Electronics World

APRIL, 1967
60 CENTS

ELECTRONIC EAVESDROPPING — How "Bugging" Devices Work
What's Available • How They Are Planted • How They Are Detected

NEW HI-FI RECEIVER Uses Integrated Circuits

SPECIAL ISSUE

RELAYS

A ZIFF DAVIS PUBLICATION

Deluxe Heathkit® "295" Color TV... $479.95

- *Hi-Fi rectangular color tube with 295 sq. inch viewing area, and anti-glare safety glass*
- *Rare earth phosphors for brighter pictures, livelier colors*
- *27 tube, 10 diode, 1 transistor circuit*
- *25,000 volt regulated picture power*
- *Automatic degaussing & mobile degaussing coil*
- *Exclusive built-in self-servicing aids*
- *Dynamic pincushioning correction circuit eliminates picture edge distortion*
- *Extra B+ boost for improved picture definition*
- *3-stage video IF strip reduces interference, improves reception*
- *Exclusive Heath "Magna-Shield" improves color purity*
- *Gated Automatic Gain Control (AGC) for steady, flutter-free pictures even under adverse conditions such as airplane traffic*
- *Automatic Color Control circuit reduces color fading*
- *Deluxe VHF turret tuner with "memory" fine tuning & long-life nickel silver contacts*
- *2-speed transistor UHF tuner for both fast station selection and fine tuning individual channels*
- *Two hi-fi sound outputs . . . a cathode follower for play thru your hi-fi system, and an 8 ohm output for connection to special contained-field 6" x 9" speaker (included)*
- *Two VHF antenna inputs . . . a 300 ohm balanced and 75 ohm coax to reduce interference in metropolitan or CATV areas*
- *Circuit breaker protection*
- *1-year warranty on picture tube, 90 days on all other parts*
- *Tubes alone list at over $277*
- *Liberal credit terms available — details in FREE catalog*

Kit GR-295, all parts including chassis, tubes, mask, UHF & VHF tuners, mounting kit and special extended-range 6" x 9" speaker, 131 lbs. (REA or motor freight only) **$479.95**

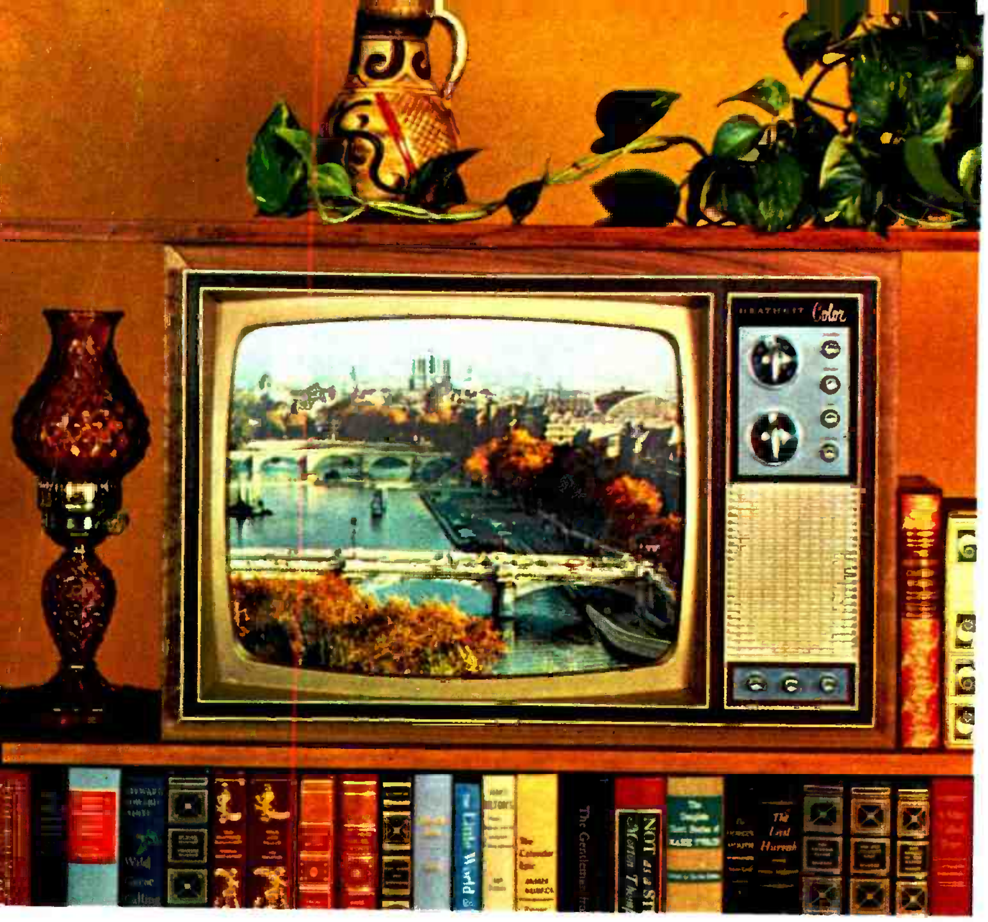
GR-295 SPECIFICATIONS — Picture size: Rectangular viewing area approx. 295 sq. inches, (23" diagonally, 20" horizontal, 16" vertical). **Tube Size:** 25" overall diagonal measurement. **Deflection:** Magnetic 90°. **Focus:** Electrostatic. **Convergence:** Magnetic. **Antenna input impedance:** 300 ohm balanced, or 75 ohm unbalanced (VHF). **Picture IF carrier frequency:** 45.75 MHz. **Sound IF carrier frequency:** 41.25 MHz. **Color subcarrier:** 42.17 MHz. **Video IF bandpass:** 3.58 MHz. **Sound IF frequency:** 4.5 MHz. **Tuning range:** VHF channels 2-13, UHF channels 14-82. **Sound cathode follower:** Output impedance; 3 K. Frequency response; ±1 db, 50-15,000 Hz. Harmonic distortion, less than 1%. Output voltage; 2 v. **Audio output:** Output impedance, 8 ohms. Output power, 2 watts. Frequency response, ±2 db, 50-10,000 Hz. Harmonic distortion, less than 3%. **Power requirements:** 110-130 v., 60 Hertz AC, 330 watts. **Wall mounting:** 20" D x 21" H x 26" W inside. Control panel assembly, 6½" W x 7⅞" H x 7" D.

Install In A Wall Or These Assembled Heath Cabinets

Contemporary Styled Walnut Cabinet
Factory assembled of fine walnut veneers and solids with oil-rubbed walnut finish. GR-295 speaker and convergence panel mount behind tilt-out grille cloth on right side. A slim 19" D x 31" H x 34½" W.
Assembled GRA-295-1, 56 lbs. (Express or motor freight) **$62.95**

Contemporary Styled Deluxe TV Cabinet
Constructed of the finest walnut veneers and solids. GR-295 speaker and convergence panel mount behind speaker grille cloth on right side. Measures 19¼" D x 33⅛" H x 41" W.
Assembled GRA-295-2, 65 lbs. (Express or motor freight) **$94.50**

Deluxe Early American TV Cabinet
Made of a special combination of maple veneers and solids . . . all beautifully finished in popular salem-maple. GR-295 speaker and convergence panel mount behind grille cloth on right side. Measures 19¼" D x 31" H x 36" W.
Assembled GRA-295-3, 67 lbs. (Express or motor freight) **$99.95**



Deluxe Heathkit® "180" Color TV... $379.95

- *Hi-fi rectangular color tube with 180 sq. inch viewing area and anti-glare safety glass*
- *Rare earth phosphors for brighter, livelier colors*
- *Extra B+ boost and smaller dot size for improved picture definition*
- *26 tube, 10 diode, 1 transistor circuit*
- *24,000 volt regulated picture power*
- *Exclusive built-in self-servicing facilities*
- *Exclusive Heath "Magna-Shield" improves color purity*
- *Automatic degaussing*
- *Automatic Color Control circuit to reduce color fading*
- *Gated Automatic Gain Control (AGC) for steady, flutter-free pictures even under adverse conditions such as airplane traffic*
- *2-speed transistor UHF tuner for both fast station selection and fine tuning individual channels*
- *Deluxe VHF turret tuner with "memory" fine tuning and long-life nickel silver contacts*
- *3-stage video IF strip reduces interference, improves reception*
- *Two hi-fi sound outputs . . . a cathode follower for play thru your hi-fi system, and an 8 ohm output for connection to special limited-field 4" x 6" speaker (included)*
- *Two VHF antenna inputs . . . a 300 ohm balanced, and a 75 ohm coax to reduce interference in metropolitan or CATV areas*
- *Circuit breaker protection*
- *1-year warranty on picture tube, 90 days on all other parts*
- *Tubes alone list at over $245*
- *Liberal credit terms available — details in FREE catalog.*

Kit GR-180, all parts including chassis, tubes, mask, UHF & VHF tuners, mounting kit, and special limited-field 4" x 6" speaker, 102 lbs. (REA or motor freight only) **$379.95**

GR-180 SPECIFICATIONS — **Picture size:** Rectangular viewing area approx. 180 square inches (18" diagonally, 16" horizontally, 12" vertically). **Tube Size:** 19" overall diagonal measurement. **Deflection:** Magnetic 90°. **Focus:** Electrostatic. **Convergence:** Magnetic and Dynamic. **Antenna input impedance:** 300 ohm balanced, 75 ohm unbalanced VHF. **Picture IF carrier frequency:** 45.75 Meg. Hz. **Sound IF carrier frequency:** 41.25 Meg. Hz. **Color subcarrier frequency:** 42.17 Meg. Hz. **Video IF bandpass frequency:** 3.58 Meg. Hz. **Sound IF frequency:** 4.5 Meg. Hz. **Tuning range:** VHF channels 2-13, UHF channels 14-83. **Sound cathode follower:** Output impedance 3K ohm, frequency response ±1 db, 50-15,000 Hz. Harmonic distortion less than 1%, output voltage 2V. **Audio output:** Output impedance, 8 ohms. Output power, 2 watts; Frequency response, ±2db, 50-10,000 Hz. Harmonic distortion less than 3%. **Power requirements:** 110-130 V., 60 Hz AC, 330 watts. **Wall mounting (mask):** 15 5/16" H x 24 3/16" W. **Chassis room:** 17½" H x 26" W x 18" D (This is with ¼" clearance on both sides and the top).

Install In A Wall Or Either Assembled Heath Cabinets

Contemporary Walnut Cabinet

Factory assembled of beautiful walnut solids and veneers with an oil-rubbed walnut finish. The GR-180 speaker is mounted behind right side of one-piece picture-control panel mask. Measures a compact 18¼" D x 28¼" W x 29" H.

Assembled GRA-180-1, 41 lbs. (REA or motor freight) **$49.95**

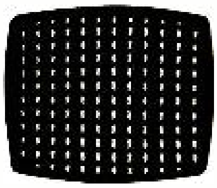
Deluxe Early American Cabinet

Factory assembled with a special combination of maple veneers and solids, finished in popular Salem-Maple. GR-180 speaker mounts on right side of one-piece face mask. Measures 18¼" D x 28¼" W x 31¾" H.

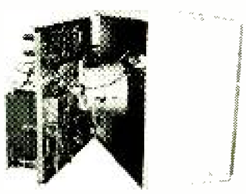
Assembled GRA-180-2, 48 lbs. (REA or motor freight) **$75.00**

Regardless Of What You Pay For COLOR TV, It Can't Perform As Well As These Two HEATHKIT® Models...

Exclusive Features That Can't Be Bought In Ready-Made Sets At Any Price!

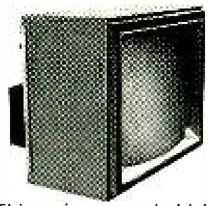


All color TV sets require periodic convergence and color purity adjustments. Both Heathkit color TV's have exclusive built-in servicing aids, so *you* can perform these adjustments anytime . . . *without* calling in a TV serviceman . . . *without* any special skills or knowledge. Just flip a switch on the built-in dot generator and a dot pattern appears on the screen. Simple-to-follow instructions and detailed color photos in the manual show you exactly what to look for, what to do and how to do it. Results? Beautifully clean and sharp color pictures day in and day out . . . and up to $200 savings in service calls throughout the life of your set. No other brand of color TV has this money-saving self-servicing feature!



Vertical Swing-Out Chassis!

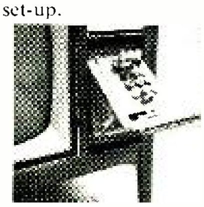
All parts mount on a single one-piece chassis that's hinged to make it more accessible for easier construction, care and installation.



Exclusive Heath Magna-Shield!

This unique metal shield surrounds the entire picture tube to help keep out stray external magnetic fields and improve color purity. In addition *Automatic Degaussing* demagnetizes and "cleans" the picture everytime you turn the set on from a "cold" start . . . also permits you to move the set about freely without any manual degaussing. A mobile degaussing coil is included for initial set-up.

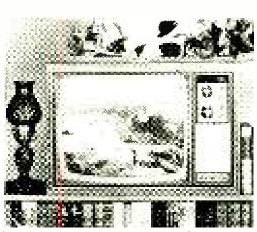
Convergence Control Board



. . . for fast, easy dynamic convergence and gray scale adjustments any time *you* decide color purity needs it. If you install the GR-295 model in any of the 3 optional cabinets, this board is mounted behind the special "tilt-out" speaker grille section. If you install the GR-180 model in any of its optional cabinets, the board can be temporarily mounted on the bottom of the cabinet underneath the tube face when making adjustments. In either case, there's *no* awkward reaching around the back of the set, or mirrors to set up. In addition, the GR-295 has a *Universal Main Control Panel* that can be mounted at the bottom, top or right side of the picture tube for more flexible in-wall installation.

Here's Why!

Your Choice Of Installation!



Another Heathkit exclusive! Both color TV's are designed for mounting in a wall or your own custom cabinet. Or you can install either set in a choice of factory assembled and finished Heath contemporary walnut or Early American cabinets (see opposite foldout).

From Parts To Programs In Just 25 Hours!

And no special skills or knowledge needed. All critical circuits (VHF and UHF tuners, 3-stage IF assembly and high voltage power supply) are prebuilt, aligned and tested at the factory. The assembly manual guides you the rest of the way with simple, non-technical instructions and giant pictorials. It's like having a master teacher at your elbow pointing out every step of the way. You can't miss.

But Don't Take Our Word For It. Read What The Experts And Owners Say!

Hubert Luckett, Executive Editor, Popular Science Magazine: "*Building your own color TV from a kit is not as outrageously impractical as you might suppose. For those who tremble at the thought of tackling something so fantastically complicated, let me encourage you with a borrowed quote: 'The only thing you have to fear is fear itself'.*"

"*The second most impressive thing about the kit is the instruction manual (the most impressive thing is the viewing quality of the color picture). If you can read and understand ordinary English, the manual is like having a master teacher at your elbow pointing out every step.*"

"*— the circuitry, features and performance match or exceed those of sets selling at twice the price. Some of the features, such as the built-in servicing aids, can't be bought in ready-made sets at any price.*"

"*With the instructions supplied, your experience in assembling the kit, and the self-servicing features built-in, you'll be able to do most servicing yourself.*"

John Drummond, Technical Editor, Popular Electronics Magazine: "*. . . we simply had to know how well a 25 hours-to-build color TV kit would stack up against the more expensive, well-advertised wired sets people are gobbling up. It didn't take us long to find out that the Heath GR-295 compares favorably with the best of them.*"

Radio-TV Experimenter Magazine, Oct-Nov. '66: "*Over the life of a color set, repair and service call costs can exceed $200. But, build the color set yourself and you will save several hundred dollars in repairs plus wind up with better color as you'll align the color reception to what you — not a serviceman — thinks is good to look at.*"

Robert F. Scott, Radio-Electronics Magazine: "*Friends who've seen my Heathkit GR-295 generally ask, 'Why can't I get a good picture like that on my color set?'*"

Audio Magazine, May '66: "*. . . sets similar in appearance seem to run around $700, without the built-in service features like the dot generator. Add to this the saving in service costs which the average set would require, since the builder would undoubtedly service his own set throughout its life, and the Heathkit GR-295 is a real bargain.*" "*Besides that, it is capable of a great picture*".

Mr. Robert D. Taylor, Sacramento, Calif.: "*. . . it's the best TV on the market, nothing compares with it (I have been looking at and checking TV's over 2 years). The manual (service) is a 'gold mine' of savings.*"

Mr. C. A. Petrarca, West Caldwell, N. J.: "*We are still getting oohs, ahhs, 'best I've ever seen', 'how bright the colors are', etc. from our friends and neighbors.*"

Mrs. Joseph Gesswein, Bethesda, Md.: "*If a housewife with 3 children under 4 years old can successfully build it in her few spare moments, it has to be good.*"

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World's Largest Electronic Kit Catalog!

Describes these and over 250 kits for stereo/hi-fi, color TV, amateur radio, shortwave, test, CB, marine, educational, home and hobby. Save up to 50% by doing the easy assembly yourself. Mail coupon or write Heath Company, Benton Harbor, Michigan 49022

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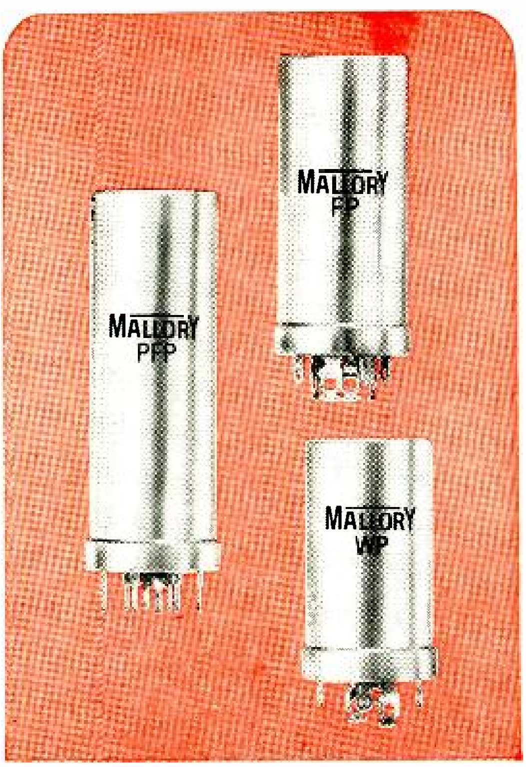
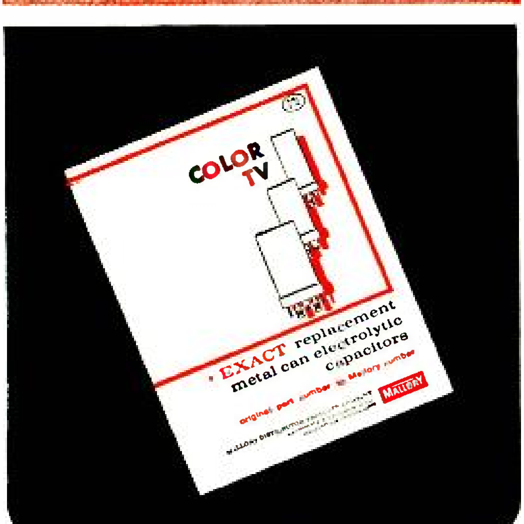
CIRCLE NO. 108 ON READER SERVICE CARD

MALLORY **Tips for Technicians**

Choosing electrolytic capacitors for color TV





When you need to replace an electrolytic capacitor in a color television, it pays to select the best. Your customer has a lot of dough invested in his color set, and he won't settle for less than top performance. And his eye can see sub-standard performance in color that would go unnoticed in black-and-white.

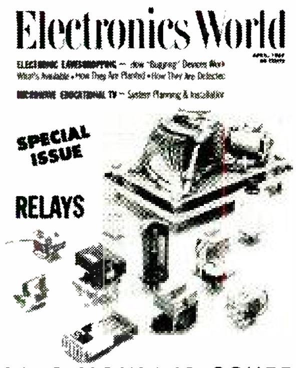
Color TV is tough on electrolytics. Ambient temperatures run hotter, because of the greater number of tubes and resistors inside crowded cabinets. Ripple currents are higher, so the capacitor has to do a better job of getting rid of internally generated heat. Voltage ratings are higher, too; most electrolytics in color TV are 400 volts or higher.

It's no surprise that leading color TV makers are pretty darn particular about the electrolytics that they use as original equipment. They demand a true high-voltage, high-temperature, high ripple capacitor . . . not one that's simply made to sell at bottom price. And meeting these demands is the way Mallory got to be the top supplier of electrolytics for color TV. We're the guys who pioneered the 85°C capacitor, who have consistently increased ripple current capacity, and who have the reputation of leadership in high voltage ratings.

Here's our tip of the month. To save yourself time, get a copy of our new cross reference, "Exact Replacement Metal Can Electrolytic Capacitors for Color TV". It lists the original part number and the catalog number of the corresponding Mallory replacement for 38 leading color TV manufacturers. To save yourself costly call backs, use only the best . . . and that's one of the Mallory FP-WP series, made to original equipment specs. To get everything you need for color TV service, see your Mallory distributor. He stocks Mallory power resistors, circuit breakers, carbon and wire-wound controls and Discap® ceramic capacitors.

For a copy of the Color TV cross reference, ask your Mallory Distributor, or write to Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

CIRCLE NO. 106 ON READER SERVICE CARD



THIS MONTH'S COVER shows a grouping of representative relays of various types that tie in with our special section on "Relays". Several of these relay samples have been cut away in order to show details of coil or contact construction. For example, the relay in the center of the photo is a mercury-wetted contact type in a metal case with an octal plug. The unit at the very bottom of the photo is a sealed-contact reed relay with four of the reed capsules showing. Our thanks to the following relay manufacturers who supplied samples for our cover photo: Automatic Electric Co., C.P. Clare, Cornell-Dubilier Electronics Div., Guardian Electric Mfg. Co., Magnecraft Electric Co., Potter & Brumfield Div., and Sigma Instruments. ....
....(Photo: Bruce Pendleton)

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MONTHLY FEATURES

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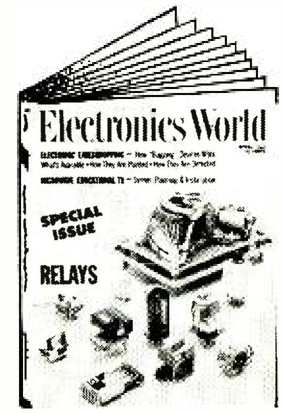
COMING NEXT MONTH



SPECIAL FEATURE ARTICLES ON:

Automotive Electronics covering **New Ideas on Automotive Safety Devices,** the **Electric Car and its Future, D.C. and A.C. Motor Drives for Electric Cars,** and **New Applications of Solid-State Devices in Cars. Also . . .**

The Automobile Diagnostic Center—the new look in service techniques—automatic devices provide complete, accurate analysis—eliminating guesswork.

IC Engine Tachometer and "Red Line" Indicator—interesting application of integrated circuits to automotive electronics. The circuit, which can be constructed by the reader, turns on a red warning lamp at some predetermined value of engine rpm, enabling the driver to shift gears at the correct rpm or warning him that his engine is now hitting its rpm limitations.

FET CIRCUITS
Six simple, low-cost circuits which can be built to demonstrate many of the principles of FET operation. Included are a source-follower, amplifier, oscillator, stretcher, and linear gate.

SELECTING AND USING PULSE GENERATORS
Basically a lab version of the square-wave generator, but with adjustable "on-off" times, a pulse generator has many applications in developing digital circuitry, in checking diode and transistor switching times, as a klystron modulator, and for impulse testing. This article explains the important applications.

RADIO MEASUREMENTS IN SPACE
Scheduled for an early launch is a new satellite which will be used exclusively for astronomical purposes. An array of space antennas, with 750-foot elements, is an interesting feature of this new vehicle.

SELECTING FREQUENCY AND TIME STANDARDS
The important standard specifications—including stability—are covered in depth in this article on precision oscillators.

All these and many more interesting and informative articles will be yours in the May issue of ELECTRONICS WORLD . . . on sale April 20th.

