessible (which it isn't, in our installation).

But these are minor complaints, indeed, in light of the many superlative features of the Citation Eleven. It is a top-quality unit worthy of the Citation name, and worth the $295.00 price tag, at least for the well-heeled audio perfectionist.—*Terry W. Barnes* **R-E**

try this one

HANDY IC BREADBOARDS



Tube sockets make handy supports for IC's in breadboard circuits. Tack-solder the IC leads to the socket lugs. Use pin tips or pins from old octal-base tubes and short leads for interconnecting jumpers. The photo shows a simple test setup.—*J. Zacarias Malacara H.* **R-E**

CBS-SONY 4-CHANNEL
(continued from page 83)

Other aspects of SQ

An important aspect of the SQ system is that its parent is a major record company. Since Columbia's main business is selling phonograph records in a highly competitive market—and who wants to be Number Two?—you can expect a continuing outpouring of SQ records to feed the format, as opposed to the token offerings other record firms have made for existing quadraphonic record systems. This, in turn, will perpetuate SQ, again in a highly competitive field—home electronics equipment. As we go to press there are some 50 SQ records under the Columbia logo. Vanguard is licensed to produce SQ records. And so is Ampex. In Japan, CBS-Sony Records will produce SQ discs. You can expect other major firms to hop on the SQ record bandwagon.

Incidentally—and perhaps ironically—the Columbia SQ program materials will also appear in the form of *discrete* Q-8 cartridges. A spokesman for Columbia Records told **Radio-Electronics** that the firm would be releasing SQ discs at a rate of about 20 every two months for the time being. The releases will cover popular, classical and show music.

SQ's sell for $1 more than conventional stereo records. Some day, we predict—and our prediction is based on previous events and trends in the record/electronic equipment industries—that premium will be eliminated. The premium, we can safely speculate, is to offset research and development costs.

On the equipment front as we go to press is "hardware" from Masterwork, co-sponsor Sony, and Lafayette Radio. Sherwood Laboratories has been licensed to make SQ decoders under its brand name.

Additionally, a decoder from Electro-Voice—a major competitor in the matrix recording system field—has been updated to decode the SQ system. By the time this appears in print there will be other companies producing SQ decoding and playback equipment. **R-E**

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BOOKS

Discounts on technical books are rare, since the publisher discounts are low, but B and F is happy to give you a 10% discount and postpaid delivery in the U.S. on what we feel are some of the best books in the electrical engineering field. They are:

☐ Alley and Atwood, *Semiconductor Devices and Circuits*, Wiley, 1971. Without relying on calculus, this book describes basic semiconductor devices and explains their use in electronic circuits. The operations and uses of linear and digital integrated circuits are given considerable coverage. List Price $11.95, B & F Price $10.75.

☐ Paul Siegal, *Understanding Digital Computers*, 2nd Edition, Wiley, 1971. A great introductory text for logic and computer design. We supply it as part of our logic experimenters kit. List $12.95, B & F Price $11.75 . . . . $11.75

☐ Eimbinders, *Semiconductor Memories*. Wiley, 1971. List $11.95 . . . . $10.75

☐ Eimbinder, *Designing with Linear Integrated Circuits*, Wiley, 1969. List $10.95 . . . . $9.85

☐ Barna, *Operational Amplifiers*, Wiley, 1971. List $9.95 $8.95

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The NE567 is second in usefulness, it is used for recognizing tones. A resistor and capacitor program the band width and center frequency. Used in touch tone decoding, remote control etc. The NE 561 and NE 565 are used in more specialized applications, such as teletype and frequency synthesizers. All devices include full data sheets *and* the 566/567 data on touch tone coding/decoding.

☐ NE 561, 565, 566 or 567 . . . . $5.00

SOCKETS FOR INTEGRATED CIRCUITS

☐ 14 pin . . . . . 3 for $1.00
☐ 16 pin . . . . . 2 for $1.00

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The response to our offerings of the Sharp Calculator in previous months has been nothing short of fantastic, and the Sharp is still available at the same price. We are now offering the Sanyo Calculator, with slightly different features, to those of you who are still looking. The Sanyo is smaller, and uses smaller L.E.D. readouts, as opposed to the Sharp's florescent. This will be an asset to some, a liability to others. The Sanyo uses automatic decimal point setting, as opposed to the Sharps floating decimal point. The former is a useful feature in dollars and cents calculation, where the Sharps floating point gets a slight edge for scientific calculations. The Sanyo is battery operated, using self contained nicads, and comes complete with charger/supply for line operation. Fully Guaranteed by Sanyo USA (and B & F). You can charge it to BankAmericard or Mastercharge. Phone orders accepted.