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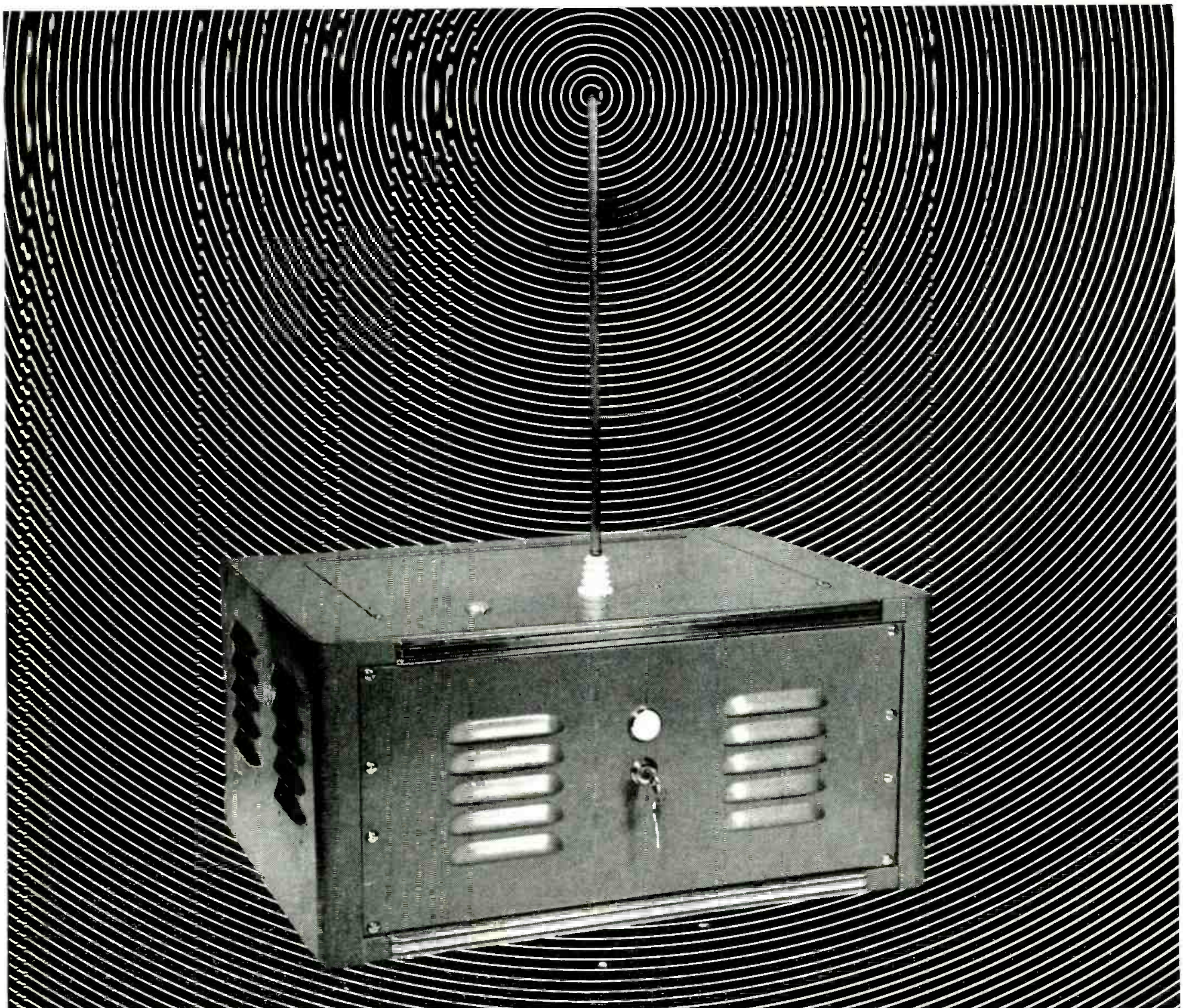

You are now in Radar Sentry Alarm's r.f. microwave field. Don't move a muscle!

This security system is so sensitive, it can be adjusted to detect the motion of your arm turning this page.

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Just this: Radar Sentry is no ordinary alarm. It is the most modern and effective security system available. And it's also electronic.

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It's been proven time after time. In fact, many of the more than one thousand readers of electronics magazines who became Dealers in the past year—sold a system on their *first* demonstration.

And that's why we need men with technical knowledge and experience.

Men like *you*.

How about it?

Do you want to start a business of your own . . . or expand your present business with a product that in 8 years has become the world-wide leader in its field?

Do you want to earn up to $5,000 a year in your spare time?

Do you want to earn $20,000 and more full time? We'll show you how.

O.K., now you can move.

Fill out the coupon and get complete Dealer/Distributor information . . . free.

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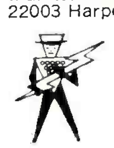

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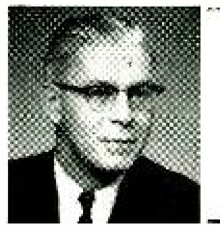

For the record

WM. A. STOCKLIN, EDITOR

COMPUTERIZED SERVICING

IT is a well-known fact that the service business is booming—yet to many it may come as a surprise that quite a few large service organizations are showing less profit now than in previous years. Whenever the volume of business goes up and profits go down, something is wrong. It seems that, as our technology advances and consumer products become more sophisticated, service profits decrease.

Good technicians are hard to come by and service managers do not foresee any immediate solution to the problem. In fact, many predict that the problem will get worse as time goes on.

Statistics have shown that approximately 80% of all house calls on monochrome sets require only tube replacement. In these receivers, even the trial and error method of tube substitution did not take too long. Now that color-TV receivers begin to represent an appreciable portion of house calls, their greater number of tubes plus the fact that antennas and color adjustment problems account for many additional troubles, has changed this percentage considerably. More time is spent per house call and the number of call-backs has also increased.

In addition, color circuitry is somewhat more sophisticated than its black-and-white counterpart and many service technicians are finding that they are taking much more time to isolate troubles. Even today's color sets are sufficiently complex to warrant a factory service engineer to solve the more difficult problems. Imagine the degree of technical knowledge that will be required when integrated circuit designs become commonplace.

Alert service managers are not only aware of the present problem but realize that the future looks pretty dim. It is inevitable that in the not-too-distant future all TV sets will be designed around integrated circuits.

Integrated circuits are supposed to last indefinitely; therefore it is apparent that there will be fewer service calls per set but, on the other hand, each call will present a more difficult service problem. It is possible that if the competence of the service technician who goes into the home does not improve materially, it may be necessary to pull every service job into the shop for repair. If we consider a house call at the rate of $5 and an additional charge of $10 for pulling the set into the shop, the consumer is then faced with a minimum bill of $15 before any work is done. Even if technicians with a much higher degree of technical knowledge could be found, their pay rate would be beyond that which the industry could afford.

There is no immediate fool-proof solution, but during a recent meeting with several service managers some ideas were discussed.

Why not go back to an old idea of having the set manufacturers bring out a multiple array of test points and then have an automatic tester provide a complete analysis of the set's performance. *RCA* tried this not too long ago. A special run of sets which were designed specifically for installation in motels, hotels, schools, etc., were built with various test points easily accessible from the rear; the idea being to save the *RCA Service Co.* considerable service and maintenance time. The Receiver Division obviously did not want to be charged with this extra cost; therefore, the Service Co. agreed to a fixed fee per set. The total cost amounted to about $800,000. The entire idea resulted in a financial loss since, as it turned out, *RCA Service Co.* only serviced about 10% of the sets.

It should be obvious that not many TV set manufacturers will spend additional money simply to provide added convenience for the service technician.

Another thought came up regarding the modularizing of TV sets. Although we know of one manufacturer doing this, we don't expect others to follow, in view of the additional cost.

The most promising idea is to computerize servicing. Why not? The medical profession is doing it now, at least in an experimental way, where symptoms of heart patients are fed into a computer. What about the auto industry? Automobile diagnostic centers are becoming widespread. So why couldn't servicing of TV sets be handled the same way? Why couldn't all the symptoms of a specific color set be programmed into a computer? This can be done to such a degree that every component, even every resistor and capacitor, could be isolated as a possible source of trouble. A service technician would then simply phone in all obvious symptoms and the computer would give him a complete list of possible trouble sources and even go so far as to suggest what would be the proper test procedure to isolate the trouble.

There are computer centers in all major areas of the country and all of them are willing to share time. Any TV service technician, whether or not he is independent, would then have the opportunity (on a fee basis) of availing himself of this service.

This idea, even though it may sound rather far-fetched, is not so remote. One service organization today is considering allocating a sizable sum of money to investigate the practicality of this idea.

It seems that in time everything will be computerized. Why not servicing? ▲

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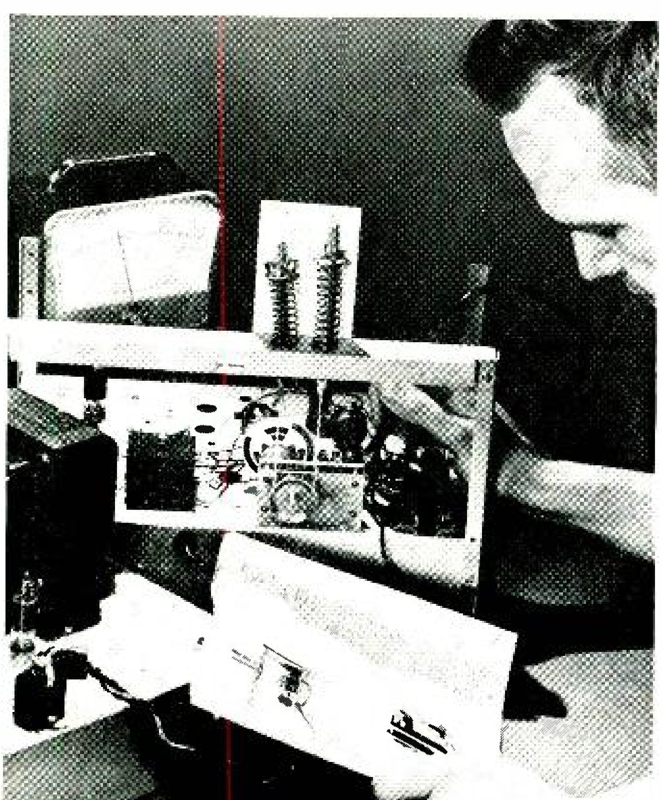
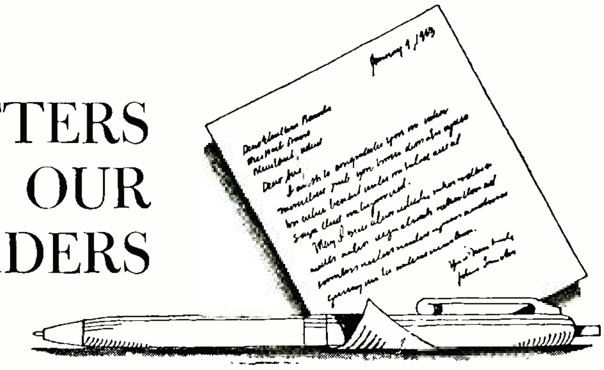


LETTERS FROM OUR READERS



TIME DOMAIN REFLECTOMETRY

To the Editors:

Since displaying reprints of John Lenk's article "Time Domain Reflectometry" (September, 1966 issue) in our department and since my letter requesting these reprints appeared in your magazine (November, 1966, p. 12), several surprising things have happened. *Hewlett-Packard* sent us a pound of application notes, for which we are grateful. Professor H. L. McKinley of our department saw the display and said, "That's nothing new; for years we had an experiment in our communications laboratory doing the same thing."

Also, I received a letter from Professor M. A. Honnell pointing this up more specifically. A copy of the letter from this creative and kind gentleman is enclosed. The article he published on time domain reflectometry was entitled "Location of Line Faults" and appeared in the November, 1944 *Electronics*.

John B. Peatman
Asst. Professor
School of Elec. Eng.
Georgia Inst. of Technology

Professor Honnell is currently Professor of Electrical Engineering at Auburn University (Auburn, Alabama). His letter said in part: "Time domain reflectometry originated at Georgia Tech. We used to run an experiment on TDR regularly in the communications laboratory courses. The enclosed reprint is the first published reference on TDR. You will find that many basic concepts are rediscovered every twenty years."

This, of course, is quite true. However, pulse generators and oscilloscopes are so much better today, thereby permitting better resolution and higher accuracies with this technique.—Editors

* * *

PATENT APPLICATIONS

To the Editors:

In his letter in the December, 1966 issue (p. 6), T. R. Parkhill criticizes Author Lancaster for deficiencies in his explanation of class-D amplifiers. As a patent attorney, I feel compelled to criticize Mr. Parkhill for making incorrect statements about patents.

Mr. Parkhill stated that a patent application was now "under study" by the Patent Office and that this application was jointly held by two other men. Actually, after a patent application is filed in the Patent Office it awaits its turn (usually several years) and it is then *examined* (not "studied"). Thereafter it is usually reexamined (after some argument) and ultimately it is either finally rejected or allowed (patented). Inventors do not "hold" their patent applications; after an inventor files an application, he is considered an *applicant*. If the application is patented, the inventor will then "hold" the patent (if it hasn't been assigned to an employer).

Aside from the above inaccuracies in terminology, Mr. Parkhill's most flagrant error is in stating that "Due to the restrictions imposed by patent laws, a paper describing this development has never been published." The patent laws contain *no restriction whatever* on publishing a paper on the invention of a pending patent application or on a patent; as a matter of fact, just the opposite is true. By giving an inventor the enticement of a 17-year monopoly on his invention, the patent system is supposed to *encourage* inventors to publish the details of their inventions early so as "to promote the progress of science and the useful arts." (U.S. Constitution, Article 1, Section 8). This is the main purpose of the patent system.

Under the U.S. patent laws, the details of an invention can even be published up to one year *before* an application on the invention is filed. (Since certain other countries do not have this one-year provision, many companies will not allow their inventors to publish details of an invention until an application is filed in order not to jeopardize their foreign filing rights.) Thus, whatever the reason Mr. Parkhill did not publish his invention, it was not due to the restrictions imposed by patent laws.

David Roy Pressman, Atty. at Law
Philadelphia, Pa.

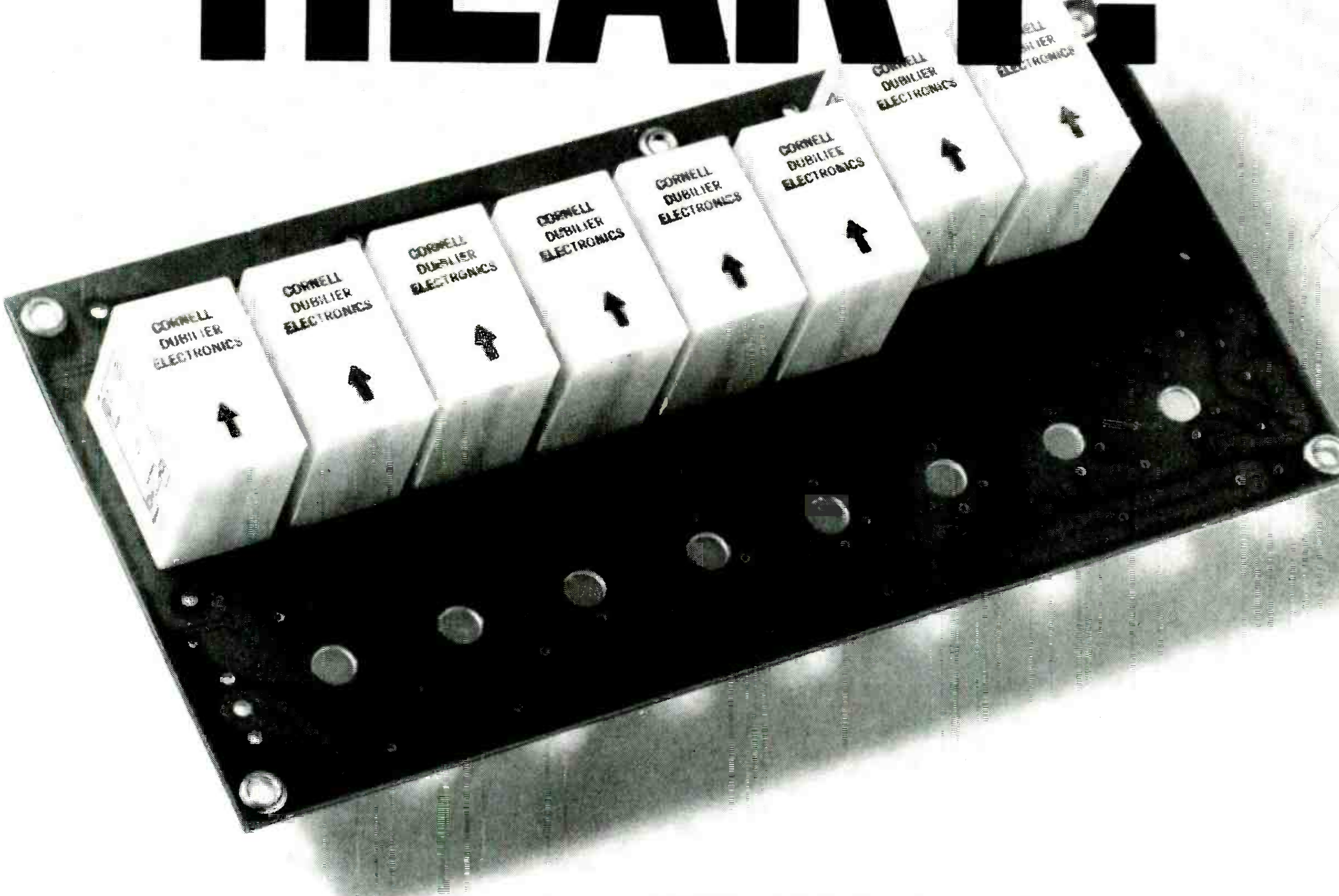
* * *

PARALLEL RESISTOR CALCULATIONS

To the Editors:

Reference is made to the slide-rule procedure for calculating parallel resistor values by Mr. Shu H. Loui on p. 60 of your October, 1966 issue and to Mr. Andrew M. Chao's letter on p. 12 of your January, 1967 issue. Mr. Chao

THE HEART!



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calls attention to a similar item published by him in the February, 1966 issue of *Electronic Design* magazine.

The same modification of the parallel resistance formula to adapt it for slide-rule use, and the slide-rule procedure for any number of parallel resistors, is developed on pp. 465-66 of *Elements of Mathematics for Radio, Television and Electronics* by Bernhard Fischer and Herbert Jacobs, 1954. *The Macmillan Co.*, New York. I doubt if Professor Fischer would claim discovery; he probably picked it up from some earlier source.

The above textbook reference is submitted with the thought that it may be of some value in settling uncertainties between Messrs. Loui and Chao as to relative priorities in the development of this procedure.

PAUL AKIN
Glendale, Calif.

To the Editors:

Concerning the method of calculating parallel resistance in your October issue, this method was shown to me in 1957 by one of my students when I was at the electronics school at Keesler AFB, Mississippi.

HELMUT E. FUCHS
Virginia Beach, Va.

* * *

THE DAMPING FACTOR DEBATE

To the Editors:

This is in reference to the article "The Damping Factor Debate" in the January, 1967 issue of ELECTRONICS WORLD. The only point I would like to accentuate is that if your table is correct (and it is), then your verbal description for computing the actual over-all damping factor for a wide range of generator impedances is not.

Mr. Augspurger stated just under Table 1 on p. 47: "The actual damping factor values are computed by adding R_s and R_{vc}, then dividing *by* the rated load impedance." It should be just the other way around.

J. J. VALENTE
Western Electric Co.
Winston-Salem, N. C.

Reader Valente is right. It is just necessary to change the word "by" in the above sentence to "into" and the statement as given is correct.—Editors

* * *

CRYSTAL-SAVING SYNTHESIZER

To the Editors:

With reference to my article "Crystal-Saving Frequency Synthesizer" in your December, 1966 issue, a patent number was given incorrectly. The correct number is 3,233,192. The number given was the file serial number.

F. PATTERSON SMITH, R & D
National Aeronautical Corp.
Fort Washington, Pa. ▲

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				Volts	Volts	Volts		
				Min.	Min.	Min.	μA (Max.)	Volts
SDT9801	TO-3	SDT9901	TO-61	60	40	12	100	40
SDT9802	TO-3	SDT9902	TO-61	80	60	12	100	60
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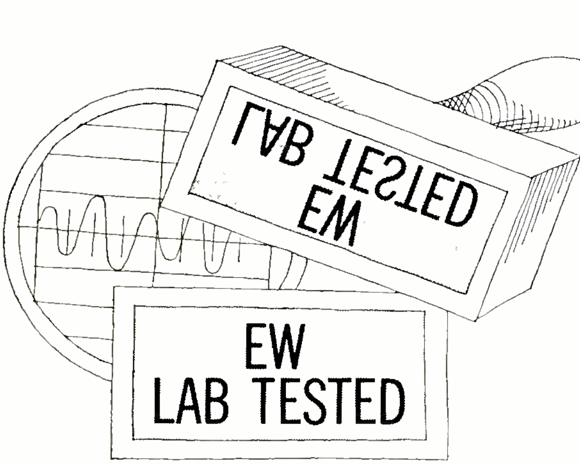


HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

KLH Model 12 Speaker System
Shure V-15 Type II Stereo Phono Cartridge

KLH Model 12 Speaker System

For copy of manufacturer's brochure, circle No. 21 on Reader Service Card

TO most audiophiles *KLH* is known as a producer of very fine miniature and compact speaker systems. Some of the earlier speaker designs, however, were far from compact and, in line with the current trend toward moderately large floor-standing speaker systems, the company has recently introduced its Model 12 acoustic suspension speaker system.

In the Model 12, the manufacturer has clearly aimed at bringing the highest possible level of sonic performance into the home. The speaker is a 3-way system containing a 12" woofer, two 3" mid-range units, and a 1¼" tweeter. The manufacturer states that the efficiency of the system is such that it can be driven by any good amplifier capable of delivering 25 watts into 8 ohms and our tests confirm this. The relatively high efficiency, compared to other acoustic-suspension designs, is made possible by the larger volume.

The system stands 29¼" high, 22¼" wide, and 15" deep and weighs about 85 pounds. It is handsomely finished in oiled walnut and has a unique remote contour control unit, quite unlike anything we have seen on other speaker systems. This is a small, flat box 9" wide, 10" deep, and 2⅜" high, finished in walnut to match the speaker

enclosure. It contains the crossover-network components, plus four switches which allow a limited control of the over-all system musical balance in segments of about 1½ octaves.

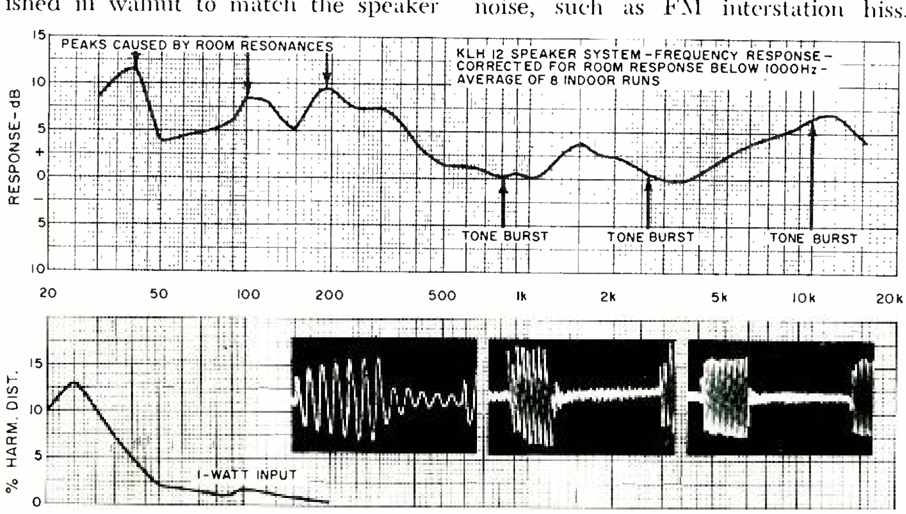
The frequency ranges affected by the contour switches are 300-800 Hz, 800-2500 Hz, 2500-7000 Hz, and 7000-20,000 Hz. The low bass response is left fixed as a reference level. Each control allows a slight boost or cut of the indicated frequency band. Anyone operating the switches casually might not detect any change in sound character. However, listening to broadband noise, such as FM interstation hiss, clearly reveals the effect of the contouring. This feature gives the discriminating listener the opportunity to tailor the system response to his own taste, in a manner not possible with conventional speaker level controls or amplifier tone controls.

Recognizing that the subtle effects of the contour control can only be appreciated from the normal listening position, *KLH* has provided a 40-foot, 4-wire cable to connect the contour control unit to the speaker system. The controls can be located at the listening position, where the speaker response can be trimmed to suit the requirements of the program material. If this type of installation is inconvenient, the control unit can be mounted on the rear of the speaker enclosure, where it is held by Velcro hook-and-pile strips. An 18" cable is provided for interconnection of the units when so mounted. The amplifier output must be connected to the contour control unit, never to the speaker itself. Thus, the location of the amplifier or receiver may influence the position of the contour control unit to some degree.

We measured the indoor frequency response of the speaker by averaging data from 8 microphone positions, with all contour controls set to their mid-positions. The over-all frequency response was very smooth and free from peaks or holes. Within each of the controlled frequency segments, the response varied less than ±3 dB. From 300 Hz down to 30 Hz, there was a ±3.5 dB variation, much of which was due to a room resonance at 40 Hz.

The harmonic distortion was under 2% down to 50 Hz, at a 1-watt drive level, and rose gradually to a maximum of 13% at 25 Hz. At 20 Hz the distortion was actually less than at 25 Hz, but the output fell off considerably. The tone-burst response, like that of other *KLH* speakers we have tested, was well-nigh perfect at all frequencies.

Good as these measurements were, they gave only a hint of the sound quality of the Model 12, which is nothing less than superb. It has an airy,



(*Continued on page 90*)

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electronic eavesdropping

"Bugs" in phones, furniture, cars, offices, and shirt pockets have become commonplace. Here is a survey of the field with detailed descriptions of what is currently available, how they work, and how they are detected.

By ROBERT M. BROWN*

IN a sensational eavesdropping disclosure last July, U. S. officials charged two Communist Czechoslovakian diplomats with attempting to "bug" the offices of Under Secretary of State George W. Ball using the system shown in Fig. 1. In this approach, the receiver portion of the bug kept the transmitter from operating by allowing the power relay to remain normally open. When the receiver picked up a u.h.f. unmodulated carrier of a certain signal strength, the relay would close, thus supplying power to the transmitter. In this way, the useful operating life of the mercury-cell power supply was appreciably extended. To prevent interaction between the bug transmitter and the external trigger transmitter, the bug unit operated about 40 MHz higher in frequency.

Interestingly, the plot was foiled not because of superior American countermeasure techniques (debugging methods) but because of the loyalty of a $9000-per-annum Department worker who informed on the Czechs to the FBI.

Similarly, U. S. Ambassador Henry Cabot Lodge shocked the civilized world in 1960 when he displayed the now-famous Great Seal (or Eagle) bug at the UN after revealing that it had been in operation, surreptitiously relaying confidential top-level conversations to the Russians, since the Soviets had presented it to W. Averell Harriman, then United States Ambassador to the Soviet Union, back in 1945. Like the recent Czech attempt, however, it was not alert American personnel who "found" the bug, but instead astute British technicians who accidentally tuned across its frequency one day.

Operation of this bug is shown in Fig. 2. Behind an opening concealed in the carving of the Great Seal was a silver-plated, high-"Q" resonant cavity coupled to a ¼-wave antenna that was also concealed within the carving. A metal diaphragm directly behind the opening closed one end of the cavity. When this diaphragm was moved by changes in air pressure due to speech within the room holding the Seal, it would change the resonant frequency of the cavity. Thus, if the cavity was supplied with r.f. at its resting frequency, when the diaphragm moved, the cavity in essence became a modulated oscillator. The beauty of this system was that it required no maintenance, batteries, or other internal power supplies and it operated only when the cavity was supplied with an accurate source of r.f. which could come from almost any point.

*Mr. Brown is the author of the book, "The Electronic Invasion" which will be issued this month by John F. Rider, Publisher, New York.

Outside the Embassy, a 330-MHz signal source located within an ordinary-looking van was aimed *via* a narrow-beam gain antenna at the Seal so as to excite the cavity. Another innocent-looking van, also equipped with a narrow-beam gain antenna aimed at the Seal, would then tune in on the bug and detect the now-modulated signal for recording.

After months of research and investigation, the British unearthed the cavity built into the wooden Seal and turned the matter over to the U.S. (Incidentally, the British tech-

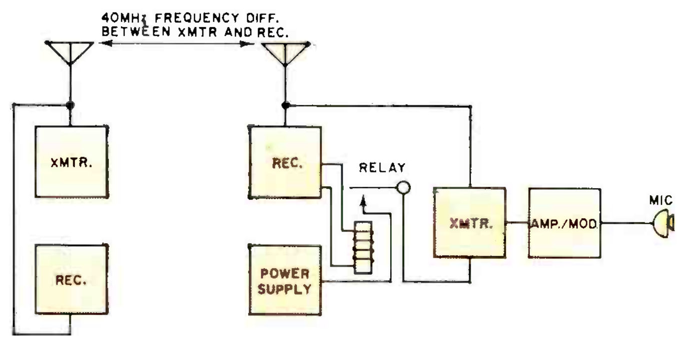
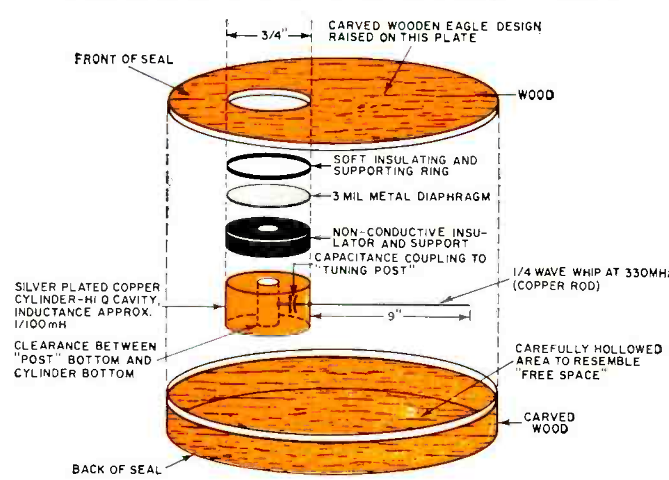
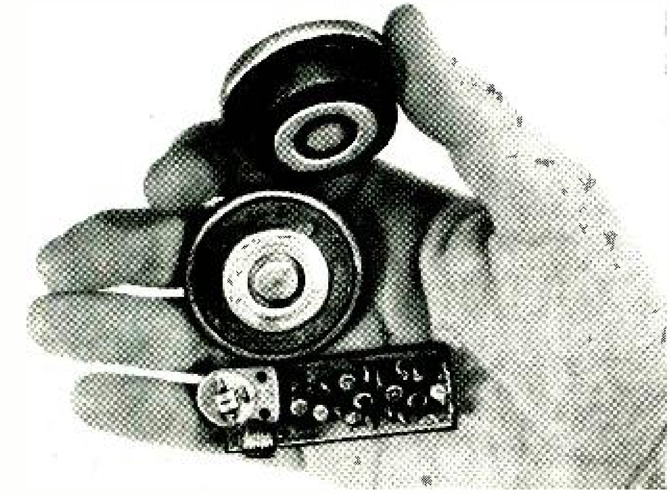


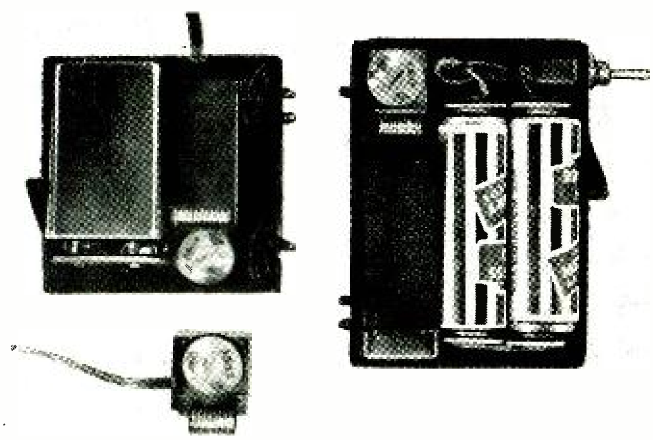
Fig. 1. In this bug, the u.h.f. carrier from a remote transmitter turns on the bug which operates about 40 MHz higher in frequency, thus extending the battery life considerably.

Fig. 2. The "Great Seal" bug concealed a delicately tuned u.h.f. cavity requiring no wires, maintenance, or batteries.





Experimental transmitter (bottom) is reworked for mounting around conventional phone carbon mike (center), then potted (top) to make direct substitute for phone mike. This does not impair normal phone operation. Both sides of the phone conversation are radiated a distance of approximately 300 ft.



Three units by Security Electronics. (Upper left) Battery-powered parallel phone tap operates when phone is picked up. Both sides of conversation transmitted about 1/4 mile. (Upper right) Self-powered wireless mike picks up sounds within 35 ft. R.f. range about 1/4 mile. (Bottom) Phone-powered series phone tap operates when phone is used. Transmits both sides of conversation 1/2 mile. All of these units are used in conjunction with specially modified FM set.

nicians also found 60 hidden microphones in the American Embassy building in Moscow while looking for the Seal bug.)

To reduce the future possibilities of illicit r.f. intrusion, in some of our Embassies overseas use is made of elaborate "silent rooms" whose walls also contain layers of r.f. screening material. These rooms are thoroughly tested for acoustic and r.f. tightness in the United States, then disassembled and shipped to the required Embassies where they are reassembled within the confines of a normal room (of sufficient size to accommodate the silent room), and retested once more. Any power lines entering the silent room are thoroughly bypassed to remove the last vestige of possible r.f. exit. Even the doors are double-screened and have numerous electrical contact "fingers" to assure absolute r.f. screening. There are no phones or other electrical devices within the room, thus ensuring that confidential discussions can be carried on without the probability of electronic snooping.

Bernard Spindell, renowned New York electronic eavesdropping expert, publicly stated at a symposium last November that key American government officials are "backward to the sophistication of modern electronic espionage and at least 10 years behind the (eavesdropping) industry". To make matters worse, though, Spindell added that "the government is afraid to admit to its faults in this area, and will almost never call in outside 'experts' for fear that this disclosure of technical incompetence might work to the advantage of the civilian professional." This might well explain the revelations of 1960 and 1961.

The Electronic Eavesdropping Industry

Electronic snooping in various stages of technical sophistication is today a big business for a relative handful of U. S. companies (their number approaches 30, although less than 10 capture most large industrial and governmental sales). Some, like *Mosler Research Products* (Conn.), *Kel Corporation* (Mass.), and *Fargo* (Calif.), concentrate on "aiding" such Federal branches as the Bureaus of Customs and Narcotics, while the rest do an estimated $20 million annually in the industrial and personal market areas. Headed by such names as *Continental Telephone & Supply Co.*, *Miles Wireless Intercom Co.*, *Security Electronics*, *R. B. Clifton*, *L. N. Schneider*, and *Silmar Electronics*, these companies specialize in equipment that often surpasses that offered the government through conventional channels yet is legally available to anyone with enough money. Although the suppliers are geographically headquartered in New York and Miami, the vast majority enjoy mail-order sales that are heavy in the Midwest and South and strongest in Southern California.

In addition to offering a diverse selection of electronic snooping devices (one even offers a mail-order course on modern eavesdropping), several have made the plunge into antibug or "countermeasure" equipment, which generally consists of r.f. field detectors and white-noise generators. Although the market for this type of apparatus is extremely small, it affords the intelligent distributor the opportunity to "go legitimate" in its advertising while at the same time creating convenient tax losses.

Bugging the Telephone

While there still exist such antiquated devices as the phone pickup coil and other induction contraptions found in almost every electronic parts supplier's catalogues, today's telephone "listener" prefers a more professional approach. It should be pointed out, however, that because these high-impedance inductive pickups do not make an actual metallic contact to the phone line, they draw no current from the line, thus making them very difficult to detect by conventional telephone line monitoring equipment. Though the government still leans toward the direct wire taps and "third-wire" techniques (it is possible to rearrange the wiring within a desk telephone so as to render the microphone circuit active even when the phone is on the hook), the civilian eavesdropping establishment is busy with the not-so-dangerous all-electronic r.f. gadgets which are infinitely simpler and less costly to install.

Reverting to induction in some instances, one type used primarily by private investigators and industrial executives employs a modified induction coil operating from the magnetic field that exists around the hybrid transformer in the telephone to modulate the transmitter. With a stage of amplification after the coil, it is possible to disguise the FM transmitting device in a number of ways, permitting normal proximity to the phone without having the device spotted. Two such items, for example, operating in the standard 88- to 108-MHz FM band are a "diary" sold by New York's *L. N. Schneider* and an "ashtray" marketed by *Tritron* of Dallas, Texas. Powered by *Mallory* "Duracells," these 100-milliwatt bugs can run for weeks, continuously relaying both sides of a conversation to the remote receiver. A variation on this theme consists of the same device with a subminiature *Sennheiser* microphone element added to take up the slack (normal room conversations) between phone calls. Thus, the eavesdropper has a combination room bug and telephone device.

By far the most popular, however, are the insertion bugs

—r.f. devices hooked directly to the phone line in one way or another. The most convenient of these consists of a transistor oscillator centered on 89 MHz and mounted on the backside of a standard carbon phone button. Carefully balanced so as not to disrupt the impedance of the telephone circuit, in practice the eavesdropper merely unscrews the regular mouthpiece cap from the phone and replaces the carbon button with the bug. Thus, both sides of all calls can be monitored. Since it is powered entirely by the phone current, the device can theoretically run forever on an automatic basis. See the upper photo on page 24.

The only drawback is its distance capability, restricted by lack of a suitable antenna. Normally, the device is coupled to the phone wires for an r.f. range of 200 to 2500 feet. An example of such a device is shown in Fig. 3. In this circuit, note that the rectifiers do not use filters of any description. Therefore, the transmitter is modulated by a d.c. voltage that is an instantaneous function of the voice frequencies existing on the line. Such equipment costs from $199.95 to $250, depending upon the distributor.

Most insertion devices, however, are priced between $70 and $200 and are identical to the unit just described except that they must be concealed in the phone base, at the terminal, or elsewhere on the line. These are frequently more practical, since a small length of wire cut in wavelength multiples can be employed effectively as the antenna, although they necessitate a somewhat more time-consuming installation. Typical of these is *Security Electronics*' SE-419 which measures only 1.5" x 0.7" x 0.7" but which can put out an 89-MHz signal for up to one mile. A series-coupled unit, it sells for $150 and employs another r.f. linear amplifier stage.

The most publicized phone bug, however, uses no r.f. field whatsoever yet achieves remote monitoring without the necessity of tapping the line. Dubbed the "harmonica bug," this ingenious configuration stands as the ultimate in bugging devices. Consisting of a subminiature resonant-reed decoder relay (such as the *Bramco Controls* model) and a miniature single-stage a.f. amplifier, the unit (see Fig. 4) is wired into the base of the victim's phone or at his terminal block on the premises.

Operation of this bug is about as state-of-the-art as eavesdropping suppliers can provide today. Essentially, the bug consists of two sections: one is a remote source of 500 Hz (either a blow-in harmonica-type device or an electronic audio oscillator) to be used by the remote eavesdropper, while the other portion contains a subminiature high-speed multi-pole relay activated by a frequency-sensitive decoder, and an audio amplifier, all contained within a package capable of being concealed within the telephone housing.

When this local decoder picks up a 500-Hz signal, the relay is activated, simultaneously opening up the bell-ringing circuit and transferring the microphone line to the audio amplifier which in turn feeds its output signal into the line that is returning to the eavesdropper.

In use, the eavesdropper dials the rigged remote telephone. However—and this is important—just after dialing the last digit, there is a time lapse of 2 to 3 seconds before the remote phone bell rings. During this period, the eavesdropper transmits his 500-Hz trigger tone down the line. The remote bell is deactivated before it can ring, and the remote microphone signal is now amplified and fed back to the eavesdropper. If another party dials the number during a period of surveillance, he will get a normal "busy" signal. In most cases, this does not arouse suspicion.

The VOX circuit shown below the resonant-reed circuit of Fig. 4 is presently being developed and should be available shortly. This circuit continuously monitors the voice circuit on the phone line, and if it "hears" a strong sound, such as when the phone is lifted from the cradle, the VOX circuit takes the bug out of the line, causing the phone to rapidly drop back to a normal operating condition.

VOX, as used here and in other parts of this article, is an abbreviation for voice-operated switch. In this type of circuit, use is made of the charge/discharge time constant of a large-valued resistor and capacitor combination when it is charged by the input signal and discharged by an active element (such as a semiconductor or vacuum tube) that in turn controls a switching relay. The relay, in turn, controls an external circuit. The elements of the VOX are arranged so as to operate the relay immediately upon receipt of a signal, while the adjustable time delay permits the relay to remain operative for some predetermined time after the signal ceases. This can occur during normal lulls in the conversation. Thus, the VOX is operative during all times that speech is taking place.

Although others have attempted to duplicate the original circuitry (*e.g.*, *Continental Telephone's* "Infinity Transmitter"), the original is still the device employed by professional eavesdroppers. Price varies from $699 to $1000, depending upon supplier.

As a defense against this type of bug, in some sensitive areas use is made of a white-noise generator that saturates the local phone line with a random noise signal (which sounds like a loud waterfall) when the telephone is not actually on the cradle. This electrical noise effectively masks any microphone signal being picked up if such a bug is used. Of course, when the local phone is physically lifted from the cradle, the white-noise signal stops, enabling normal conversation.

Room Bugs: Microphones

Since room transmitters are more prone to visual detection than insertion telephone bugs, miniaturization has become the vogue among modern keyhole listeners. Although a variety of cute items flood the market today (the "cufflink," "tie clasp," "fountain pen," etc.), their use is generally restricted to the portable personal recorder set and they

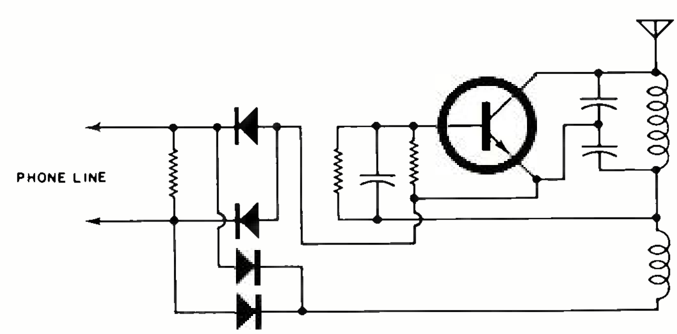
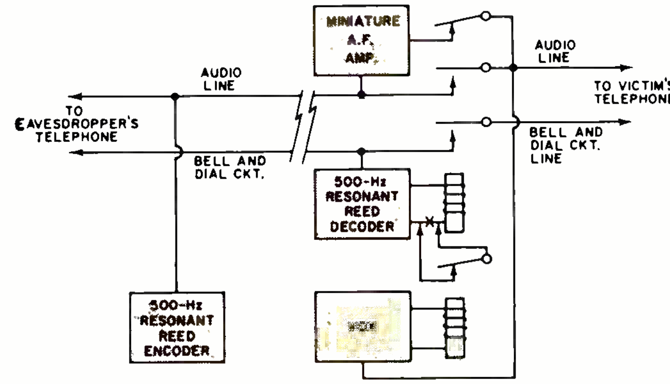


Fig. 3. Typical insertion bug mounts directly within the mike cavity of the telephone and derives both its power supply and modulation from the phone as it is being used.

Fig. 4. The "harmonica" bug makes use of the fact that a short time interval occurs just after dialing the last digit and before the remote phone rings. The name was coined because, originally, a harmonica was used to generate the trigger tone that caused the relay to operate.



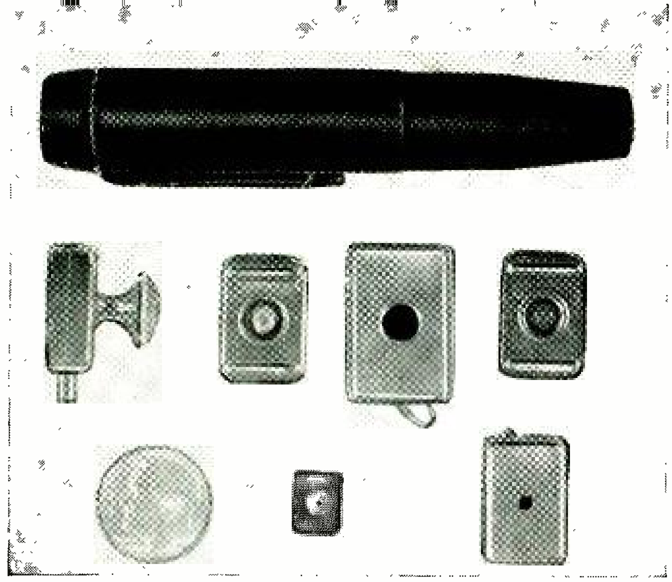


Fig. 5. A selection of tiny mikes commonly used in bugs. The sizes can be established by comparing with the dime.

are not really practical for room observation. The primary reason for this is that the same European microphone element can be purchased retail for $3 while the mounted cuff links and other devices generally cost anywhere from $25 to $50 apiece.

By and large, the most popular miniature design is the tiny rectangular model distributed in America by *Telephone Dynamics Corp.* for the hearing-aid market (see Fig. 5), although a few bug manufacturers use *Astatic* and *Electro-Voice* elements. The preferred types are magnetic designs which weigh less than one-fifth of an ounce; they are rated at a —60 dB sensitivity or so at 1000 Hz under a standard 2000-ohm load, since these preclude the need for matching transformers and are fairly rugged in terms of temperature variations and physical jarring. Most eavesdropping manufacturers simply mount the microphone atop an FM oscillator module and leave it at that, although a few interesting exceptions exist.

One of these is the fastening of a slender, hollow, flexible plastic tube to the front of the microphone element, resulting in something that looks very much like a snake (which is what it is called). This permits modern keyhole listening in deluxe fashion, though the preferred method is to drill a tiny hole through the wall, inserting the spaghetti tube for proper acoustical pickup. (This same technique, by the way, was what the Soviet technicians employed in the U. S. Embassy building in Moscow in some sixty places. The plastic tubing is extremely difficult to detect, since the remote microphone/amplifier stages are sufficiently far from the front of the tube so as to preclude effective detection by means of metal locators, the most widely used technique employed by U. S. government departments.) Almost everyone "home-brews" his own snake microphone, although one can be purchased commercially from *Continental Telephone* for about $30.

The spike microphone, another popular variation, is nothing more than a vibration or conductance device (similar in operation to a phono cartridge and attached needle) which is constructed in such a way as to render the spike as the extension of the normal contact surface. This type, too, sells for about $30. Also of 2000-ohm characteristics, the spike microphone has been used in emergencies by detectives and police investigators but is not generally employed since the conductance theory has never quite proven itself in the field. As one user explains, "Everything is fine until someone on the third floor flushes a toilet. That can ruin the most rugged pair of eardrums".

Room Bugs: Transmitters

Basically, these units consist of little more than a miniature microphone and a minimum-performance v.h.f. oscillator, "modified" from wireless microphones found in many electronic construction magazines.

On the whole, though, a wealth of comparatively sophisticated circuitry can be found if one knows where to look. Electronic research and development shops often fill in during slack periods with "custom-engineered" bugs for the larger suppliers, many of whom use the latest in high-powered v.h.f. semiconductors to achieve sought-after miniaturization and increased range capability. The general "minimum" range is 150 feet, although many transmit up to one-half mile from conventional transistor radio batteries.

Fig. 6 shows an example of two typical designs. In the first (A), FM modulation is produced by the varying audio signal changing the anode bias of the tunnel diode. With tunnel diodes, the characteristic curve is never perfectly linear in the negative resistance region, so the resonant frequency of the diode is affected enough to create an FM signal in step with voice frequencies. In Fig. 6B, the microphone output causes sufficient changes in the resistance of Q1 to vary the bias of Q2. With Q2's base-to-collector

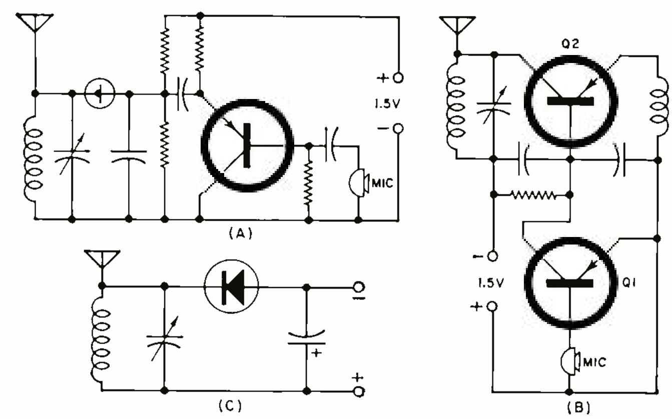


Fig. 6. (A) FM bug using a tunnel diode. (B) Another bug using two transistors. (C) The basic idea of "free power."

capacitance altered accordingly, once again frequency-modulated r.f. results.

Still in the development stage is the so-called "free-power" bug transmitter, widely publicized as the ultimate in present-day eavesdropping. As indicated in Fig. 6C, in theory it is essentially a tuned circuit followed by a diode rectifier and hefty storage capacitor. When the circuit is tuned to a high-powered local commercial broadcasting station, sufficient d.c. power can be generated to operate a very-low-power bug almost indefinitely. In practice, unfortunately, this proves to be less than enough for most FM transmitter circuits.

Bugging devices are available in a number of exotic styles, although most buyers are concerned with the transmitter element itself, leaving the concealment to individual circumstances. A few exceptions, however, are worth noting. *Continental Telephone* offers for $150 a "beautiful decorator" bedroom lamp with a built-in FM transmitter that uses the a.c. line cord as its inductively coupled antenna. *Mosler Research Products* makes available an exquisite framed reproduction of a church-in-the-valley scene. A tiny hole drilled through the wooden frame permits voices to reach the transmitter, which is crystal-controlled in the 70- to 72-MHz region. Large long-life batteries are strategically clamped in place to help balance the weight throughout the instrument, which is presented as a "gift" to the victim.

Of course, a radio or TV set can not only very easily conceal a bug but can also power it even when the front-panel "on-off" switch is turned off. In this case, the bug's power supply is connected to the a.c. line *before* the set's power switch. Also, in many cases it is possible to use the set's own loudspeaker as a microphone when the set is not in use.

In testimony before the Senate Judiciary Subcommittee on Administrative Practices and Procedures in Washington, D.C. on February 18, 1965, New York's Manny Mittleman revealed his "perfect bug". (See Fig. 7.) Designed primarily to conserve battery drain, this modified room bug has a built-in VOX circuit that can be adjusted for sensitivity and delay.

Once installed, the device is activated by the first click of the doorknob and operates whenever there is a sound in the room. It does not operate when there is silence (such as when the room is empty or at night when everything is quiet); therefore, it conserves battery capacity.

Note also that there is another VOX circuit used at the remote receiver. The addition of this element now makes the over-all system completely automatic, as the tape recorder will only start up when a signal is received from the bug. This not only conserves tape but requires no human monitoring, thus saving expensive operative time. Of course, the tape recorder is transistorized so there is no warm-up time and no loss of speech beginnings.

Mittleman remarked that "a private detective can install this several days in advance of whatever action he is interested in (for example, such as in an unoccupied motel room), and then when people get there it will turn itself on the minute they put their hand on the doorknob and it will stay on for as long as they continue to talk, walk around, or what-have-you." It can be purchased from *Steckler Sales Co.* (New York) for $450.

The VOX Phenomenon

Since a great deal of electronic eavesdropping is conducted by private agencies and independent investigators, it frequently becomes profitable for the client to "rent" the equipment and do the job himself, thus avoiding paying both the rental rate plus the $100-per-day-per-man fees imposed for the agents. Additionally, the agencies themselves often find FM-receiver monitoring not only tedious and time-consuming but also costly. The answer, quite naturally, lies in automation.

Simple voice-actuated relay circuit configurations like those sold for tape-recorder add-on applications are uniquely suited for this work. By coupling the VOX between the monitor receiver and tape recorder (as shown in the receiver portion of Fig. 7), virtually no manned listening is required except to periodically check frequency variations caused by declining battery currents and to make sure the tape hasn't run out.

Professional systems of "double-VOX," such as shown in Fig. 7, command the top rental fees since they cannot ordinarily be purchased commercially but rather must be custom-tailored. With this arrangement, another VOX circuit is added to the bug itself (as with Mittleman's "perfect bug"), which is crystal-controlled in design. By careful trial and error methods, current drain on the VOX is reduced to absolute minimum, greatly extending the life of the system and further reducing the likelihood of false starts at the receiving end.

Electronic "Tailing"

Two devices are currently sweeping the electronic surveillance marketplace: the bumper beeper and the high-powered car bug, both of which are elementary in design yet rugged and durable for practical use. Vehicular eavesdropping is generally split into two categories—"quick slap" and "internal"—which are determined by the time one has to make the installation and what distance requirements must be met.