☐ Sanyo Calculator $215.00

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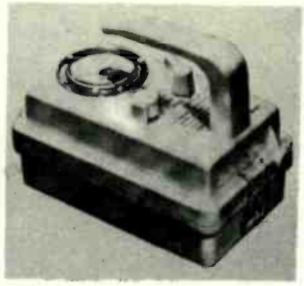
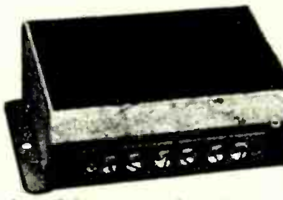


You can buy a complete radiation meter, complete with original instruction books, at less than the price of the meter movement alone. Range is 0.02 to 50 Roentgens/hour. This is not sensitive enough for prospecting, but useful for other radiation measuring and monitoring purposes. If not used for its original function, then the case, meter and battery holder alone are worth our asking price as a basis for building a metal locator, etc. Uses standard D cell and 22.5 volt Battery.

☐ Radiation Meter . . . . $9.50 + $1.00 postage & handling

ALL PURPOSE 12 VOLT SUPPLY



This supply delivers 12-14 volts D.C. at 12 amperes. Useful for hundreds of applications, use it to power projects, as a battery charger, for toy trains, you name it. At our low price you should order several to have around. No filtering is supplied, use an external capacitor.

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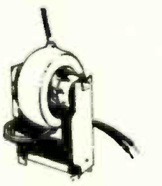

We have thousands of flyback transformers for TV sets, and have worked out an interesting modification of them so that using a pair of power transistors and a few resistors you can build a 12 volt D.C. powered oscillator converter providing an output of 18,000 volts. With this high voltage output you can perform many interesting experiments and demonstrations, such as a Jacobs ladder . . . or lighting a florescent tube by just holding it near the supply. We supply the flyback transformer, two power transistors, resistors, instructions and an experiment manual. Use our 12 volt supply advertised on this page as a supply for this if you don't already have one.

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☐ Flyback Transformer only, with Instructions $2.75
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☐ 25 Watt RMS Amplifier $14.75
☐ 50 Watt RMS Amplifier $22.50

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☐ Same for 50 watt rms stereo amplifier includes two 25 watt Sankens, etc. $58.00

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Circle 92 on reader service card

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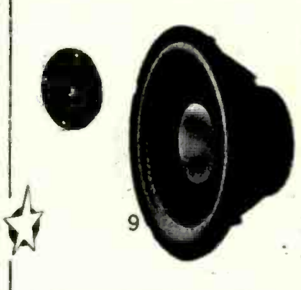

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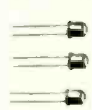

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Circle 101 on reader service card

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Circle 102 on reader service card

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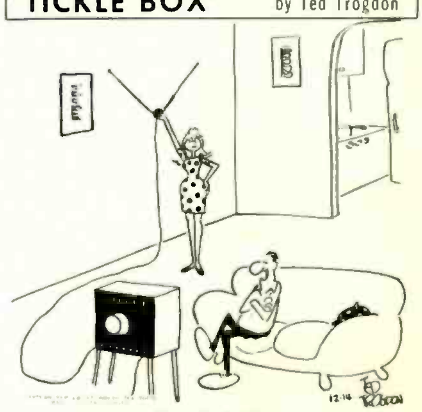
TICKLE BOX by Ted Trogdon



"There! That's it."

SHORTWAVE PROPAGATION COURSE

Radio Nederland begins broadcasting a *Shortwave Propagation Course* for SWL's on its weekly "DX Jukebox" on March 9. The course covers many problems related to SW propagation: how it is influenced by distance, season and time of day; and how it is affected by atmospheric, solar and cosmic disturbances. Also covered are such topics as fading, ground and sky absorption, sun spots and flares.

Printed text material is available free of charge. Address applications to DX Juke Box, c/o Radio Nederland, P.O. Box 222, Hilversum, Holland.

The DX Juke Box (via Bonaire, West Indies relay) can be heard on Thursdays in Atlantic, Eastern and Central time zones on 11.73 MHz, beginning at 9:13 EST. In Pacific and Mountain Standard Time zones, listen on 9.715 or 11.73 MHz at 9:13 PST.