Naturally, the quick-slap packages are the most popular, since they only necessitate the rapid affixing of a strongly magnetized boxed transmitter to the underside of the vehicle, letting the antenna wire trail as it may. Powered by self-contained mercury (or often nickel-cadmium) cells,

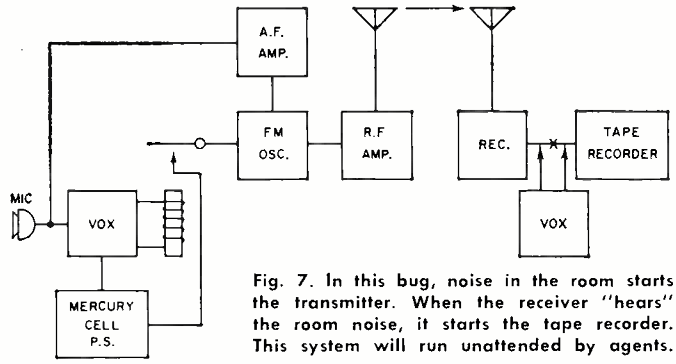


Fig. 7. In this bug, noise in the room starts the transmitter. When the receiver "hears" the room noise, it starts the tape recorder. This system will run unattended by agents.

these transmitters are modulated by pulsed tones, generally at 400 Hz, and are available in various frequency ranges from 35 to 160 MHz. A late addition, however, is the CB channel 3 (27-MHz) bumper beeper. This has been widely accepted for tailing because of its crystal-controlled design and the easy availability of a compatible receiver. *Fudalla & Associates* of Toronto offers a device for $75 that will operate on any of the 23 available CB channels.

Quick-slap bugs are also easy to find, although applications for car intelligence-gathering devices are rare and installation is somewhat more complicated. Essentially, these units consist of a simple room bug equipped with a noise-canceling microphone hidden under the dash or behind the glove compartment. Antenna wire is dropped through the engine compartment (using shielded RG-58/U *en route*) to the underside of the auto, where the wire is exposed and left trailing.

The internal devices are much the same except that they draw power from the car's 12.6-volt d.c. system and are coupled directly to the car's radio antenna for effective radiation. Many operatives even readjust the car's antenna height for maximum power output (and minimum s.w.r.).

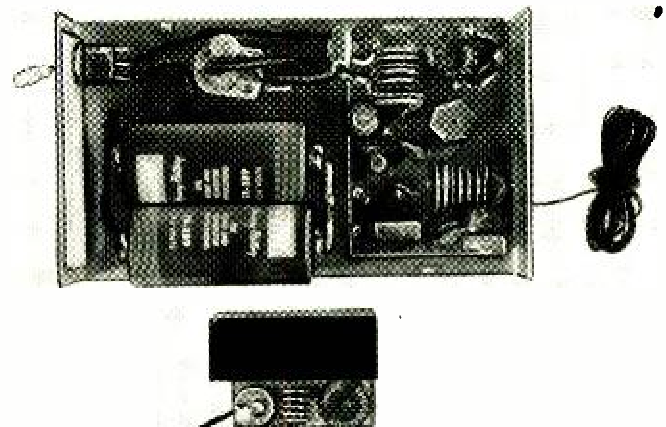
These same vehicle-buggers also make a point of adding an "S" meter to their mobile monitor receivers, which they find of great help in approximating distances. Others install another radio antenna on the opposite (left or right front) fender, phase the antennas correctly, and then take careful note of the resultant null when the suspect's car is directly in front of or in back of the bugger's auto.

Electronic Countermeasure Equipment

As indicated earlier, countermeasure (or debugging) equipment is not used to the extent that the mass media would lead one to believe, but it does exist and is interesting at least from a technical viewpoint.

Certain design packages are on the market for bug detec-

Two examples of tailing beepers. (Top) Large high-powered unit (shown uncased) is self-powered and attached to car by strong magnets. Antenna trails under car. Bottom unit is powered by vehicle battery and is mounted within car.



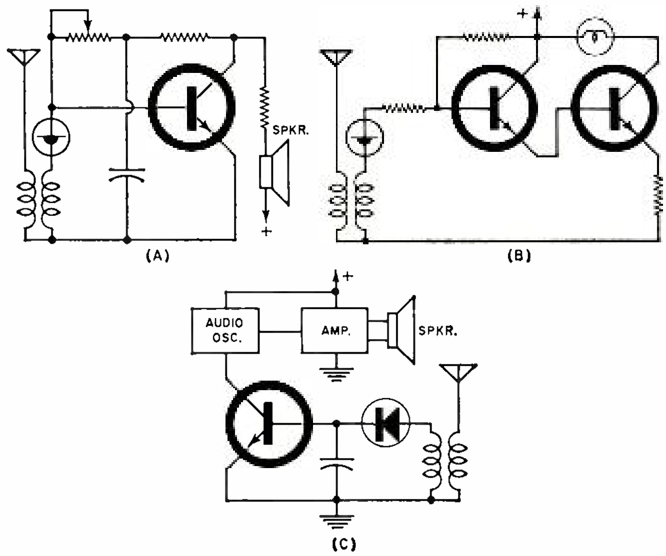


Fig. 8. Examples of r.f. field detectors. (A) The audio oscillator is triggered into operation by the tunnel diode. (B) When the tunnel diode detects an r.f. field, the light comes on. (C) The audio oscillator is turned on when the transistor saturates due to operation of the r.f. detector.

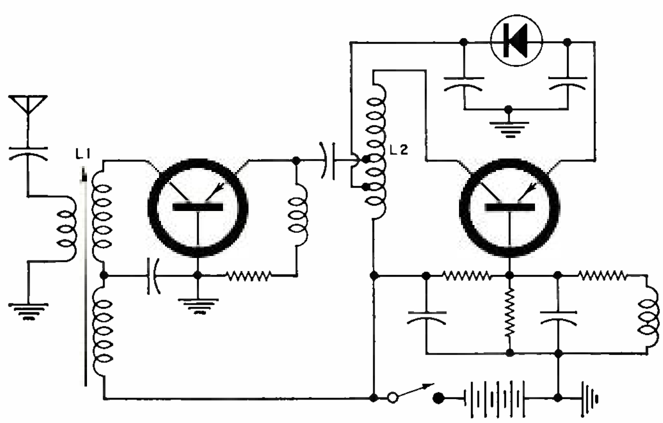


Fig. 9. R.f. white noise generators are supposed to flood area with r.f. noise, jamming any radio bugs in the room. The use of such devices is frowned upon by government officials because they interfere with legal communications.

tion which concentrate for the most part on r.f. transmitting bugs, although a few exist for telephone direct-line wiretaps. For example, for $250 one New York supplier has a repackaged telephone lineman's monitor meter, which samples the load on the line. If this load exceeds the level that the average phone in use actually consumes, a deflection past the clearly marked spot on the meter signals the wiretap. For practical purposes, however, it is good to remember that very few professional eavesdroppers would allow this to happen, since it would also trigger a "general area" meter at the downtown business office and the vicinity would soon be swarming with curious phone company investigators.

Metal locators also have their drawbacks, since metallic wall studs, steel reinforcements, and even finishing nails will register positively, necessitating a meticulous checkout of every reading. Most industrial paranoids abandoned this technique long ago.

This leaves detection up to r.f. field detectors, which amount to little more than souped-up (two or three stages of transistor amplification) field-strength meters. These devices may be quite simple, but they do work in close proximity to the concealed transmitter.

Tunnel diodes have also proved of use here. The circuit shown in Fig. 8A, for example, uses a tunnel as a broadband (untuned) r.f. detector. Essentially, this circuit is a normally quiescent audio oscillator that triggers into operation when a low-level r.f. signal is presented to the tunnel diode. In operation, the potentiometer is adjusted until the device is just on the fringe of bursting into audio oscillation. The detector is then moved around the suspect area until the antenna picks up an r.f. field. When this happens, the tunnel diode triggers the audio oscillator on, creating the loudspeaker tone. The potentiometer also acts as a sensitivity control and is adjusted so as not to trigger on any local broadcast station that may be coming into the same area. These detectors cost about $250 and are a specialty item of Houston's *Dee Co.* (Similar units have been sold for use as automobile sunshade-mounted devices for detection of police speed radars.)

A flasher variation as shown in Fig. 8B is also available, though few are in actual use. In operation, the actual indicator unit is placed on a desk while the antenna is located on the door jamb. When an operating r.f. bug passes the antenna (for example, carried within an innocent-looking package or concealed in a (*Continued on page* 88)

Legal Aspects

Transmitting Bugs: On April 8, 1966 the FCC adopted certain amendments to its Rules that were designed to prohibit eavesdropping. Although entered as a specific regulation (Part 2, Subpart H, Section 2.701), the Commission also spelled out the same ruling in Part 15 in two separate instances.

> "No person shall use, either directly or indirectly, a device required to be licensed . . . for the purpose of overhearing or recording the private conversations of others unless such use is authorized by all persons or parties engaging in the conversations."

Additionally, this exception was entered:

> ". . . this section shall not apply to operations of any law enforcement officers conducted under lawful authority."

This, however, only affects the use of those devices already functioning on the frequencies already under direct control of the FCC. Obviously, the Commission cannot apprehend all violators, since the vast majority of such equipment is extremely low power and used only for short periods of time.

On September 19, 1966 Congressmen Gallagher and Moss introduced legislation (H.R. 17826 and 17827) aimed at the ultimate destruction of the eavesdropping industry:

> "A bill to prohibit the shipment in commerce of electronic eavesdropping and wiretapping devices."

In essence, the legislation if enacted would give exception to law enforcement agencies and "any department, agency, or instrumentality . . . authorized to used such devices by Federal statute." It would take effect 180 days after passage.

The bills were promptly referred to the Committee on Interstate and Foreign Commerce, where they remained as Congress closed in November.

Telephone Devices: In this area no legislation is currently pending, although Sen. Edward V. Long's (Dem.-Mo.) Senate Judiciary Subcommittee is expected to propose drastic measures late in 1967.

Presently, the only agency which can become involved is the FCC, which holds as a violation of Rules Section 605 the "unauthorized interception" of telephone communications by induction-coupled devices or direct wiretaps. But for the FCC to take action there must be a clear effort to divulge the information obtained by eavesdropping or in any other way make evident its "beneficial" value.

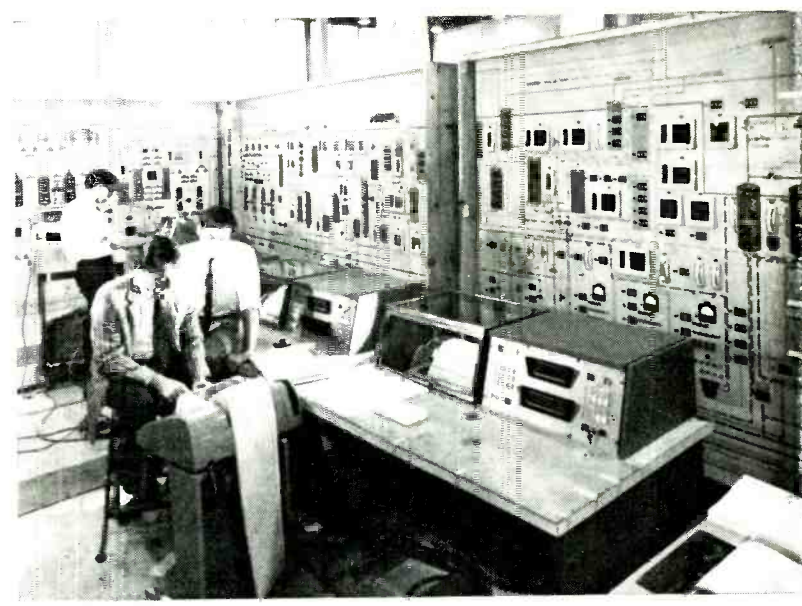
Although seldom enforced, many telephone companies have policies that read similar to this one issued by the Wisconsin Telephone Company:

> "No equipment, apparatus, circuit, or device not furnished by the telephone company shall be connected with the facilities furnished by the telephone company, whether physically, by induction, or otherwise, except as provided in this tariff."

The tariff permits only connection of radio facilities of the Armed Forces, the railroads, and mobile telephone systems.

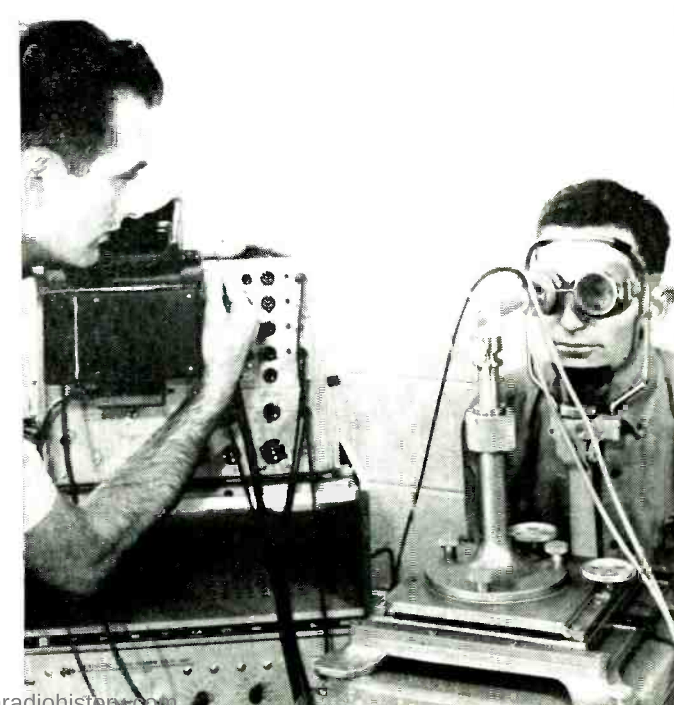
Morse Code Trainer. (Right) An electronic system which will provide individual audio-visual instruction in Morse code for 24 students simultaneously is shown here. Consisting of computer-controlled training consoles, the system was designed to speed training in the traditional "dot-dash" method of communication. A letter is transmitted to the student through earphones and then flashed on an illuminated keyboard. When the student recognizes the letter, he depresses the proper key on his typewriter. A computer, which controls each console separately, analyzes every response and adjusts to the learning ability of the individual. The system is being built for the U.S. Army by Sylvania Electric.

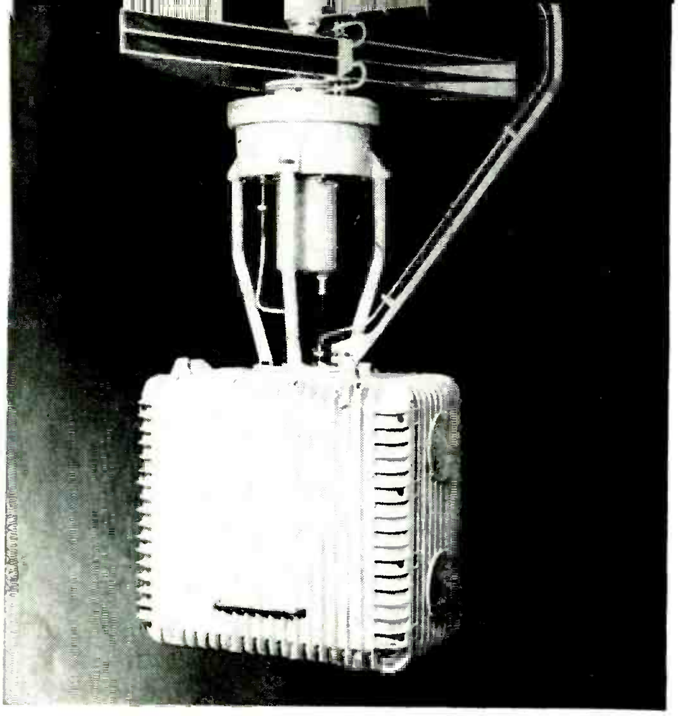
Computer-Controlled Coke Oven. (Center) Electronic controls for one of the largest coal chemical process-control systems are now undergoing final simulation testing. To be installed at U.S. Steel's Clairton Works, near Pittsburgh, the supporting system will monitor the production of anhydrous ammonia and the extraction of other chemicals from coke-oven gas produced by the large coke oven installation at the plant. Fuel gas will also be produced. A constant check on the installation will be provided by electronic analog instrumentation and eight huge graphic panels (background) totaling 400 feet in length, along with five Westinghouse computers.



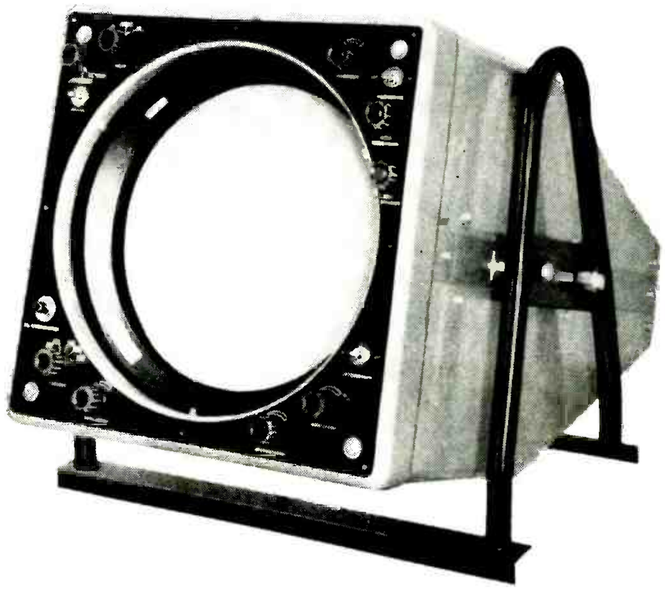
Jet Dual-Cockpit Flight Simulator. (Below left) The instructor's console in the Boeing 707 simulator allows the instructor to throw any one or combination of 160 malfunction problems at the student during a simulated training flight. Built to Pan Am specifications by Link, the simulator uses a new type of digital computer which can be programmed to operate two cockpits simultaneously but independently. Cost of the system is $2.5 million. It has already gone into operation at New York's J. F. Kennedy International Airport, and two similar systems have been ordered for use in Miami and San Francisco. The simulators will be used 17 hours a day, 7 days a week training and requalifying flight crews.

Ultrasonic Eye Measurements. (Below right) A new precise measurement instrument for the eye specialist that uses ultrasonic waves to determine eye-length intraocular distances to an accuracy of 0.03 mm, or 0.0012 in, is shown. The patient wears rubber goggles which act as liquid-couplant reservoirs for the ultrasonic energy. Measurement of the ultrasonic beam, which is not felt by the patient, enables the system to detect and display both front and rear surfaces of the cornea, both surfaces of the lens, and the retina, choroid, and sclera interfaces. The instrument was developed by Automation Industries.





Transmitter-receiver unit and double antenna of Q-band radar.



Indicator unit of the Philips marine radar uses a 12-in CRT.

New Q-Band Marine Radar

By RICHARD HUMPHREY

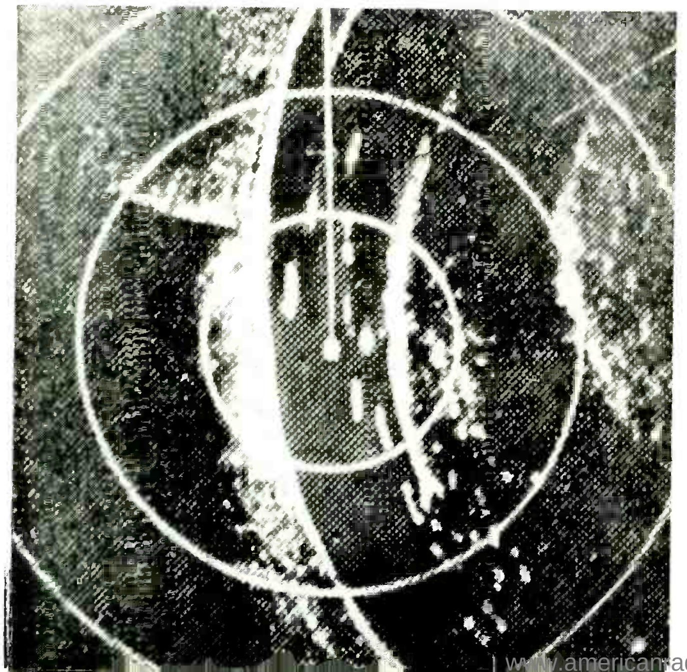
Radar operating at 8-mm wavelength (about 35,000 MHz) is now being used on crowded European waterways. It provides better resolution, will pick up smaller targets and show their shapes.

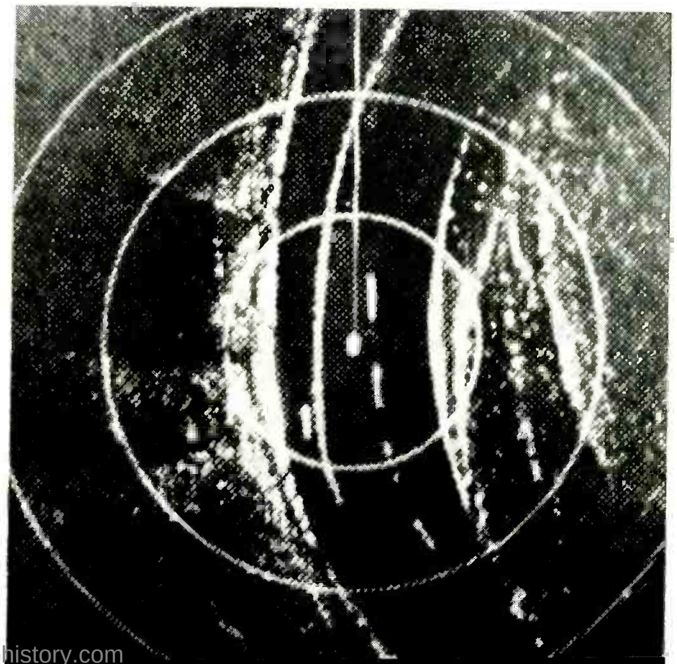
IN talking with many users of radar—Coast Guard, commercial, and military—the author found that the emphasis in marine navigational radar is on *close* capability and performance. In many cases, existing equipment (operating mainly in the 9000-MHz range) sometimes is just not good enough in this regard.

A distance potential of 200 miles or more is necessary in search radar or that used by the U.S. Weather Bureau (the radar used by the Bureau's New York office has a range of 250 miles), but a cargo vessel steaming at 15 to 17 knots on the open sea or 3 to 7 knots in inland waters has little interest in a radar contact on the extreme range of its instrument unless the course and speed of the target vessel can be seen as constituting a converging course with its own. Even then, if the speeds involved are not too great, another bearing and range check will not usually be made for some time.

What the captain or pilot of a freighter or tanker *is* interested in are the near targets, the ones that he might hit or that might hit him. Here, *minimum-range capability, high bearing resolution,* and *high range resolution* are essential.

(Left) Radar display produced on equipment installed in vessel traveling along the Rhine. The vessel's position is at the dot at the center of the inner range ring. These rings are about 1000 feet apart. The river banks, which are about 500 feet from the vessel, as well as other ships can be clearly discerned. (Right) Same display taken about 6 minutes later.





These three factors become more and more important as the ship progresses from port area to port proper and are vital when the vessel enters certain inland waters where channel width and congestion are considerations.

There is increasing need for radar which will have better range and bearing resolution, pick up smaller targets, have faster picture recovery, and actually present the shape of the target on the viewing screen as well as be capable of much closer work than heretofore possible.

All these requirements are said to be found in the new 8-millimeter wavelength radar (approximately 35,000 MHz) now coming into use on narrow, crowded European rivers such as the Rhine where traffic sometimes reaches a count of 35 vessels per kilometer.

This 8-millimeter or Q-band radar, in its upward excursion in frequency, has gained many advantages for navigational radar. [Actually, there are two frequency bands involved in millimeter-band radar. One of these, 34,500 to 35,200 MHz (nominally 8 mm), is in use in Europe, and the other, 31,800 to 33,400 MHz (nominally 9 mm), is not permitted in Europe].

First, Q-band radar has increased small-target recovery, since higher frequency waves are more readily reflected by smaller targets.

Second, since high bearing discrimination or resolution is a function of antenna beam width, and beam width in turn is a function of antenna size, it becomes possible for small antennas to have very narrow beam widths at these higher frequencies.

This physically smaller antenna, also being lighter, can be given a higher rate of rotation (typically 40 rpm in Q-band use) which leads naturally to better close-range capability and faster picture recovery.

Unfortunately, there was a bad side effect resulting from this small-target advantage gained by using higher frequencies. Since smaller targets are reflected much better at these 8- and 9-millimeter wavelengths, the interference from rain and drizzle is also increased. This was a major problem with Q-band radar. A radar which is inoperative during drizzle and rain cannot be classified as a useful navigational instrument.

This rain- and sea-clutter interference problem, according to one maker (*Philips*), is now solved by a refinement of the basic r.f. sensitivity time-control circuit used in most radar equipment for suppression of clutter.

With marine commerce becoming ever more sensitive to "man-hour" figures, the need to keep cargo vessels (especially in port and inland water use) moving in all sorts of weather is assuming vital importance. The ability of a radar to allow the master or pilot of a ship to thread a narrow, constricted, and usually well-traveled waterway is probably the most important factor in judging a radar's usefulness. This capability seems to be quite high with Q-band radar.

Possibly the most significant contribution to marine navigation offered by Q-band radar is in very quick determination of any change of course of the target vessel. With optical observation, the changing silhouette of the ship will immediately tell the captain that the vessel is altering course. On *centimeter* radar, the target ship must progress a certain distance along the new course before the radar operator can detect that such a change has in actuality been made.

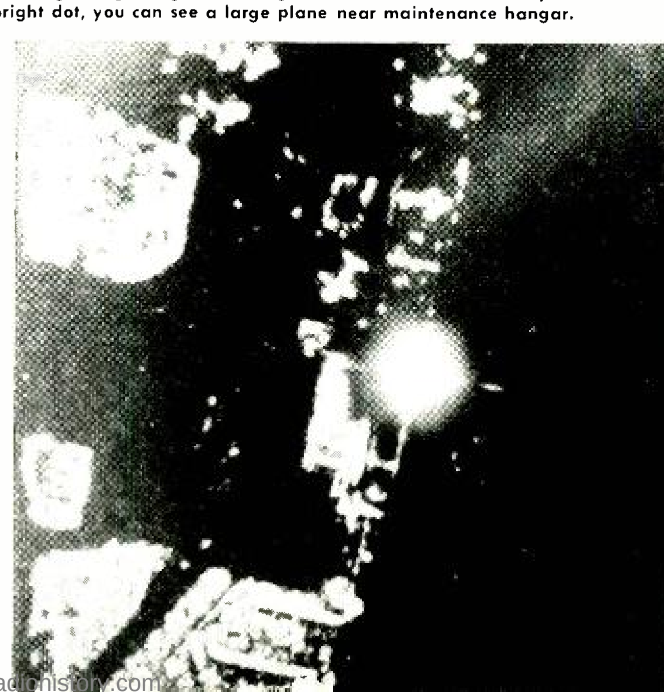
In some cases, 8-millimeter radar will make a course change apparent even before it is possible by visual observation because the actual outline of the ship is presented on the display screen. The swing of the target vessel is seen in an instant, and for this reason 8-millimeter radar is often used in clear-weather navigation.

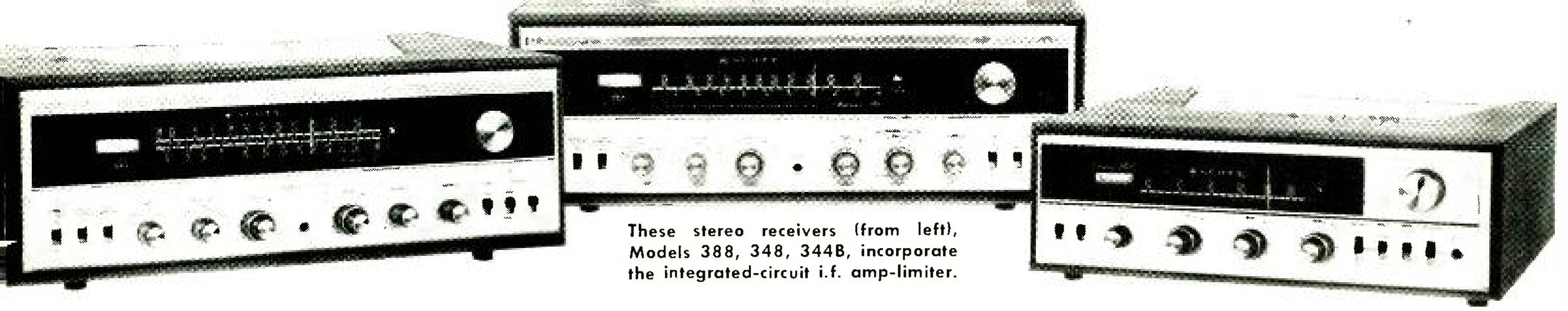
Among captains and pilots of commercial craft on inland waters and harbors, the true yardstick of a radar's performance is its minimum-range capability. With millimeter radar's ability to "see" as closely as 35 to 40 feet, with its better delineation of small targets, and with its high range and bearing discrimination, close-in navigation in sticky situations is no longer the nerve-wracking job it once was. The only factor preventing quick acceptance in America is its price, and the fact that the only major manufacturer (to come to the author's attention) is a European concern.

The *Philips* 8GR260 marine radar shown in the photos is transistorized (with the exception of the magnetron, video output tube, klystron, and CRT). It has a peak power output of 20,000 watts on 35,000 MHz, with a pulse length of only 0.04 μsec.

This unit uses the "double-cheese" type of antenna (0.6° horizontal beam width by 17° vertical) since a duplexer and T/R units for the frequencies involved are too expensive and prone to failure. This small antenna has solved one difficulty associated with harbor-monitor radar which is mounted in many instances on lighthouses. The larger cross-section presented to the wind of *centimeter* radar often sets up a vibration in the optical system of the light and makes it impossible to maintain focus. The small cross-section of a millimeter radar antenna makes it especially well adapted to this service. ▲

(Left) Radar display shows small portion of an airport. Runways are clearly visible and, if you look to the left of the bright dot near the center of the display, you can see a small aircraft moving along the ground. (Right) Another view of the airport but taken at somewhat reduced range. Above and to left of the bright dot, you can see a large plane near maintenance hangar.





These stereo receivers (from left), Models 388, 348, 344B, incorporate the integrated-circuit i.f. amp-limiter.

Integrated-Circuit I.F. Amplifier Used in New FM Receiver

By DANIEL R. von RECKLINGHAUSEN

Chief Research Engineer, H.H. Scott, Inc.

Use of four IC's as i.f. amplifiers and limiters in new Scott stereo receivers results in improved sensitivity and selectivity, more stereo separation and AM rejection, and better capture ratio—all with a simpler i.f. strip.

DURING the past few years the electronics industry has converted a large portion of its products from tubes to transistors. The desire to reduce the size, weight, and temperature rise, combined with an improvement in reliability provided the major impetus to the development of transistors. New circuit design methods and new circuits were developed, but not all goals were reached successfully. A new generation of integrated circuits promises the solution to many of the remaining problems.

In the manufacture of transistors there has always been considerable variation in performance from one transistor to another; however, transistors which were formed close to each other on the same silicon wafer are remarkably similar in their characteristics. Since the individual transistors on an integrated circuit are adjacent to each other, they are closely matched. This permits the design of integrated circuits containing circuit functions which would not be practical in circuits employing individual transistors.

The first major use of integrated circuits was in digital-computer circuits, where size and cost reduction were imperatives. A linear circuit is an amplifier by definition and the tolerance requirements of its components are substantially greater than those in digital circuits.

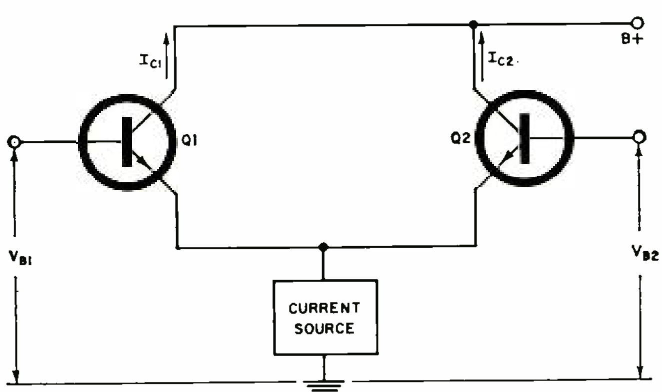
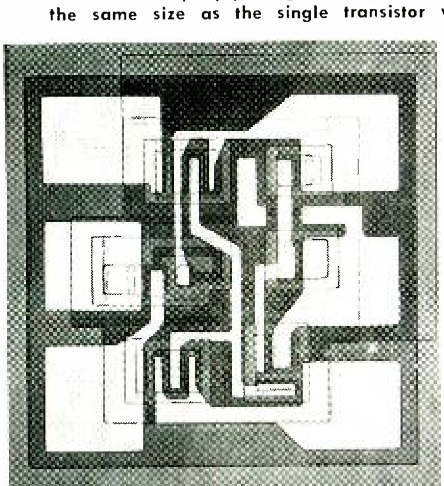


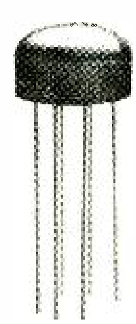
Fig. 1. The basic two-transistor emitter-coupled pair circuit.

Emitter-Coupled Pair Limiter

The most common building block in a linear integrated circuit is the emitter-coupled pair. (See Fig. 1). Here the emitters of transistors Q1 and Q2 are connected together and the emitter currents for both transistors are supplied from a common current source. If the two transistors match each other and are supplied from identical voltage sources V_{B1} and V_{B2}, the two collector currents I_{C1} and I_{C2} will be identical and equal to one-half the current supplied from the current source.

If the input voltage V_{B1} to transistor Q1 should increase, the collector current of transistor Q1 would also increase. Since the total of the two collector currents must be equal





(Left) Photomicrograph of the μA703 IC. On a silicon chip only 20/1000-in sq. (less than 1/32nd in) are deposited 5 transistors, 2 resistors, interconnections, and terminals. (Right) The 6-lead epoxy-packaged integrated circuit is actually the same size as the single transistor which it replaces.

Table 1. Comparison between a silicon planar transistor and the integrated circuit when employed as i.f. amplifier stage.

Typical Characteristic at "B+" = 12 V, f = 10.7 MHz	Silicon Planar Transistor SE 1001	Integrated Circuit μA703
Transconductance, G_m	90,000 μmhos	30,000 μmhos
Phase Angle of G_m	34°	17°
Feedback Capacitance	2 pF	0.05 pF
Input Resistance	360 ohms	3000 ohms
Input Capacitance	15 pF	7 pF
Output Resistance	1500 ohms	35,000 ohms
Output Capacitance	3.5 pF	2 pF
Gain/Bandwidth Product	400 MHz	900 MHz
Available Power Gain	32 dB neutralized	41 dB unneutralized

Resistor-Selection Nomogram

By SYLVESTER SALVA

Resistance values and power dissipations may be readily determined by the use of a straightedge.

FOR the man involved in the electronics field, it frequently becomes necessary to determine the value of a resistor and its wattage. The nomogram below was designed to give the resistor value and its wattage simply by placing a straightedge from the potential scale to the proper current scale and reading the answer on the Resistor Value Scale or the Wattage Scale.

It will be noted that there are two current scales on the nomogram. They are listed as Current (Milliamps) Scale No. 1 and Current (Milliamps) Scale No. 2. Scale No. 1 is used only when determining the value of the resistor. Scale No. 2 is used for determining the wattage of the resistor.

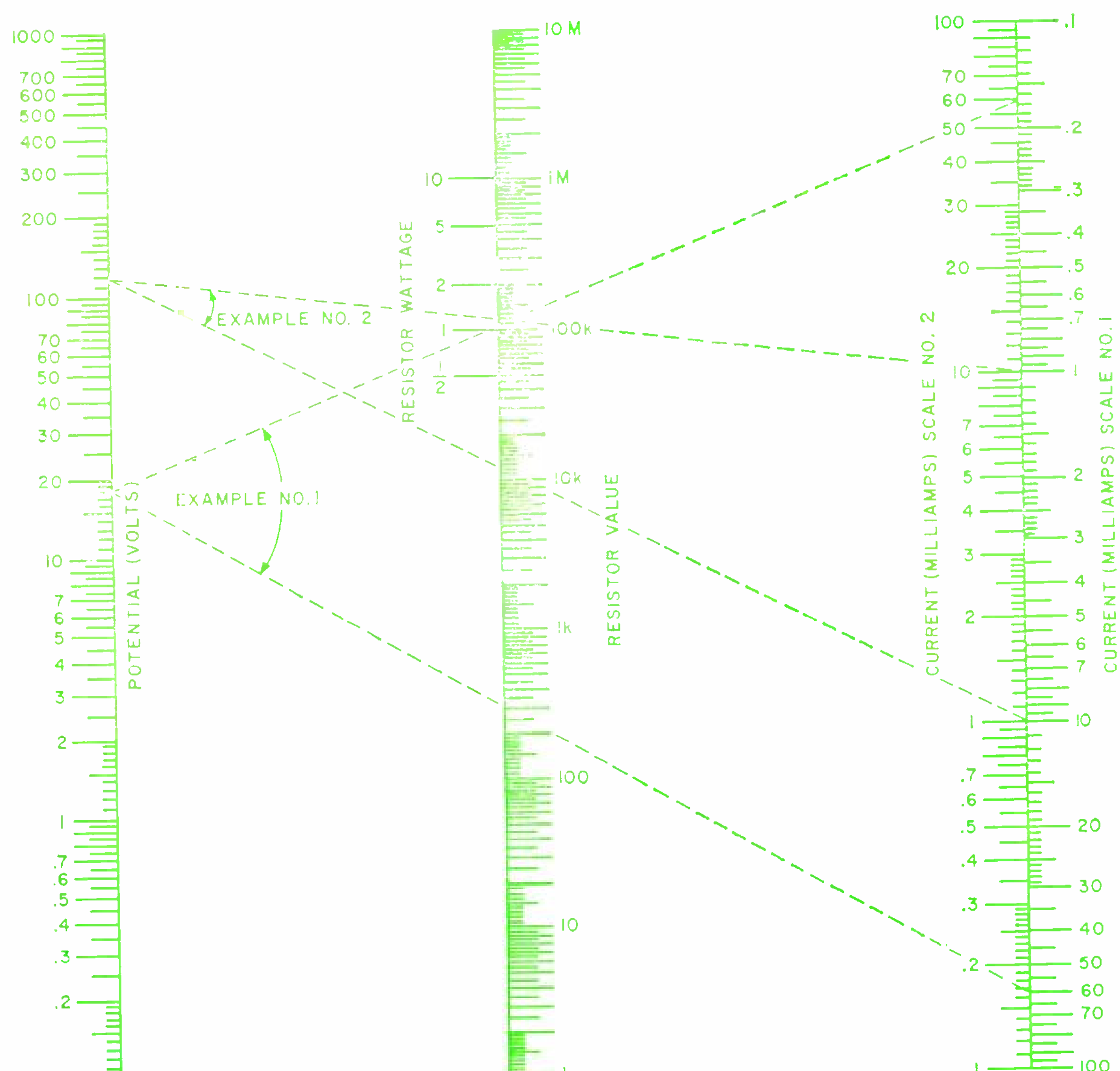
Following are two examples illustrating the use of the nomogram.

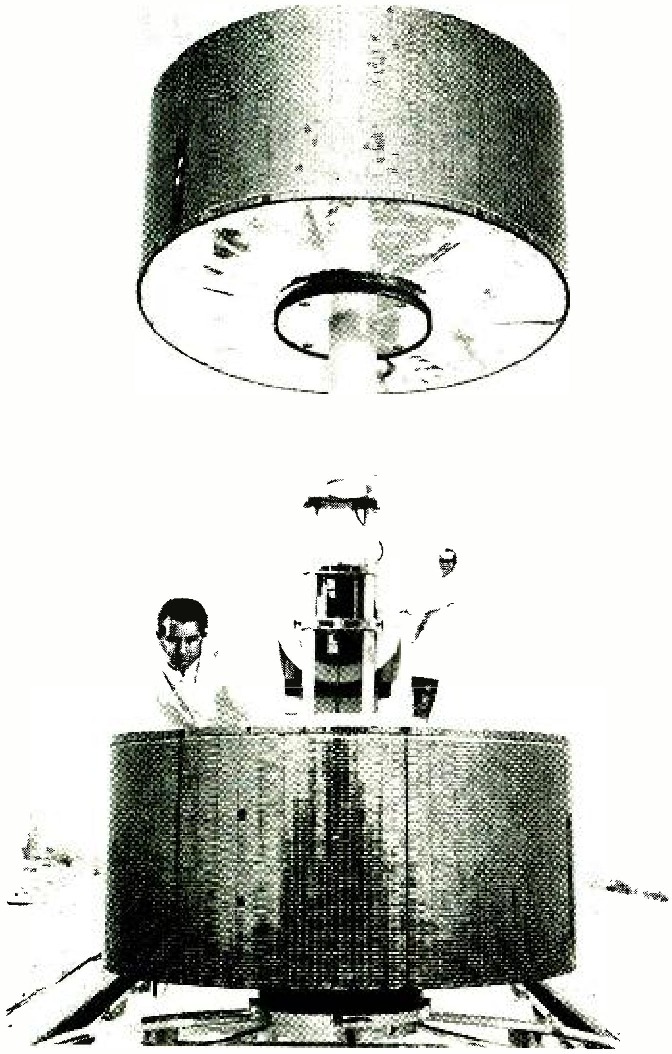
Example No. 1: It is found that a cathode bias resistor is burned out and no schematic is available. Total current of the tube is rated at 60 mA. Grid bias is −18 volts. Determine the value, in ohms, and wattage of the resistor.

Solution: Extend a straight line from 18 on the Potential Scale to 60 on the Current Scale No. 1. Read the value of the resistor at the intersection of this line with the Resistor Value Scale as 300 ohms. To determine the wattage, extend another line from 18 on the Potential Scale to 60 on the Current Scale No. 2. At the intersection of this line with the wattage scale, read the answer as slightly over 1 watt. Since the value is higher than 1, use the next higher value, namely 2 watts.

Example No. 2: Determine the value, in ohms, and wattage of a resistor under the following conditions: Voltage is measured at 117 volts, current at 10 mA.

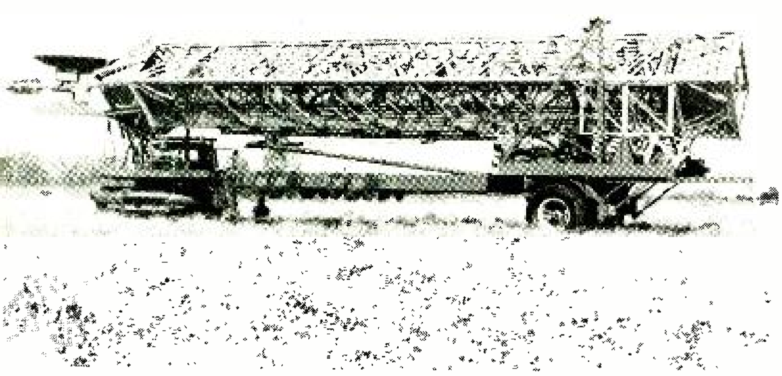
Solution: Extend a straight line from 117 on the Potential Scale to 10 on the Current Scale No. 1. At the intersection of this line with the Resistor Value Scale read the value as 11.7 kohms. To determine the wattage, extend another line from 117 on the Potential Scale to 10 on the Current Scale No. 2. At the intersection of this line with the Resistor Wattage Scale, read the answer as just over 1 watt. Assigning the next highest value, the answer then becomes 2 watts. ▲



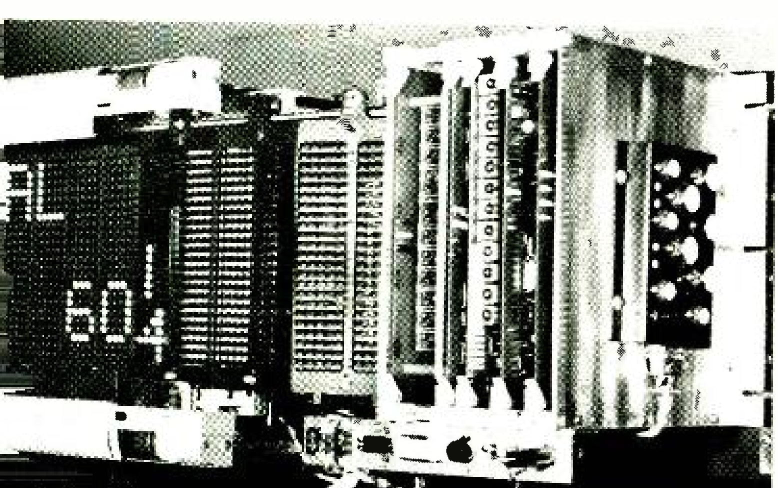


RECENT DEVELOPMENTS IN ELECTRONICS

Intelsat Communications Satellite. (Top left) One of these two satellites, shown here undergoing final checkout tests, should be in full commerical service over the Pacific Ocean by the time this is being read. The satellite was launched successfully for Comsat in mid-January, and it achieved a synchronous orbit some 22,000 miles above the equator. The satellite is available for commercial telephone, television, and teletypewriter communications 24 hours a day. The Defense Department is expected to use 40 of its 240 communications channels. The 192-pound satellite has joined a sister satellite that's been hovering high above the Pacific and relaying signals since last fall, although the earlier satellite failed to achieve a synchronous orbit. The new orbiting microwave relay station, built by Hughes, links North America with the Far East through earth stations located at Brewster Flat in Washington, Hawaii, Australia, and Japan.



300-Foot Quick-Erect Microwave Tower. (Center) This microwave tower, compactly arranged on a trailer, can be untelescoped quickly to restore service to a microwave system that has been disrupted. The tower can be raised to a maximum height of 300 feet or to any lesser height to match the tower it replaces. Four 6-foot parabolic antennas and associated waveguide, all for use at 6000 MHz, can be mounted on the structure. Erection requires the services of five men. Guy wires are stored on a reel so they can be unrolled quickly. An associated gas-driven generator provides sufficient power to erect the tower and to provide lights for the tower and working area. The structure is being completed by Andrews Towers, Inc. for a major telephone company.



Stock-Price Display Uses IC's. (Left) A new display system with a semiconductor electronic "brain" will soon give investors and brokers a better picture of the stock market. The display, the very end of which is shown here with its electronics exposed, is legible in any light and is able to keep pace with the busiest market. The system, built by Trans-Lux Corp., links directly to the nation-wide stock exchanges' communications networks to instantly display market quotations. It uses neither ticker nor tape because the brain converts network signals into quotations by means of pneumatically driven, high-contrast luminescent discs fixed to a conveyor belt. Solid-state components used are: IC's for control and logic, small-signal transistors for interfacing, SCR's and power transistors for character generation and motor drive, silicon light-sensors for readout and synchronization, diodes and unijunction transistors for timing and control. These semiconductor components are all from Texas Instruments' industrial line of epoxy-packaged devices.

to that supplied by the current source, the collector current I_{C2} of transistor $Q2$ will decrease. This process can continue until transistor $Q2$ is cut off. Similarly, if the input voltage V_{B1} of transistor $Q1$ should decrease, the collector current I_{C2} of transistor $Q2$ will increase and will reach as a maximum the current supplied by the current source when transistor $Q1$ is cut off. The maximum currents in the transistors are not accomplished by saturation of one transistor or the other; consequently an emitter-coupled pair can be used as an effective current limiter in an FM tuner. A good limiter should also be able to act as a good amplifier up to the point of limiting and should then clip symmetrically when driven by a large signal.

It is difficult to construct a high-performance emitter-coupled amplifier with individual transistors because of transistor tolerances. For example, due to variations in the base current of a given transistor of the same type operating at the same collector current, the normal base operating voltage can vary by 100 mV. When the two bases are connected to a common bias voltage, the collector currents may vary as much as 30 to 1. In an integrated circuit, the base voltages of a transistor pair will be within a few millivolts of each other and the collector currents will be matched to about 10%. Consequently, an input signal to the emitter-coupled pair can be applied between the bases of transistors $Q1$ and $Q2$ with the base of transistor $Q2$ effectively grounded for alternating voltages. The resulting transfer curve of output current to input voltage is shown in Fig. 2.

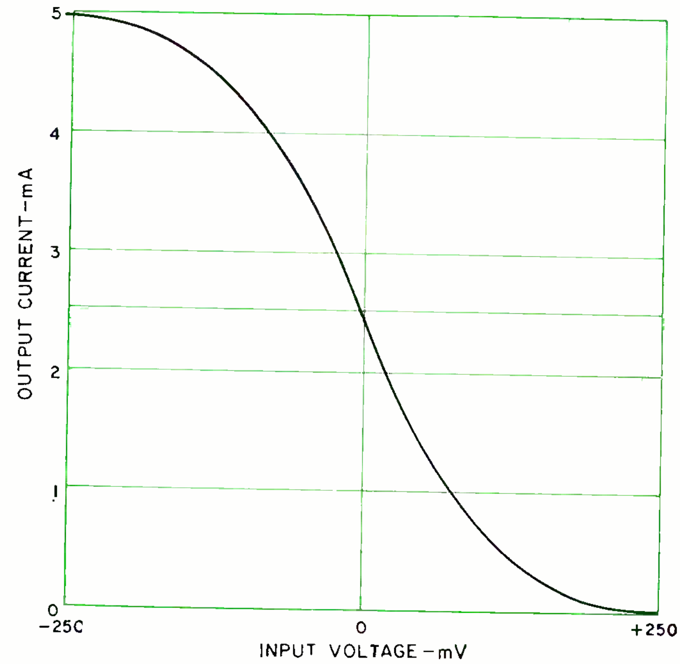


Fig. 2. Collector current of second transistor in emitter-coupled IC pair with respect to differential input voltage. Circuit is linear up to point of symmetrical limiting.

The Complete Integrated Circuit

A complete diagram of the integrated circuit used in the i.f. strip of the new *Scott* receiver is shown in Fig. 3. Here, transistor $Q3$ acts as the current source for transistors $Q1$ and $Q2$ because its collector impedance remains very high for collector voltages as low as 0.3 to 0.4 volt. Transistors $Q4$ and $Q5$ are connected as diodes and are identical to the other three transistors in the circuit. Since all transistors are identical, the collector currents of transistors $Q3$ and $Q4$ will also be identical. Consequently, the current through current-source transistor $Q3$ will be approximately equal to the current through the 2000-ohm resistor connected from the filtered "B+" terminal (1) to the diode-connected transistors $Q5$ and $Q4$. The current through transistor $Q3$ will be equally divided between transistors $Q1$ and $Q2$. Since all current is supplied from the "B+" supply, the idling current through transistor $Q2$ will be approximately one-fourth of the total supply current, or 2.3 mA out of 9.2 mA total.