CONFERENCE ON FOUR-CHANNEL STEREO

The annual *Midwest Acoustic Conference* meets Saturday, April 15 on the theme "Four-Channel Sound Reproduction, Creation and Re-creation of a Sound Field". Professionals and non-professionals are invited. The meeting will be held in the Auditorium of the Technical Institute of Northwestern University in Evanston, Ill. Meeting opens at 9:00 am under the chairmanship of Daniel Queen. Other chairmen include Marvin Camras, Bruno Staffen and James Kogan of ITT, Motorola and Shure, respectively.

For further information, contact Mr. Daniel Queen, Daniel Queen Associates, 5524 W. Gladys Ave., Chicago, Ill. 60644 or telephone (312) 261-5738.

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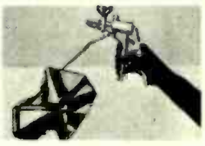

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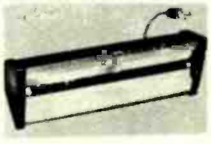

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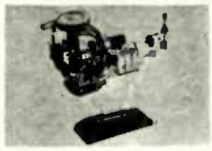

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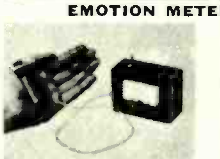

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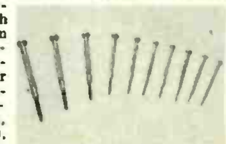

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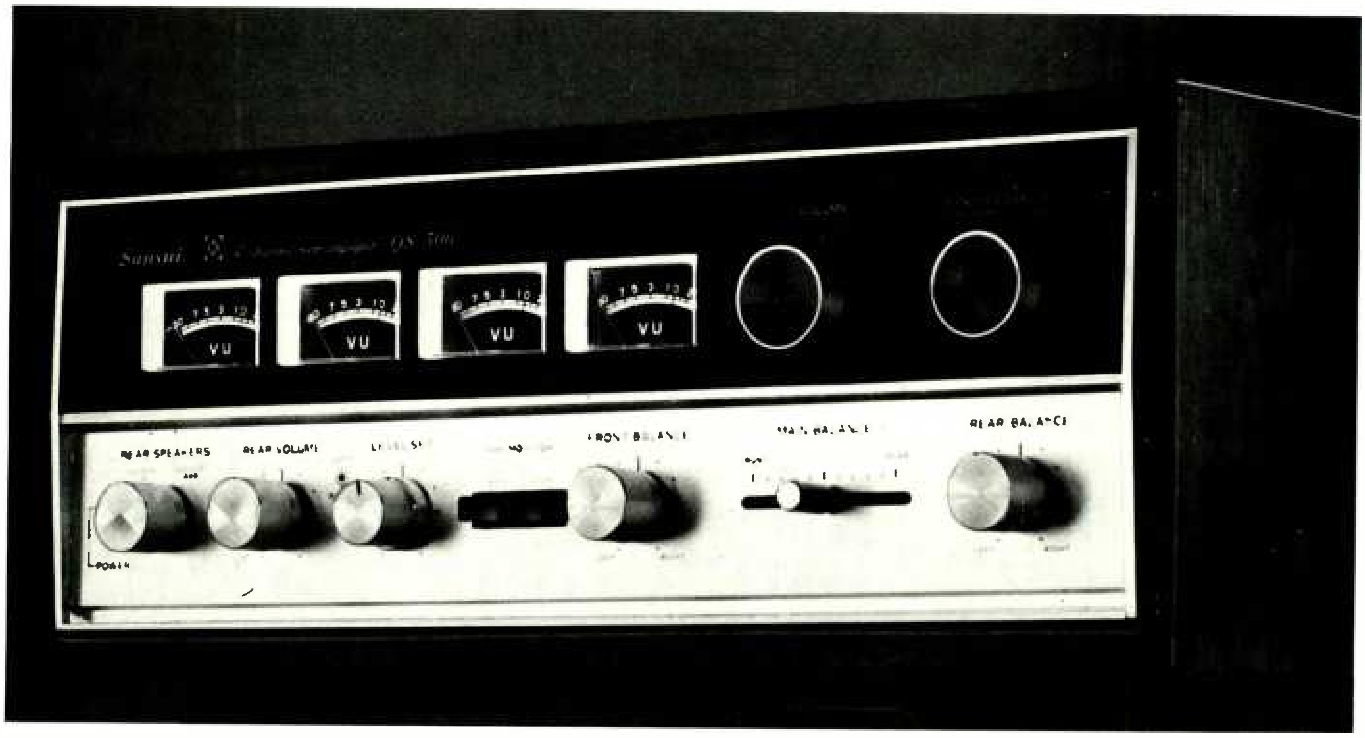

you don't have to go for broke

Buy yourself a miracle for as little as $214.95 That's all it takes to get your conventional two-channel stereo to do anything any total four-channel receiver and control center can do, now or in the future.