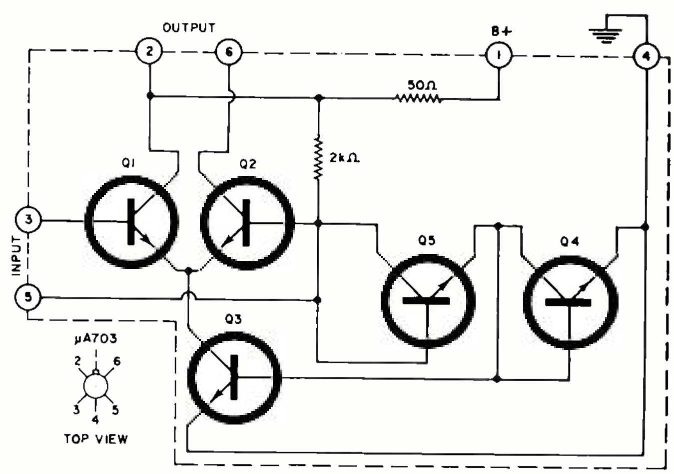
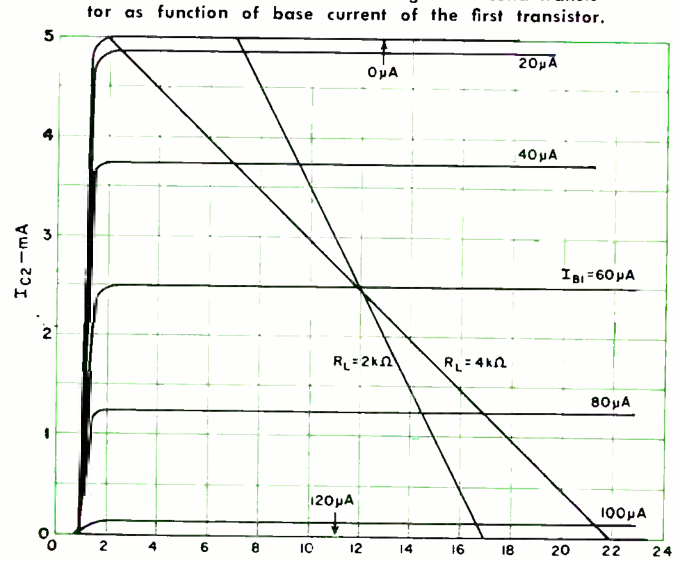


Fig. 3. Circuit diagram of the μA703 integrated circuit. Transistor Q3 acts as the current source for Q1 and Q2.

The "collector curves" of the integrated circuit of Fig. 3 are shown in Fig. 4. They look very similar to normal transistor curves except that collector current does not begin to flow unless the voltage at the second transistor collector is greater than 1.5 volts and maximum second transistor collector current occurs for zero first-transistor base current.

Fig. 4. Collector current and voltage of second transistor as function of base current of the first transistor.



Other Advantages

Aside from the ability to perform as a good current limiter, the emitter-coupled pair in an integrated circuit has other advantages. $Q2$ is a common-base amplifier driven by the emitter-follower transistor $Q1$. It therefore operates with a substantially wider bandwidth than a common-emitter-connected transistor. Also its collector impedance will be that of a common-base amplifier, *i.e.*, very high, thereby causing very little damping on the tuned output circuit. Furthermore, the use of the emitter-coupled amplifier pair reduces the coupling between input and output. This integrated circuit is capable of having an unneutralized power gain in excess of 40 dB at 10.7 MHz. The individual transistors have a gain-bandwidth product of more than

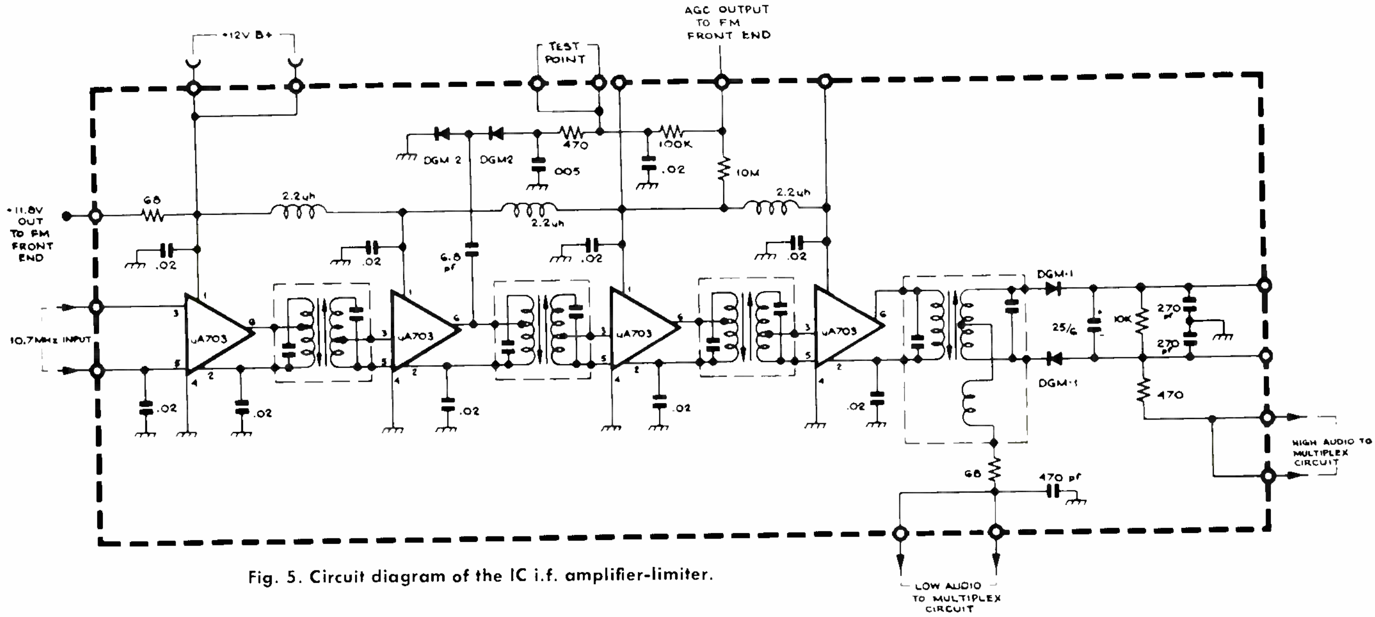


Fig. 5. Circuit diagram of the IC i.f. amplifier-limiter.

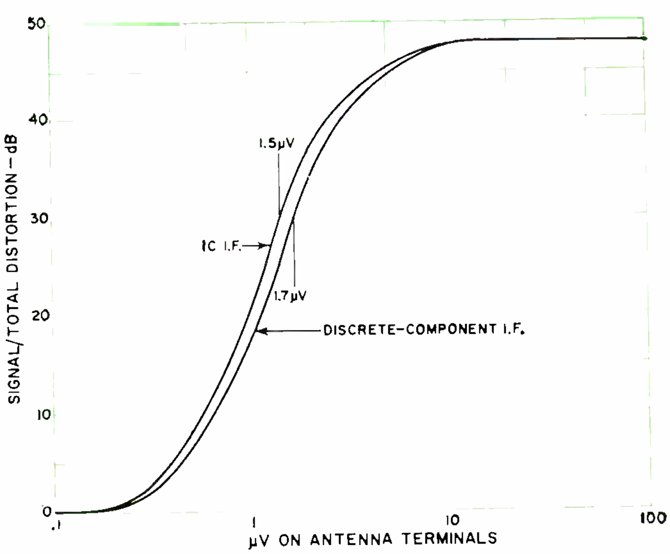
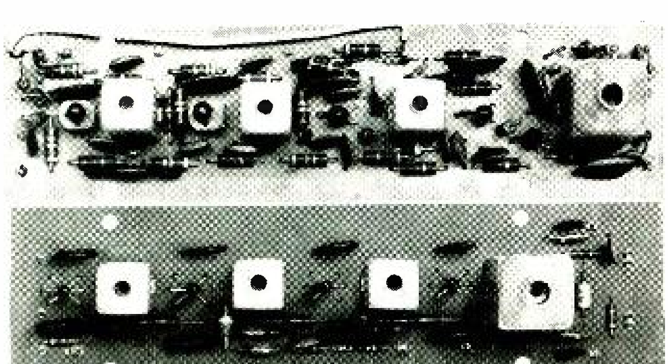


Fig. 6. Signal-to-distortion ratio with respect to antenna signal level for an FM tuner with an integrated circuit i.f. strip compared to one using a discrete-component i.f. strip.

	Silicon Planar Transistor	Integrated Circuit
IHF Usable Sensitivity	1.7 µV	1.5 µV
Capture Ratio	3 dB	1¾ dB
Selectivity	45 dB	46 dB
AM Rejection	46 dB	52 dB
Stereo Separation		
400 Hz	35 dB	41 dB
15 kHz	19 dB	30 dB

Table 2. Comparative characteristics of the tuner section with silicon planar transistors and with the new integrated circuits.



900 MHz and consequently useful amplification is possible to 150 MHz.

Table 1 shows the relative performance of the integrated circuit compared with a transistor used as a typical i.f. amplifier stage. Although the transconductance of the integrated circuit is only one-third that of the silicon transistor, the input and output resistances are about 8 and 23 times larger, respectively, and the internal feedback capacitance is one-fortieth that of the silicon transistor.

The wide bandwidth of this integrated circuit results in a phase shift of only 17° per circuit, which varies less than 5° between normal weak-signal amplification and full limiting. This causes no more than 1% distortion of a stereo signal, which has 30% incidental amplitude modulation and substantially less distortion than a mono signal.

The data of Table 1 shows that an FM i.f. amplifier-limiter can be designed so that no neutralization is required. This has been accomplished previously with silicon planar transistors (see the author's "Silicon Transistor I.F. Amplifier," October 1965 issue). Here the loaded "Q" of the i.f. transformers was held to 75% of the unloaded "Q". Because of the higher impedance and higher available gain of the integrated circuits, the loaded "Q" of the i.f. transformers can be increased to 83%. This causes the bandwidth of the IC i.f. amplifier to change less than ± 5% if the characteristics of the integrated circuits vary as much as two to one between units.

The Tuner Design

A high-quality FM tuner should have a power gain of approximately 115 dB so that limiting just occurs from off-station random noise created by the 1st r.f. amplifier. Approximately 10 dB more gain must be provided for almost complete limiting on off-station noise—bringing the total to 125 dB. An FM front-end usually has a gain of at least 35 dB. Therefore, at least 90 dB gain at 10.7 MHz must be provided by the i.f. amplifier/limiter combination.

In an i.f. amplifier using discrete components and silicon planar transistors, the required gain of at least 90 dB was achieved using a 3-stage i.f. amplifier and a two-transistor limiter. In the present design with integrated circuits, a minimum gain per stage of 26 dB is obtained with each integrated circuit operating into a load impedance of 3300 ohms, which is lower than the critical load of 4000 ohms. Four such stages have a gain (*Continued on page 72*)

← Fig. 7. Top views of discrete-component (above) and integrated-circuit i.f. amplifier-limiter strip. Note simplicity of IC strip.

The author is presently employed as Solid State Products Sales Manager. Prior to this, he did circuit design in the Solid State Switching Group. He holds a BSEE from Evansville College, Evansville, Ind. and has done graduate work at Purdue. He is a member of IEEE and Sigma Pi Sigma.

Time-Delay Relays

By JERRY E. ELPERS
Solid-State Products, Potter & Brumfield (Div. American Machine & Foundry)

Factors to consider in selecting a relay that produces a predetermined delay. Included is data on thermal, motor-driven, pneumatic, RC, slugged, hydraulic, escapement, and solid-state types.

THE fantastic growth of the field of automatic industrial control has increased the demand for new and more versatile devices to perform the basic electrical switching functions required. The use of time-delay relays has grown rapidly to keep pace with the demand for the basic function which they can perform: that of obtaining a predetermined delay from one switch operation to another.

Time-delay relays perform in a manner quite similar to a standard relay in that they have contacts that open and close when power is applied and removed from the input terminals. The basic difference is that a delay is incorporated into the contact opening or closing. Time-delay relays are used in a wide range of applications: from determining how full your coffee cup will be when you put a dime in a vending machine, to shutting off the cutting oil on a milling machine.

The most popular time-delay relay is the delay on operate, or energization, in which the normally open load switching contacts transfer at a predetermined time after power is applied to the input. The contacts drop out immediately upon removal of the input power (Fig. 1A).

Often a time delay on release, or de-energization, is required. In this case the normally open load switching contacts operate immediately when the input power is applied and remain in this position as long as the input power remains "on". Upon removal of this power the timing begins, and after a predetermined delay, the contacts drop out (Fig. 1B).

Several variations on these two basic timing modes are used, such as interval "on", automatic recycle, combined "on" and "off" timers, and sequence timers. Many of these can be made by simple connections of the two basic types.

Factors to Consider

There are many types of time-delay relays available which will provide the timing action desired, including thermal, motor-driven, pneumatic, *RC* circuit, solid-state, slugged, hydraulic, and escapement.

There are many factors which must be considered when choosing one of these time-delay relay types. Consideration should be given to how each fulfills the following criteria: accuracy, reset time, repeatability, load-switching capabilities, price, life, mounting configurations, size, length of delay, temperature effects, and adjustable or fixed time delay.

Also, various time-delay relays have certain peculiarities in their operation which should be determined in order to select the type that will do the job reliably and economically. Some of these peculiarities are covered below.

Thermal Time Delays

The basic operation of this timer takes advantage of the difference in the thermal expansion of two metals. A bi-metallic element is placed in close proximity to a heating element, and when power is applied the bi-metal deforms and closes or opens a contact. The time required for the contact to operate is generally determined by the physical characteristics of the bi-metallic strip and the amount of power applied to the heating element.

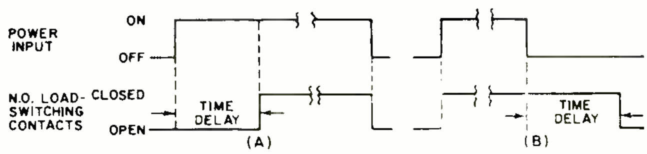
Thermal time-delay relays are usually used where a time delay on energization is required and the accuracy of the time-delay period is not critical. One manufacturer states an over-all accuracy of ± 30% for a miniature or octal plug-in timer, with delays available from 2 to 180 seconds. Another manufacturer gives accuracies of ± 20% from 0.75 to 1 second, ± 15% from 1 to 4 seconds, and ± 10% for delays up to 360 seconds. This is also an octal plug-in type time-delay relay.

Contact forms are usually limited to s.p.s.t., N.O. or N.C. with ratings that normally do not exceed 5 amperes, 115 volts a.c. resistive (100,000 operations). Since the thermal time delay uses the I^2R heating effect, the device is somewhat sensitive to input voltage variations. Voltage variations of ± 10% will change the delay period approximately ± 5%.

The biggest drawback to the thermal time-delay relays is their long reset time (the time required for the contacts to open and to achieve an appreciable percentage of the nominal delay time on the succeeding cycle of operation). This reset can be as long as 50 to 200 percent of the operate delay in order to achieve 80% of the nominal delay period on the next cycle.

One thermal-delay relay manufacturer recommends the use of an auxiliary relay to overcome this reset time problem. This unit uses two sets of contacts, one that closes at the end of the heating interval which pulls in the auxiliary relay and interrupts the input power. The cooling interval

Fig. 1. (A) Delay on energization. (B) Delay on de-energization.



A selection of typical solid-state time-delay relays, many of which provide an adjustment for the amount of delay provided.

then begins, after which the second set of contacts drop out completing the load-switching circuit. Using this method, approximately 85% of the nominal operate time is achieved on the succeeding cycle.

Most of the better known thermal time-delay relays are of the plug-in type and range in price from $2 to $20.

Pneumatic or Air-Operated

The term "pneumatic" (meaning air-operated) immediately indicates the basic principle of operation of this type of time delay. A mechanism is used in which a controlled amount of air under pressure is displaced from one place to another. (This can be a unit isolated from the surrounding air, in which the air is displaced from one chamber to another, or where the air is drawn from or dispelled into the atmosphere.) A typical unit uses a diaphragm, a coil, a plunger, and an orifice. When power is applied to the coil, the plunger (which is mechanically tied to the diaphragm) is drawn into the coil. The rate of plunger movement is controlled by the rate of air escape from the diaphragm, which is controlled by the orifice adjustment. When a predetermined position is reached, a set of contacts operate as a result of the plunger movement.

The pneumatic time-delay relay has been in use for 25 years and has a well-established reputation in heavy industrial applications. Several manufacturers have units available which lend themselves to these types of application. They are available for control-panel mounting, have screw terminals, and are designed for use in severe industrial environments. This type of time delay is available as an adjustable unit: some with time-calibrated dials and some with screwdriver-slot adjustments. The repeat accuracy is usually ± 10% and the reset time is approximately 25 milliseconds (this reset also applies in case of power interruption).

Units are available in both time delay on energization, delay on de-energization, and also with both of these functions packaged in the same enclosure. Some can be converted in the field from delay on energization to de-energization by a simple mechanical change. Contact ratings are available up to 20 amperes, 120 V a.c., 60 Hz, resistive (100,000 operations life).

Time-delay periods are available from 0.2 second up to 30 minutes from one manufacturer and 0.050 second to 3 minutes from another. The temperature range of operation is in the area from −50° C to +65° C. Supply voltages of 6 V a.c. to 550 V a.c., 60 Hz and 6 V d.c. to 250 V d.c. are available. Input power requirements range from 5 to 8 watts. Prices range from $18 to $100.

Many of the pneumatic units are fairly large due to the space required for the mechanical mechanism, although some smaller versions are also available with lower contact ratings (10 amperes) and shorter delays (180 seconds) at a higher cost. Pneumatic delays can cause a problem in application where a dirty atmosphere exists. Any clogging of the orifice will cause changes in the delay period.

Motor Driven

A synchronous motor is normally used in motor-driven timers to drive a gear train which controls the load-switching contacts. When power is applied, the movement functions until a predetermined time has elapsed, at which time the output contacts are switched. This timing method depends upon the input line frequency for its basic accuracy, in a manner similar to a standard 12-hour, 120-V a.c., 60-Hz clock. The majority of these timers use a magnetic clutch in conjunction with the clock movement which serves the function of engaging the movement when power is applied, and allowing it to reset when the power is removed. The unit is reset by a return spring when the clutch is released.

The time-delay period is set on these units by a pointer on the front or top of the relay (this may be continuously adjustable or in increments). A second pointer is usually used to indicate the elapsed time. The setting accuracy of the continuously adjustable timers is generally ± 0.5% of full-scale, and the repeat accuracy is ± 1% of full-scale, or better. The reset time is proportional to the time required to reset the spring-loaded mechanism and will be less than 500 milliseconds, depending on time setting relative to full-scale.

Motor-driven time-delay relays are available in both delay on energization and delay on de-energization. The load contacts of the delay on de-energization operate immediately when power is applied to the clutch and removal of clutch power starts the timing interval. When this interval is completed, the contacts drop out. The delay on de-energization will reset when a momentary power loss occurs.

Delay lengths of 5 seconds to 60 hours are available from one manufacturer and 5 minutes to 5 hours from another. Life ratings of these timers range from 500,000 operations for one manufacturer to a contact life rating of 5 million operations for another. Life is usually limited by clutch failure rather than contact life. Input power ranges from 5 to 15 VA, including clutch coil and motor. Contact switching ratings up to 15 amperes continuous are available. Most of the units available are for 120/240-V a.c., 60-Hz operation. D.c. units are not generally available. The temperature range of operation is −20°C to +50°C. Prices range from $5 to $50.

The majority of the motor-drive time-delay relays have some kind of adjustment feature, some of which are for front-panel mounting, with a knob to set the time-delay period and are intended for industrial control-panel use. Others are available with pointers that can be set to adjust the timing in increments and are not intended for applications requiring front-panel mounting.

Delay Slug Relays

A time delay can be produced on a telephone-type d.c. relay by placing one or more shorted turns around the magnetic circuit (usually the core) so as to produce a counter-m.m.f. which retards the build-up of the operating flux, and upon de-energization provides an m.m.f. to retard the collapse of the flux. This shorted turn, or turns, is called a slug. Usually it consists of a copper collar on the core of the relay. In some designs, a copper sleeve is used over the full length of the core, and the coil is wound on the sleeve.

The principle of operation of the slug is as follows: When the relay coil is energized, the flux build-up passes through the slug and by self-inductance produces an m.m.f that opposes the coil m.m.f. This opposing m.m.f. delays the build-up of the magnetic field in the air gap to a strength that will cause the armature to close. The time delay on drop-out occurs in the opposite manner. When the relay coil is de-energized, the field starts to collapse, thus inducing a current in the slug that provides an m.m.f. oriented so as to sustain the magnetic field and thus delay the drop-out.

Pickup delays up to 120 milliseconds and drop-out delays up to 500 milliseconds can be achieved by the use of slugs. The delay time will vary due to mechanical wear over life and ambient temperature and this type is not intended for high-accuracy applications. Slugged relays are not generally an off-the-shelf item and are available only on a special-order basis from most manufacturers of telephone-type relays.

RC Circuit

Various methods have been used to devise time delays using combinations of resistors, capacitors, and relays. All of these circuits use the basic principle of charge and discharge of a capacitor and one of the simplest circuits using this principle is shown in Fig. 2A.

When the switch is closed, the capacitor charges toward the applied voltage and, after a period of time determined by the resistance and capacitance (assuming the relay coil resistance to be very large compared to the resistor), the relay pulls in. When the power is interrupted the capacitor discharges through the relay at a rate controlled by the size of the capacitor, the inductance, and the resistance of the relay coil. This circuit does not produce an accurate time delay since the time is dependent upon many factors. Variations in the resistance, the capacitance, the input voltage, and relay pull-in voltage will cause changes in the time-delay period. Delay-period accuracies of ± 30% are to be expected. The reset time is also long, due to the high-resistance, capacitor-discharge path. In practice these timers can be purchased with delays up to 30 seconds and in both a.c. and d.c. versions.

Variations of this basic circuit are available which use additional components to increase the accuracy and speed up the reset time. One popular circuit uses a neon bulb to sense the voltage level on the capacitor and a photoresistive cell to drive the relay. The photocell offers a low impedance in series with the relay when the neon bulb fires and causes the relay to pull in (Fig. 2B).

This circuit has several advantages over the previous circuit in that the neon bulb senses an accurate voltage level and does not rely on the relay pull-in voltage for the accuracy of the delay. Also, the relay drops out immediately when the power is removed, and the timing can be reset with another set of contacts across the capacitor if desired.

This circuit is used in several commercially available time-delay relays. The units are generally adjustable (a potentiometer is used in series with the resistor), and the enclosure is an octal plug-in type. The accuracy of this unit is usually stated as ± 10% over a limited temperature range. Relay outputs on these timers are usually d.p.d.t., 5-ampere, 120-V a.c. resistive.

Solid-State

The latest entries into the time-delay relay field are the solid-state types. There are presently two basic types available using entirely different principles of operation. One manufacturer is marketing a relay that uses an accurate oscillator and a counter to perform the timing function. An output from this oscillator is initiated when power is applied and is fed into an amplifier circuit. This amplifier shapes the pulses and feeds them to a magnetic-core counter. When a predetermined count is reached, the output load switching contacts are operated through a logic circuit. The time delay period is determined by the logic and by how many counters are used after the oscillator.

This time-delay relay is intended for applications where a high degree of accuracy is required (± 2%). The standard operating voltage is from 18 to 32 V d.c. It has either a relay or a solid-state output and requires 0.4 sec to reset the delay to the stated accuracy. Enclosures are available with the popular plug-in feature or with hook solder terminals and a side mounting bracket. This unit is expensive as time-delay relays go and sells for $100 or more.

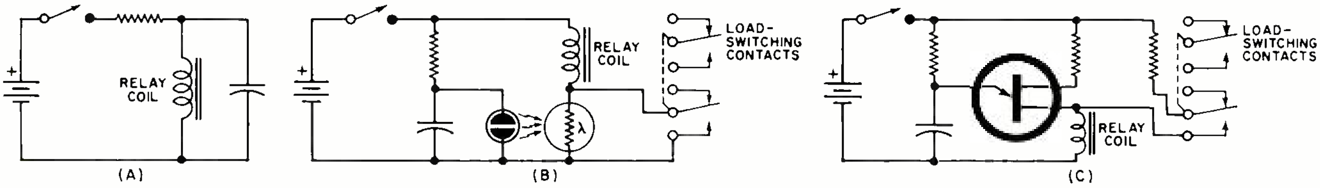
The most popular circuit used in solid-state time-delay relays employs the *RC* charge principle, mentioned previously. The reason for the popularity of this method stems from the use of the unijunction transistor.

The unijunction transistor has the inherent ability to offer a high input impedance to the capacitor voltage until a predetermined voltage is reached. At this point the device fires and discharges the timing capacitor.

The circuit of Fig. 2C can be used to illustrate this operation. When the switch is closed, the capacitor charges at a rate controlled by the *RC* product. At a voltage level controlled by the unijunction transistor, the capacitor discharges through the relay coil and causes the relay to operate. This pulse is only momentary and a set of relay contacts serves to latch in the relay.

The unijunction circuit has several advantages over the neon-bulb circuit in that the firing level is proportional to the input voltage. Therefore, any input voltage variations are compensated for by a proportionate change in firing voltage. Other devices can be added to this circuit to overcome some of the deficiencies of the previous circuits. Zener diodes are added for better compensation of time changes due to input voltage variations. An SCR can be added to give the relay more pull-in and hold-in power.

Fig. 2. (A) RC circuit may be used to provide time delay. (B) Neon bulb and photocell or (C) unijunction transistor may be used.



The circuit shown in Fig. 2C also has the drawback that the capacitor will discharge through the relay coil immediately if the power is interrupted and this causes the relay to pull-in momentarily. The addition of an SCR eliminates this problem.

Line Transients

One problem peculiar to the solid-state time delays has been that of line transients, particularly on time-delay relays used on 120-V a.c. line voltage. These transients, or momentary overvoltage conditions, are common on a 120-V a.c. line. They can be produced from a wide variety of conditions including lightning striking the line, switching of inductive loads on the line, or making and breaking of the transformer input supplying the time-delay relay. These transients are usually not a severe problem because they do not contain much energy.

Solid-state time-delay relays used on a 120-V a.c. line normally employ a silicon rectifier at the input in order to produce the required d.c. voltage for time-delay operation. This rectifier is susceptible to the energy contained in these transients if the voltage is allowed to exceed its reverse rating. Two methods are commonly used in better solid-state units to suppress these transients. One method is the use of a controlled-avalanche rectifier for this input rectifier. When the reverse input voltage exceeds the rectifier reverse voltage, the device avalanches and dissipates the transient energy. Special selenium breakdown devices are also used which can withstand even more energy. Transient problems are better understood now than in the past and adequate protection can be provided.

Since solid-state time delay relays use transistors in the timing portion, and transistors have long life, a very reliable timer can be built using these devices. Many of the units available have an integral relay for load switching; typically, d.p.d.t., 10-ampere, 120-V a.c. resistive. In this case the life is limited to the life of the relay, usually 10 million mechanical operations.

Several manufacturers market an all-solid-state timing module to drive an external load-switching relay. In this case, the timer life is nearly infinite and is very useful for applications where high cycle rates are experienced.

Types Available

Solid-state units are available in fixed delays, internal potentiometer adjustable delays, and external resistor adjustable delays. The external resistor can be a potentiometer mounted remotely and wires run to the delay unit.

A wide range of mounting configurations is available, including screw-terminal dust covers, plug-in types, hermetically sealed military types, and panel-mounted types. Units are available in d.c. voltages from 12 to 100 V d.c. and 24 to 240 V a.c., 60 Hz and require approximately 3 watts of power. The timing range is usually limited to delays from 0.10 second to 5 minutes on commercially available units. Delay accuracy varies from one manufacturer to another and can be as good as ± 5% over the temperature range from −40°C to +55°C, and a voltage range of ±10%.

Several manufacturers are marketing knob-adjustable solid-state time-delay relays with time-calibrated dials. The reset time varies, but is usually fast—from 40 milliseconds to 100 milliseconds—depending upon the circuit configuration. Time-delay relays are available in both delay on energization and on de-energization. (The delay on de-energization requires an auxiliary source of power during the delay period to hold in the load switching relay and cannot be used for a momentary power failure delay.)

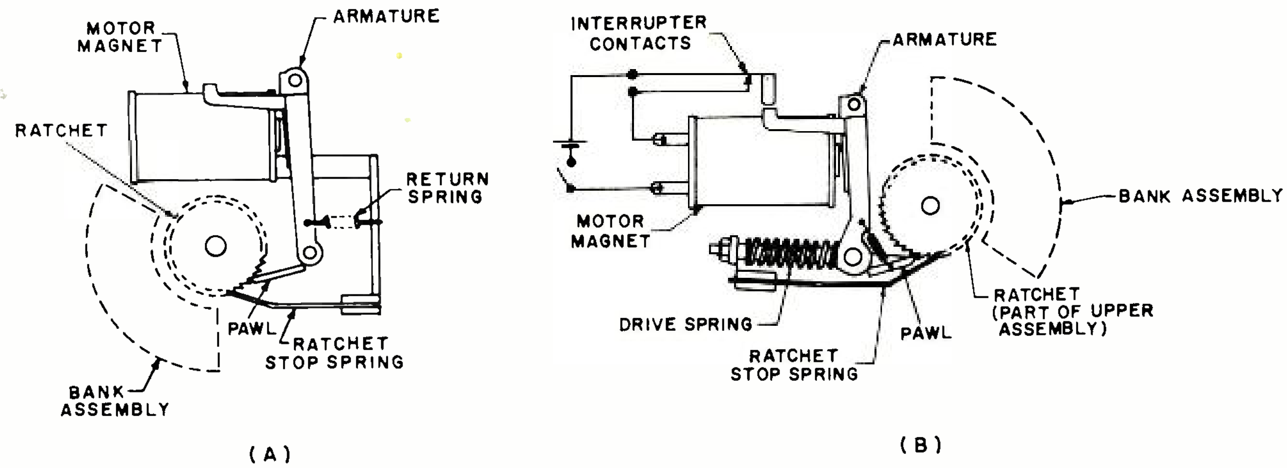
The solid-state time-delay relays are available in small enclosures and range in price from about $10 to $60. ▲

STEPPING RELAYS

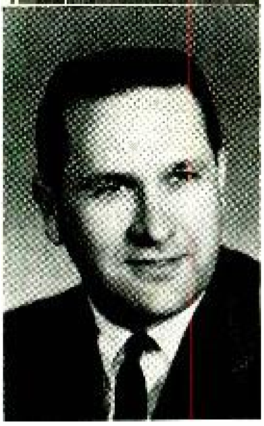
THERE are two types of driving mechanisms used in stepping relays (often called stepping switches): the indirect and the direct. When the armature-pawl combination acts directly on the ratchet under the power of the electromagnet, the device is said to be directly driven, as shown in Fig. A. When the pawl acts on the ratchet wheel from force stored in a drive spring, the mechanism is said to be indirectly driven. An example of this method is shown in Fig. B. The indirectly driven system is the most commonly used. The spring-driven system is more consistent in performance, more efficient, and capable of faster stepping than the directly driven type, besides having a longer operational life.

In an indirectly driven unit, when the proper voltage and power is applied to the motor magnet coil, the armature is attracted and holds the drive spring in the "cocked" position. When the coil is de-energized, the energy stored in the drive spring pushes the pawl against a ratchet wheel tooth, causing the wiper assembly to take a step. Repetitive pulses will cause the switch to take as many steps as the number of discrete pulses received. The length of time the circuit is closed (and opened) in a series of fast pulses is critical.

Self-interrupted operation, such as shown in Fig. B, is used to step the switch rapidly from one point to another without the use of discrete pulses from outside sources. In this method, a circuit is closed to the coil through a set of interrupter contact springs that are opened by an arm of the armature before it is fully seated. Breaking the coil circuit causes the armature to fall away, driving the wiper assembly one step and simultaneously reclosing the interrupter contacts. The armature is again attracted, re-cocking the switch and thus causing a re-opening of the interrupter contacts. The switch runs self-interruptedly until the circuit is again opened. ▲



(A) (B)



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Reed Relays

By ROGER L. ROSENBERG/Systems Project Engineer, C.P. Clare & Co.

Long electrical life resulting from precious-metal contacts sealed in inert atmosphere and absence of wearing mechanical parts are the most important advantages of this increasingly popular relay type.

WITHIN the last ten years the reed relay has become recognized as a reliable, low-cost switching device. The apparent simplicity of the reed relay probably influenced some designers to use it, but its more subtle features have increased its popularity. Long electrical life resulting from precious metal contacts sealed in an inert atmosphere and absence of wearing mechanical parts head the list. The relatively high speed and varied package configurations give it advantages over conventional relays. The price of a reed relay begins in the $2 to $7 bracket, varying with the quantity, the number of contacts, the coil size, and the manner of packaging. Its low cost, high circuit isolation, and insensitivity to noise make it an ideal replacement for electronic switches in many applications.

The heart of the reed relay is the reed switch. Discussion of reed relays must begin with the switch since the former can be no better than the switch it contains. To meet the demand, reed-relay manufacturers have had to automate their production.

Automation of reed-switch manufacturing has required much tighter control of all components and a better understanding of what is required to make consistently good switches. As designers found new applications, manufacturers had to develop both new design and new processes. The pressurized reed switch and mercury-wetted reed switch, along with varied contact material, have resulted. The simplicity of the switch belies the sophisticated technology required to manufacture switches with consistent electrical and mechanical properties. A description of the reed switch and its operating parameters will help illustrate the need for this control and technology.

The Reed Switch

The basic reed switch is a normally open contact. It consists of two ferromagnetic reeds, each of which is sealed in an end of a glass tube. The reeds are positioned so that their free ends are overlapping (typically 1/16 in) and are separated by a gap (between 0.005 and 0.012 in). These reeds constitute the magnetic circuit of the switch. When a magnetic field is introduced to the switch, the reeds become flux carriers. The overlapping ends assume opposite polarities and attract each other. If the attraction is strong enough to overcome the deflection characteristics of the reeds, they will move together and touch, making electrical contact.

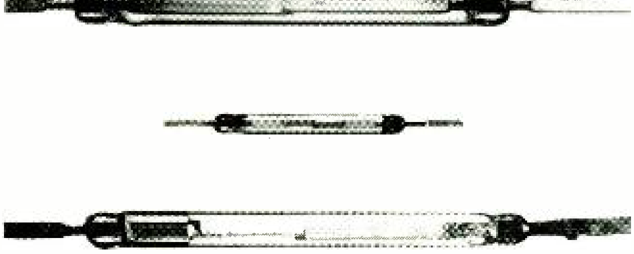
For consistent contact resistance the overlapping ends of the reeds are precious-metal plated. The contact plating must be thin and uniform so that the magnetic properties of the switch are not adversely affected. If the plating is too thick, the magnetic gap will be too great to insure sufficient contact pressure and will result in a high release characteristic. The field strength required to close the switch depends on the size of the reeds, the effective gap (atmosphere and plating) between them, and the amount of overlap. Small changes in any of these parameters can significantly alter the operating characteristics of the switch. These factors must all be controlled to insure the consistent characteristics necessary for designing the switches into relays. Other factors which must be controlled to obtain consistent and reliable operations are blade alignment, contaminants in the gas, and seal integrity.

The amount of power required to operate a reed switch is typically 125 mW. The more power applied, the faster the reeds will close, until the saturation point of the reeds is reached. The maximum speed is typically 0.8 ms, but this is usually impractical in most circuit applications because of the power requirements. Contact bounce is also increased when the switch is driven hard, so speed should never be considered alone.

Contact life is affected by contact bounce, the load switched, and the repetition rate. End of contact life, however, can only be determined by the circuit requirements. The load which can be handled by the reed switch depends on the contact material, the number of operations expected, and the failure criteria.

The most common contact material is plated and sintered gold. This contact has a relatively high rating of 15 VA and a life in excess of 20 million operations. Plated bright gold contacts can perform well with low-level loads because of their low and constant contact resistance. Bright gold presents a hazard, however, in that the closed contacts may fail to release because of a phenomenon spoken of as "particle migration" or "cold welding". Rhodium contacts appear good on both high- and low-level loads. Difficulties in controlling the plating can result in in-

Fig. 1. (Top) A standard dry reed switch. (Center) Miniature or micro dry reed switch. (Bottom) Mercury-wetted reed switch. These mercury-wetted types of switches, because of a pool of mercury at one end, must always be used in vertical position.



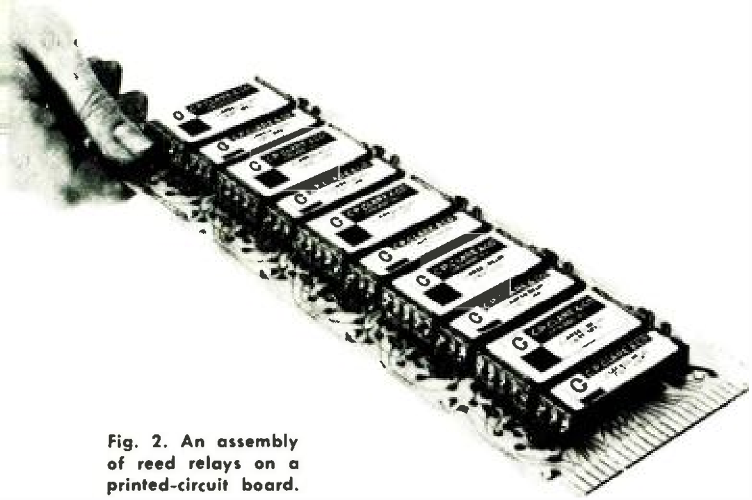


Fig. 2. An assembly of reed relays on a printed-circuit board.

consistent switches. Tungsten contacts are good performers in switching high loads such as lamps and solenoids.

Mercury can be used to coat one of the reeds so that it becomes a fluid contact. It eliminates operate bounce and maintains a constant, low contact resistance. The switch becomes position-sensitive since the mercury is fed up the lower reed by capillary action from a mercury pool at the bottom of the switch. (*Note that one of the reeds is dry as contrasted to the mercury-wetted contact relay, discussed elsewhere, in which all contacts are wetted by mercury.—Editor*)

While the basic switch is a normally open contact, other forms are available. The normally closed contact is made by affixing a permanent magnet of sufficient strength to close the switch. The operating flux must oppose the magnet sufficiently so that switch will open and remain open as long as the operating flux is present. "Break" and "make" can be accomplished by combining a normally open and a normally closed switch in the operating coil. The normally closed contact can be adjusted by magnet biasing so that break-before-make operation can be achieved. Break-before-make is also available in a single capsule. The break contact is accomplished by magnet or spring biasing the armature or swing contact to one of the stationary contacts. The most commonly used reed switches are:

Standard Dry Reed Switches. The standard reed switch, Fig. 1 (top), is approximately 3¼ in long by 7/32 in in diameter. It has plated and sintered gold contacts and is rated at 15 VA resistive (250 V maximum, 1 A maximum. Contact resistance initially is less than 50 milliohms. The standard switch will withstand shocks of 11 milliseconds' duration to 40 G peak without false operation.

Micro Dry Reed Switch. The micro, or miniature, reed switch, Fig. 1 (center), is approximately 1⅝ in long and 0.10 in in diameter. It is rated at 10 VA resistive (200 V d.c. maximum, 750 mA maximum). Initial contact resistance is typically 100 milliohms. The micro reed can withstand shocks of 11 ms duration to 50 G peak without false operation.

Mercury-Wetted Reed Switch. The mercury-wetted reed switch, Fig. 1 (bottom), is approximately the same size as the standard reed switch. It is rated at 50 VA resistive (400 V maximum, 2 A maximum). It is position-sensitive and must be mounted within 30° of vertical.

High-Voltage Reed Switch. The high-voltage reed switch has the same dimensions and contact rating as the standard reed switch. It is pressurized to achieve the high stand-off rating of 1500 V r.m.s. Special reed switches with stand-off voltages to 5000 V peak are available.

Reed Relay

The reed relay is made by enclosing one or more reed switches in an operating coil. The coil is usually wound on a bobbin made of nylon or other similar material. The bobbin may also have anchors or pins for attaching the coil leads and reed switches. The number of capsules to be placed within the coil determines the bobbin size. Most manufacturers limit the coil to handle 12 of the standard reed switches. Above this size proper operation of all switches is limited by the efficiency of the coil. Different contact forms can be combined in the same operating coil so that contact configurations such as 12A, 8B, or 4C or combinations of these are possible in a 12-switch coil.

Because the coils are wound on bobbins of a certain size, the resistance and turns of coils offered are determined by wire sizes. For a given bobbin, the turns and resistance will vary with each wire size and thus the operating voltage of the relay will change with each wire size for switches with the same operate characteristics. For example, a one-switch bobbin wound with #29 wire has 1200 turns and a resistance of 10 ohms while the same bobbin wound with #42 wire has 22,200 turns and a resistance of 3750 ohms.

The coil power required to operate the relay is determined by the number and configurations of contacts and by the operating speed required. A typical single form A relay will require approximated 125 mW, a 5 form A relay, approximately 450 mW. Most open-type relays will dissipate 4 watts in 25° C ambient. The maximum dissipation of the relay will depend on the coil wire insulation and construction materials.

No matter what package configurations the coil and reed switches acquire, there should be no stresses on the reed blades. Stresses can fracture the glass-to-metal seal on the switch and result in an early failure. Another factor which should be considered in the final package is shielding. Shielding of the relay can improve its characteristics and eliminate its influence on other relays or avoid its being influenced by them. Magnetic flux of one relay might actuate an adjoining relay. This can be significant when sensitive relays are packed closely together.

Relay-Application Considerations

The load to be switched must be evaluated so that the proper reed switch can be chosen. Loads such as lamps which have a high in-rush current can reduce life. Such schemes as having a resistance in the lamp circuit to keep it hot but dim can add millions of operations to the reed switch. Suppressing an inductive load also extends contact life. Contact protection such as an *RC* network can be applied, but is required only when the load exceeds the published ratings or when life expectancy must be extended.

After the proper switch has been chosen, the next consideration is to select the best package for application. The reed relay may be potted in a can and fitted with an octal-type base for chassis mounting. Other special packages are made.

The most popular means of mounting the reed relay is on printed-circuit boards. Its low profile and contact termination adapt it very well to such mounting. The coil bobbin is usually fitted with terminals which make the relay easy to install and give protection to the reed switches. A typical example of a reed relay printed-circuit board assembly is shown in Fig. 2. This 4¼" × 10⅞" board, having five counting stages, can be mounted on 25/32" centers. The reed switches are replaceable in this type of assembly if a change is required. For severe environments the relay may be potted or molded into special configurations. An epoxy-molded assembly is available for printed-circuit board mounting. The open-construction relay is quite adequate for most industrial applications.

These relays will operate over a temperature range from −65° C to 85° C. Special assemblies are made to operate to 125° C. The minimum breakdown voltage is typically 500 V r.m.s. 60 Hz, and the insulation resistance is greater than 100,000 megohms. Magnetic shields are supplied on the relays in most cases. Even with shields, the relays should not be located close to any device which can generate a strong magnetic field. The reed relay, if properly chosen, does not require a close-tolerance power source. One with a tolerance of ±10% is adequate for most applications.

When choosing a relay for an application, the worst-case power and temperature conditions must be considered together with the most unfavorable coil-manufacturing tolerance. If under worst-case conditions the available power diminishes to approach the just-operate value of the switches, the operate time will increase. Reed switches release in less than a millisecond in most relay assemblies. If the coil is shunted by a diode or by an *RC* network, however, the release time may reach several milliseconds.

High insulation resistance requires special materials and handling during the manufacture of the relay. Relays with insulation resistance greater than 500,000 megohms have been made in different configurations. Higher break-down voltage requires special assemblies.

Circuit Considerations

After the relay has been chosen it must function in the circuit. The fast operate-time of reed switches can become a problem unless care is taken to insure that the drive pulse is free from "grass" or discontinuities. If the discontinuities are long enough to allow the reed switch to release, random faults can occur. It is recommended that reed-switch counters, shift registers, etc., be driven by a mercury-wetted contact relay which has been buffered against possible discontinuities.

When the coil is de-energized and the reeds move apart, they swing through their neutral position and oscillate at their resonant frequency until all their energy is dissipated. Unless the switches are damped, the application of a holding voltage during this oscillating period can cause the reeds to reclose. An "off" time sufficient to insure the settling of the reeds is required to provide proper operation and repeatable timing.

To get the maximum number of operations from the reed switch every opportunity to first establish the path and then switch the load with a single heavy-duty contact should be explored. The most reliable circuits are those which use a combination of coil and switch logic. An example of this is the binary-coded decimal counter in which none of the contacts switch a load; they only perform the steering function for the count pulse. The output contacts can also be connected so that they can be strobed by a single contact thus insuring the same long life for them.

The addition of *RC* networks can make reed relays slow-release or slow-operate and slow-release. If the relay which is to be slowed has several switches, staggered operate and release can occur. The interposing of a single form A contact relay, having the proper delay network, to drive the multi-contact relay will solve the problem. Since the relay which now has the delay has a higher resistance, lower capacitance is needed.

Special Relays

Reed relays with multiple wound coils yield all of the basic logic functions and numerous special devices. Reed-relay two- and four-state flip-flops can perform all of the standard counting functions at speeds more than adequate for most industrial applications.

One of the most popular special relays is the magnetically latching or bi-stable relay, the windings of which are connected to oppose each other. A magnet is adjusted to a level not sufficient to close the reed but strong enough to hold it closed. The winding which aids the magnet is the "set" winding. The one opposing is the "release" winding. Voltage applied to the "set" winding causes the reed to close. When the voltage is terminated, the magnet holds the reed closed. Voltage applied to the "reset" coil opposes the magnet flux causing the reed to open.

Reed relays are used in a variety of industrial control devices, in telephone switching, materials handling, and in manufacturing automation. They provide the true isolation between input and output of a contact device, yet perform faster than conventional electro-mechanical relays. They permit multiple inputs, thus enabling logic to be performed by both the coils and contacts. ▲

MERCURY-WETTED RELAY CONTACT PROTECTION

CONTACT life expectancy is based on the use of proper contact protection, usually in the form of an **RC** network installed as close as possible to the relay terminals. Three methods of applying this protection, and means of calculating the capacitor and resistor values, will be covered here.

In the following discussion, the value of the capacitor (in microfarads) can be found from $C = I^2/10$, where **I** is the current in amperes immediately prior to contact opening. The value, in ohms, of the associated resistor can be found from $R = E / (10I)\alpha$, where **E** is the source voltage just prior to contact closure and $\alpha = 1 + (50/E)$.

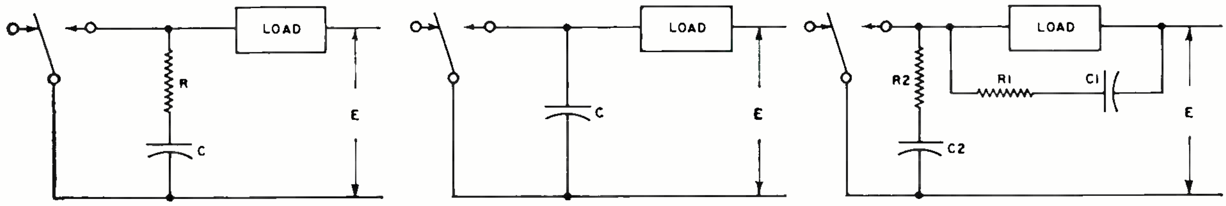
Where **E** is less than 70 volts, **R** may be three times the calculated value; where **E** is greater than 70 volts, but less than 100 volts, **R** may be ± 50% of the calculated value; where **E** is greater than 100 volts but less than 150 volts, **R** may be ± 10% of the calculated value; and where **E** is greater than 150 volts, **R** may be ± 5% of the calculated value. In all cases, the minimum value of **R** is 0.5 ohm, and the minimum value of **C** is 0.001 μF.

The arc suppressor shown in Fig. A is suitable for most load switching demanded of mercury-wetted contact relays. If desired, the value of the capacitor may be increased as much as 10 times to help reduce voltage transients of inductive loads.

When contact load current is 0.5 A or less, and the source voltage is 50 volts or less (peak values for a.c. circuits), the resistor may be eliminated as shown in Fig. B. The capacitor value must not exceed the calculated value.

For certain extreme loads, such as highly inductive a.c. loads at voltages above 100 V a.c., it may be desirable to place the main **RC** arc suppressor (**R1-C1**) across the load as shown in Fig. C. This alleviates the problem of a.c. leakage current through an **RC** arc suppressor in parallel with the contacts, but may result in a condition which exposes the contacts to voltage transients having a rate of rise in excess of 5 V/μs maximum, due to the inductance of the lead wires. A secondary arc suppressor (**R2-C2**) must then be included across the contacts. However, a.c. leakage across the contacts is markedly reduced since **C2** need only be one-hundredth of the calculated value.

Both resistors should be the calculated value although the value of **C1** may be increased up to 10 times the calculated value to further reduce transients. ▲



(A) (B) (C)

The author holds a B.S.E.E. from Illinois Institute of Technology. Before joining Magnecraft 14 years ago, he was associated with Motorola for 3 years. He is a member of NARM and has served on several steering committees.

Relay Coil Considerations

By M. S. STEINBACK
Chief Engineer, Magnecraft Electric Co.

In order to specify type of coil input for a given relay, the basic considerations covered here must be taken into account.

THE primary objective of a relay is to provide reliable closing of contacts that serve to open or close external circuits with a reasonable expenditure of remotely controlled electrical power. To effect this objective, there are many mechanical, electrical, and magnetic techniques to be considered.

Basic Operating Principles

Fundamentally, electromagnetic relays consist of a coil to provide the necessary energy and a permeable iron circuit. The iron circuit contains a fixed portion represented by the heelpiece and coil core and a movable member or armature. The armature responds to the magnetic attraction generated by coil energization so as to complete or close the magnetic circuit. In this manner a relay converts electrical energy into mechanical energy which, through mechanical linkages, actuates electrical contacts or conductors and, in turn, controls electrical circuits.

Fig. 1 illustrates the basic mechanism of a clapper-style relay which will ably convert electromagnetic energy into a contact-actuation system. As we can see, the armature must be mounted in a manner which will allow it to pivot properly and at the same time provide the necessary constraints so that its movement will be converted into useful work efficiently. The armature return spring will provide the stored energy required to return the armature to its unenergized position when coil power is removed. This return spring is also responsible for maintaining contacts in the closed position, when the relay is in the unenergized condition.

A.C. Relays

Fig. 1, together with the above discussion, is basic to d.c. electromagnets. Alternating-current relays provide additional problems in obtaining quiet, chatter-free operation due to the fact that the energizing current will pass through zero twice each cycle. Providing a shaded-pole magnetic structure (Fig. 2) is one method of overcoming this problem. The a.c. shaded-pole relays are similar to the d.c. electromagnetic relay shown in Fig. 1 except a separation is provided in the core pole face. A portion of this pole face is enclosed in a copper loop, generally referred to as a shading ring. The shading ring acts as a shorted turn around that portion of the core thereby producing a lag or delay in the change of magnetic flux. This will tend to hold the armature in the energized position, even though the energizing current continues its periodic cycling through zero. The ability of the armature to maintain its energized position is also dependent on the forces provided by the contact systems, return spring, gravity, etc. These forces are attempting to restore the armature to its unoperated position.

One begins to understand that the a.c. relay cannot provide the same "working-force" efficiency associated with the d.c. relay with its constant, non-varying magnetic field. Therefore, a.c. relays should not normally be considered for complex switching circuits or for those applications requiring precise pickup and/or drop-out or where critical timing is important. Despite their inherent limitations, a.c.-operated relays are quite popular due to the always convenient supply of a.c. power and, when properly used, they can offer excellent reliability.