The Sansui QS500 and QS100 converters are complete Four-Channel Synthesizer-Decoder-Rear-Amplifier-and-Control-Center combinations that transform standard two-channel stereo totally. The only other equipment you need is another pair of speakers.

You can decode any compatibly matrixed four-channel broadcasts or recordings and reproduce them in four authentic channels. You can detect the ambient signals present in most two-channel recordings or broadcasts and propagate them through the rear channels. In Sansui matrixing, the exclusive phase-shift technique prevents the cancellation of some signals and the change in location of others that occur in many matrixing systems. And the exclusive phase modulators restore the effect of the live sound field.

You can plug in a four-channel reel-to-reel or cartridge deck or any other discrete source. In the future — if you should have to — you can add any adaptor, decoder or what-have-you for any four-channel system for disc or broadcast that anyone's even hinted at. And a full complement of streamlined controls lets you select any function or make any adjustment quickly and positively.

The QS500 features three balance controls for front-rear and left-right, separate positions for decoding and synthesizing, two-channel and four-channel tape monitors, electrical rotation of speaker output, alternate-pair speaker selection, and four VU meters. Total IHF power for the rear speakers is 120 watts (continuous power per channel is 40 watts at 4 ohms, 33 watts at 8 ohms), with TH or IM distortion below 0.5% over a power bandwidth of 20 to 40,000 Hz. In its own walnut cabinet, the QS500 sells for $289.95

An alternate four-channel miracle-maker is the modest but well-endowed QS100, with total IHF music power of 50 watts (continuous power per channel of 18 watts at 4 ohms and 15 watts at 8 ohms). In a walnut cabinet, it sells for $214.95

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Breakthrough!

The new B & K Precision 1440 General Purpose Oscilloscope breaks through with laboratory performance at a Service Technician price.

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About the Cali-Brain® System

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Cali-Brain® in Action

Use CALI-BRAIN when you want to measure peak-to-peak voltage of the waveform displayed on the scope screen. Here's what happens when the CALI-BRAIN switch is activated:

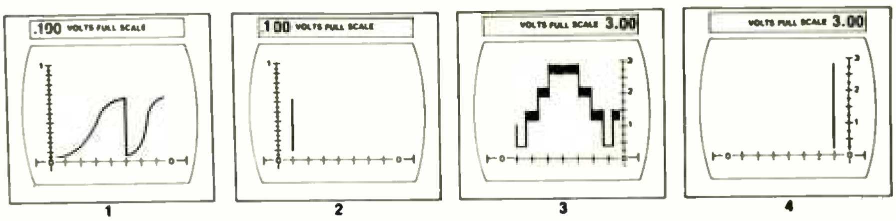
A. The horizontal sweep collapses and the waveform under examination appears as a straight vertical line.

B. A numerical indicator in the CRT bezel lights up to show the full scale voltage (including decimal point) corresponding to the Vertical Attenuator setting.

C. A graduated scale on the graticule overlay is illuminated on either side of the scope screen. The scale corresponds to the full scale voltage indicator in the bezel.

D. The vertical waveform line on the CRT moves to either side of the screen, to align itself with the illuminated scale.

The entire CALI-BRAIN action is automatic—and takes less than a second. After you have read waveform voltage, you deactivate CALI-BRAIN system with a single switch, and the waveform is again displayed. One probe and one test instrument—lets you concentrate on trouble shooting, not the test equipment!



1 2 3 4

To read peak-to-peak voltages utilizing Cali-Brain, note the full scale voltage reading in the bezel above the screen (fig. 1–.100 volts full scale) (fig. 3–3.00 volts full scale). Pull out the Cali-Brain knob and you will notice that the 1st waveform in fig. 2. reads .067 volts P-P and the second waveform in fig. 4. reads 2.95 volts P-P.

See your local distributor or write us for more information

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