Another method of providing a.c. relay operation is to employ a.c. rectification ahead of a conventional d.c. relay. However, care must be taken, in terms of providing proper filtering, to eliminate any pulsating d.c. effect. Once this is accomplished, the inherent d.c.-relay characteristics will be available to the user.

Power Considerations

In general, the relay user is concerned with "how much power do I have to provide to do the job?" The relay, on the other hand, is concerned with ampere-turns. This is the product of current (in amperes) multiplied by the number of turns of magnet wire in the coil. This product determines the electromagnetic energy developed which, in turn, dictates the amount of work the relay structure can accomplish.

The ideal relay would convert all the power applied into the useful work of switching contacts. To approach this end the mechanical structure of the relay must provide low reluctance and an efficient armature-movement system. The photo of Fig. 3 illustrates a clapper-style relay featuring an armature hinge-pin bearing system capable of providing stable, low-friction movement over long life.

Relays certainly can be considered as excellent amplifiers. If this term seems somewhat strange in this context, consider that it is possible with several milliwatts of coil input power to switch several kilowatts of power with the contact system providing an "amplification factor" approaching several hundred thousand to one. The photo of Fig. 4 shows a small power relay which is capable of switching in excess of 10,000 watts on the contacts with less than one watt of coil power. General-purpose, commercially available relays will require approximately one to three watts of coil power. Sensitive relays, operating in the 100- to 200-milliwatt range are also readily available. The amplification factor associated with electromagnetic relays makes them compatible with the reduced sizes and power needs afforded the equipment designer by the advent of solid-state devices.

Coil Rating Considerations

Relays are obtainable with a wide range of both voltage- and current-operated coils. In particular, 6,12,24,48,110, and 230-volt (both a.c. and d.c.) relays are commonly available. When considering whether to specify a coil rating for either voltage or current operation, the user should keep the following in mind. If a relay is to be operated in parallel with a power source where there are no other components in series with the relay coil, it is proper to specify the performance characteristic in terms of voltage. If there are other items in series with the coil-winding circuit, it is better to specify relay operation in terms of current.

It must be remembered that most power supplies associated with equipment designs will allow some voltage and current fluctuation depending on the degree of their regulation. The minimum value of voltage and/or current which will be provided in the circuit must be made part of the specification so that the relay manufacturer can assure operation of his product at that value. The above common voltage values are provided by most manufacturers so that the relay will "pick-up" or operate satisfactorily at a value which is 85% or less of the nominal coil voltage. At the other end of the scale the maximum variations must also be made known so that the relay coil design can properly dissipate the additional heat generated by the voltage or current excesses.

The ambient temperature range over which the relay is required to operate must also be stipulated. The resistance of the coil winding is proportional to the temperature in accordance with the formula: $R2 = R1\,[1 + \alpha 1\ (T2 - T1)]$ where $R1$ = resistance at the initial or standard temperature ($T1$), in ohms; $R2$ = resistance at a temperature ($T2$), in ohms; $T1$ = initial or standard temperature, in degrees C; $T2$ = temperature at which resistance $R2$ is desired, in degrees C; and $\alpha 1$ = temperature coefficient of resistance corresponding to temperature $T1$ and to correct conductivity of the wire whose resistance is $R1$.

For further simplification and easier use, this formula can be expressed as: $R1/R2 = (T1 + 234.5)/(T2 + 234.5)$. In this formula the 234.5 represents that temperature (in degrees C) below zero at which copper has zero resistance.

Therefore, we must consider that if the relay is to operate from a fixed voltage source with a fixed coil resistance, it will produce a given amount of current at room temperature (about 25° C). If the temperature ambient associated with the relay rises due to self-generated heat of the equipment or other external sources, the coil resistance will increase and the coil current will decrease. This will result in a lower ampere-turn product and the relay will not operate as reliably or perhaps not at all. This inherent effect can be compensated for by designing the relay to pick up at a properly reduced value at room temperature and thereby maintain correct operation at elevated temperatures.

Special Coil-Rating Considerations

There can be many "specials" associated with coil-operating parameters that may be required by the equipment designer. Some of the more common ones are best explained by the following definitions:

1. The relay is required to operate within a specific range of voltage or current which is defined as follows:

a. Non-operate or non-pick-up is the voltage or current at or below which the armature shall not move from its unoperated position and all contacts will remain in their unoperated position.

b. Operate or pick-up is the voltage or current at or below which the armature should assume its operated position and open or close all the required contacts.

2. The relay is required to release or drop out within a specified range which is defined as follows:

a. Hold is the value of voltage or current at or above which the armature shall not move from its operated position and all contacts shall remain in their operated position.

b. Drop out is the voltage or current at or above which the armature shall restore to its unoperated position and all contacts shall return to their unoperated condition.

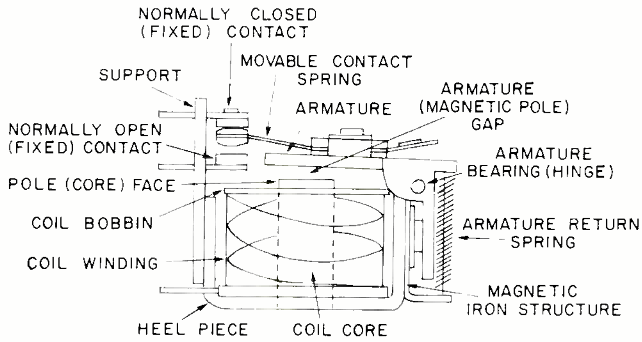


Fig. 1. Basic mechanism of conventional clapper-style relay.

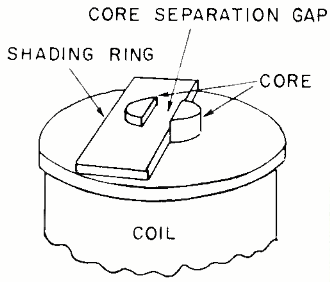


Fig. 2. Use of shading ring for alternating-current operation.

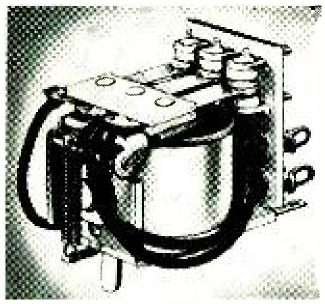


Fig. 3. Typical general-purpose clapper-style relay.

Fig. 4. This small power relay is able to switch in excess of 10,000 watts of power with less than 1 watt of coil power.

For most applications where the voltage or current is either completely on or totally removed, it is only essential to specify *pick-up* requirements. Applications that provide slowly changing input to the relay coil or where the relay is being used to sense a given level of circuit voltage or current may require the *non-pick-up* specification.

Many relays now operate in conjunction with transistorized circuitry which does not provide a true "off" or complete removal of voltage or current. This is due to an inherent "idling" or leakage current associated with most transistors. A relay operating in a circuit of this sort should have its *drop-out* requirement specified to insure that the relay will not remain in its operated position when the transistor is supposedly "off". Precise relay adjustments, as described earlier, are primarily associated with d.c.-operated relays. As previously stated, a.c. relays are best used in those applications providing true "on-off" coil inputs.

The importance of shock and vibration requirements as related to coil input considerations is that enough power be provided for coil operation so that the moving parts of the relay can be kept "stiff" and thus be more resistant to unwanted movement. In general, the more sensitive a relay of a given design is made, the less resistance it will have to shock and vibration effects. Certainly, the packaging and mounting of the relay by the user will be important factors in vibration and shock resistance.

For additional information on this and other related relay subjects, the author recommends the "Engineers' Relay Handbook" sponsored by the National Association of Relay Manufacturers (NARM) and published by *Hayden Book Company, Inc.*, New York, New York. ▲

Arc, Surge, and Noise Suppression

By R.M. ROVNYAK* / Staff Engineer, Product Design Section, Automatic Electric Co.

When relays are used in switching circuits, conducted and radiated r.f. interference as well as contact erosion may occur. Here are some of the techniques that are employed in order to minimize these harmful effects.

THIS article will discuss the suppression of interference associated with a relay. The entire system contributes to the noise problem and all factors such as grounding, shielding, bonding, wiring and component layouts, and choice of inter-system connection points must be adequately engineered to minimize noise.

Switching electrical loads may:

1. Develop voltage and/or current transients of sufficient magnitude to damage or destroy components within the system, rendering it inoperable.

2. Produce unwanted electrical disturbances which can cause circuit malfunction either within or external to the system.

3. Decrease the useful life of the system and its reliability by excessive wear and tear on its components.

The high-magnitude transients are associated with breaking inductive loads such as the coils of relays. The problem is most severe when the inductor is rapidly switched to the "off" state. Under these conditions the voltage can be very large and is of opposite polarity to the supply voltage. This presents a hazard to polarity-sensitive devices or it may initiate a high-energy discharge across a set of contacts or the insulation between windings on the coil or elsewhere.

Load switching may also generate coincident parasitic electrical disturbances or RFI (radio-frequency interference). This broad classification spans a frequency spectrum of about ten decades and can be classified into three types: *induced*, *conducted*, and *radiated*. The bandwidth associated with these are approximately: induced—10 Hz to 10^5 Hz; conducted—10^3 Hz to 10^8 Hz; and radiated—10^4 Hz to 10^{11} Hz.

Disturbances by conduction are derived from such things as dynamic regulation from the supply or down the line within the system, loop imbalances, recirculating currents from inductive loads, and poor connections. They are not particularly associated with any one type of load but are more dependent on the magnitude of the current being switched. Such disturbances are minimized by applying good techniques in inter-circuit connections, component layout, wiring practices, and the proper choice of hardware.

Inductive coupling between circuit loops or between an inductor and a loop can result in more than sufficient energy to cause circuit malfunction. Careful analysis of normal circuit current paths will pinpoint the need to either inhibit the source or minimize the pickup. Physical isolation between source and susceptible pickup points and the use of twisted-pair leads to reduce the area included within the loops are the principal cures although magnetic shielding is frequently required.

Arcing which occurs upon both make and break of a load by a set of contacts is a source of radiated electromagnetic interference. All load types (R, C, L) with open-circuit voltages above about 12 volts can initiate an arc at the contacts. This occurs in relay circuits as opposed to semiconductor switching. Suppression of some sort is required, the type depending on the load. The objective is to prevent or minimize the energy in the arc.

The final area of concern is the erosion of the contacts. We first choose a contact material which is optimum for the load and limit the arc energy by the application of suppression elements.

If we put a series RC network across the contacts and make R small, the impedance under the transient condition may keep the switch voltage (which includes applied and self-induced voltages) small immediately after the contacts break. This arrangement is preferred for most inductive loads, the contact voltage at the instant of opening being limited to $I_L R$, where I_L is the load current just prior to the break. In the case of the load being substantially removed from the switch, however, it may be best to suppress at the load unless the sole objective is to prevent contact erosion.

Two other factors associated with inductive load switching are interwinding capacitance and magnetic flux leakage. The capacitance is effectively in shunt with the coil and will draw high, short-duration charge currents. It is occasionally necessary to include a small inductor or resistor ahead of the load to limit the surge. The leakage flux will induce a voltage in a coupled loop and, if intolerable, magnetic shielding must be used.

Capacitor in-rush currents must be limited to reasonable values or high-energy arcs will be sustained on contact closure. Intense RFI will be generated unless the contacts weld first. Capacitive loads *per se* are routinely taken care of in the design; however, lead and winding capacitance, often overlooked, can play havoc with a system susceptible to such occurrences.

With any type of suppression scheme it is necessary to first establish the main circuit suppression requirements—such as to protect a solid-state device, minimize contact erosion, etc.—before deciding which technique represents the best compromise.

Arc-Suppression Practices

The selection of a suppression technique depends on the objectives to be obtained and the price one is willing to pay. The objectives can be categorized in three main areas: protection of components from destruction or abuse due to the transient; reduction of the erosion rate of the contact to increase the useful life of the contact; and reduction of the electrical disturbances produced by switching a load. The relative ease with which each may be accomplished is in that order and, as a general rule, one that satisfies the more difficult requirement will also take care of the less difficult ones, *e.g.*, a suppression scheme that inhibits RFI will also provide long life and protect associated components.

The price paid for achieving the required degree of suppression may be any one or more of the following: cost including component and installation; more power con-

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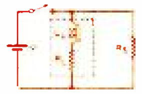
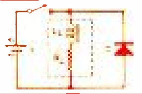
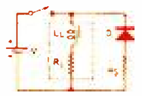
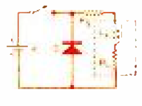
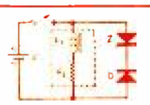
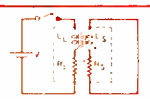
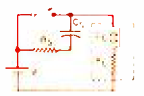
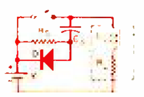
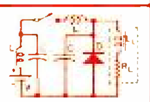
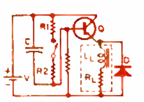
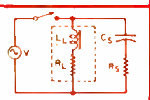
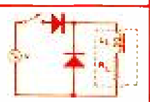
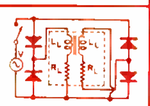
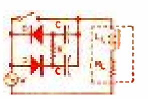
*The author is a 1961 graduate of Indiana Institute of Technology with a B.S.E.E. degree. His efforts have been in design and development of electro-magnetic switching devices. He has published several papers on related subjects and holds one patent, with another pending.

Table 1. Various suppression techniques used in relay circuits along with comments on their general characteristics.

DESCRIPTION	POWER a.c.	POWER d.c.	CIRCUIT DIAGRAM (Note 1)	PRIMARY Advantage / Disadvantage	COMPATIBLE WITH SOLID-STATE?	EFFECTIVE FOR SUPPRESSING Trans. Surge	Contact Erosion	Conducted RFI	Radiated RFI	RELEASE-TIME RANGE AVAILABLE	OPERATE TIME AFFECTED?	COMMENTS
Shunt Resistor		X		Low cost B.e.m.f. has fast dV/dt (Note 2)	Yes	X	Limited			Short	No	Low cost, non-polarized; power drain, peak b.e.m.f. = (V) (R_s/R_L). Release time is proportional to $1/(R_L + R_s)$. Typical values of R_s are $3R_L$ to $7R_L$.
Shunt Diode		X		1 V b.e.m.f. Long release time	Yes	X	X		X	Long	No	Polarized; peak b.e.m.f. = diode V_F. See Note 3. Frequently used with transistor switch because max. switch voltage is about 1 volt above V.
Shunt Diode, Resistive		X		No power drain Added cost	Yes	X	X			Medium to Long	No	Polarized; peak b.e.m.f. = diode V_F + (V) (R_s/R_L). Release time approx. proportional to $1/(R_L + R_s)$. Typical values of R_s are $0.2R_L$ to $5R_L$.
Shunt Diode, Series Res.		X		1 V b.e.m.f.; short release time More power in ckt.	Yes	X	X		Limited	Short to Long	Yes (faster)	Polarized; peak b.e.m.f. = diode V_F. Release time approx. proportional to $1/(R_L + R_s)$. Used for short release time when b.e.m.f. must be minimum. Typical values of R_s are $0.5R_L$ to $5R_L$. Works well on sensitive relays because R_s may be large.
Shunt Zener and Diode		X		Shortest release time per V b.e.m.f. Added cost	Yes	X	X			Medium to Long	No	Polarized; costly; peak b.e.m.f. = diode V_F + V_z. May obtain moderate reduction in release time compared to shunt resistor-diode for same peak b.e.m.f.
Shunt Non-linear Voltage-Sensitive Device	X	X		Low cost; short release time High b.e.m.f.	No	X	Limited			Short	No	Varistors and thyrites; non-polarized. Best results obtained if peak b.e.m.f. + V is less than 250 volts. Suppression for 115 V a.c. circuits is adequate for many applications. Peak b.e.m.f. is typically 150 to 250 V.
Shorted Bifilar Winding		X		No external element required Sacrifice coil power	Not Recommended	X	X	Limited	Limited	Medium	Yes (slower)	Non-polarized. May have advantages at environmental temperature extremes.
RC		X		Good contact protection Large b.e.m.f. peak	Not Recommended	X	X		Limited	Short	No	Across contacts preferred but may be across load. For load currents above 0.25 amp, RC-diode scheme is recommended. First approximation values: C = 1 μF per amp load current, $R_s \leq R_L$. Contact peak voltage should be limited to 250 volts. Non-polarized.
RC, Diode		X		Good all-around suppression Added cost	SCR's only	X	X	Limited	X	Short	No	Best suppression scheme, any load current. Recommended for I_L > 0.25 amp. $R_s \cong R_L$ (may be larger), C chosen to limit peak contact voltage to 250 volts max. Diode rating: $I_F = I_L$. $V_{p.r.v.}$ > peak voltage across R_s.
Shunt Diode and LC Filter		X		Suppresses conducted RFI Cost, weight, size	No	X	X	X	X	Long (deliberate)	Yes (slower) (deliberate)	Locate filters at switch, diode at coil. Polarized.
Transistor Driver		X		Excellent RFI suppression Added cost	—	X	X	X	X	Long (deliberate)	Yes (slower) (deliberate)	Best RFI suppression. Two stages required for heavy loads. Circuit variations are many. Object is to reduce current switched at contacts (5 mA or less) and prevent abrupt changes in load current. R1 = R2 and as large as circuit may tolerate (50-100 ohms, min.). C small but sufficient to slow transistor turn-off.
Shunt RC	X			Limits b.e.m.f. Power drain	No	X	Limited					Will suppress moderate arcing. $R_s \cong R_L$; C ≃ L/R_L^2. Object is to make the load more resistive.
Double Diode	X			Low b.e.m.f. Long release time	No	X	X		X	In general, a.c. relay timing is fast but varies depending on which part of the cycle the switch opens and closes. Diodes across the coil will increase release time as in d.c. relays.		Use with d.c. relay structures with light mechanical spring load or armature chatter may occur.
Double Diode, Two-Section Coil	X			Max. mag. mechanical efficiency Long release time	No	X	X	Limited	X			Used for maximum mechanical spring load with d.c. relay structure and two-section coil (not bifilar). Unlike conventional diode bridge, one side is line-connected.
RC, Diode	X			Good-all-around suppression Cost	No	X	X	Limited	X			Locate at the contacts. Diode $V_{p.r.v.}$ = 3 times supply peak, $I_f = I_L$. R ≅ 100 k, 1 W. C should be such that contact voltage is less than 250 volts peak. Switch bypass current must not be prohibitive for application.

NOTES: 1. L_L = Coil inductances (henrys); R_L = Coil d.c. resistance (ohms); I_L = Coil steady-state current (amps); R in ohms; C in microfarads; V in volts; t in seconds. 2. B.e.m.f. (back electromotive force) is common terminology for induced reverse voltage transient. 3. Diode rating unless otherwise indicated: $V_{p.r.v.}$ ≥ 2 V; I_F = max. load current, silicon generally preferred. Maximum release time is obtained with germanium diodes with low V_F.

sumption; increased space or weight requirements; or longer release times, in the case of relays. The circuit designer should approach the selection of a suppression technique by: first, deciding the objective; second, determining the effectiveness of the various techniques to accomplish the objective; and finally, resolve the best technique, based on a trade-off in parameters, including the reliability level of the suppression elements themselves.

Table 1 shows various suppression techniques used in relay circuits, with comments on each regarding general characteristics. It should be pointed out that, except for meeting elementary objectives, the final determination of values and suppression schemes is empirical.

Testing Suppression

Evaluation of suppression is a two-phase operation, observation of the transient magnitudes and degree and nature of the arc and then testing under operating conditions for the performance characteristic desired. A fast oscilloscope and a probe that does not load the circuit are required to observe the transient and arc. A small resistor, suitably located, may be needed in order to observe the current in some circuits.

The nature of the load characteristics will determine the approach and interpretation of the results to arrive at the most suitable suppression scheme; *i.e.*, the prime factor in an inductive load is the surge voltage, in a capacitive load it is the surge current, and in an arc it is its power level and energy content. If the load is a relay, the effect on timing may be important.

A common method of measuring this effect is to trigger the scope at the instant the coil is de-energized either from the decay slope of the energizing pulse or the induced transient and measuring the time until contacts change state by displaying the voltage drop across a resistive load switched by the contacts. It is good practice to use a dual-trace preamp and to display the trigger because false triggering can lead to confusing results.

Switching electromechanical devices with semiconductors presents no particular hazard if the transient voltage, current, and time dependency (dV/dt rate in the case of an SCR) are maintained within rated limits. Three basic things should be kept in mind: 1. The peak voltage across the switch is the static off-voltage plus the transient peak when the suppression is across the load. 2. The peak turn-off current will be the load current at time of switching. 3. The decaying current must recirculate decaying to zero, and will seek the part of lowest impedance which should be, by design, the suppression elements.

Testing the effectiveness of RFI suppression involves a fairly complex approach. Relative estimates can be made for conductive disturbances by monitoring with an oscilloscope, for radiated interference by observations of arc characteristics, and the coupling interference must be built into the circuit as previously described. Beyond this, standard apparatus and measurement schemes must be employed, and the reader is referred to the following Military Specifications for further guidance in this area MIL-I-26600, MIL-I-6051C, MIL-S-10379, MIL-I-11748B, and MIL-I-6181D. ▲

FINDING RELAY OPERATE AND RELEASE TIMES

By DONALD LUDWIG

WHEN designing circuits using relays it is often necessary to know the relay's operate and release times. Because of certain circuit conditions, the times given by the manufacturer will not always hold true. The method to be described will help establish these parameters and requires only a regulated power supply, a single-trace oscilloscope, and two simple circuits—as suggested by the National Association of Relay Manufacturers. This article illustrates the standard s.p.d.t. break, make Type-C relay under test. This type of relay is frequently used and the circuits employed can easily be converted to test other types of relays.

Operate time begins when the energizing voltage is applied to the relay coil and ends when the wiper arm has reached the energized (N.O.) position. See Fig. 1. Release time starts with the removal of the energizing voltage from the coil and ends when the wiper arm has returned to the deenergized (N.C.) position. See Fig. 2.

The checks should be made under conditions closely approximating actual operating conditions. These include temperature, mounting position, use of arc suppressors, and any other circuit conditions that may affect operate and release times. It should also be remembered that the accuracy of the test is dependent on the accuracy of the scope, if all other precautions are taken.

If the relay being tested has more than one set of contacts, the operate and release times of each set being used should be checked. The time required for each set of contacts to function may differ from one set to another. An increase in coil temperature due to repeated operations of the relay may cause the resistance of the coil to change and affect the time elements of the relay. Each set of contacts should be checked several times before calling the test conclusive.

When determining relay operate and release times, the scope's sweep speed should be set with a time base which will permit viewing of the waveforms and still allow accurate readings to be made.

This method requires no elaborate equipment to establish the relay's operate and release times. Using an oscilloscope also permits contact bounce to be examined. ▲

Fig. 1. Circuit used to find operate time of relay along with oscilloscope display that is produced with setup.

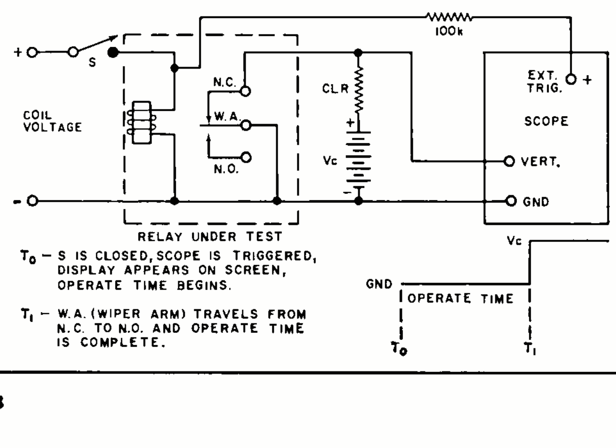
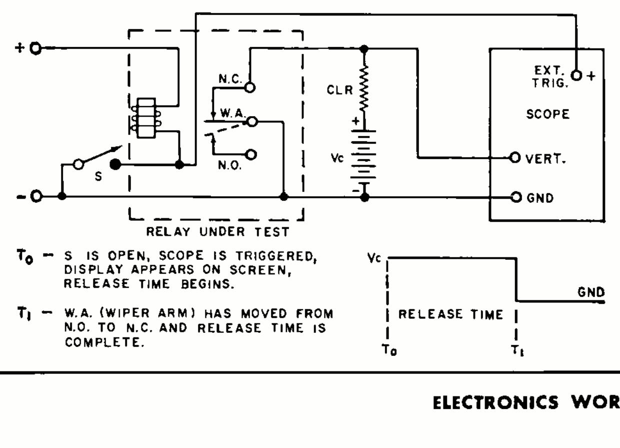


Fig. 2. Circuit used to find release time of relay. The values of CLR and V_C depend on particular application.



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Electrical Contact Considerations

By ARTHUR O. CAPP, Jr./Engineering Mgr., Electrometals Group, Fansteel Metallurgical Corp.

Specifying the best contact material for a relay requires a knowledge of what materials are available and their operating characteristics. The various design factors that must be taken into account are covered.

SPECIFYING the best contact material for a relay, switch, or other such device is one of the essentials for the designer in his initial design considerations. A wide variety of materials is available, each developed to provide certain specific electrical and mechanical advantages for the particular application. Also, because precious or semi-precious metals are often involved, cost is a very important factor which must be considered. An understanding of the influence of electrical and mechanical characteristics of the device upon the selection of the proper contact material for the application is a "must".

Know Your Requirements

The designer must first consider what is expected of the contacts in his device. In general, they must: 1. conduct the maximum current to which they will be subjected; 2. dissipate the maximum amount of heat; 3. remain sufficiently clean so that uniform contact surface resistance will be maintained; 4. resist sticking or welding, even after long service; 5. resist corrosion in any atmosphere to which they may normally be subjected; 6. be sufficiently hard to withstand expected mechanical wear; and 7. be capable of withstanding expected erosion.

Factors to be considered include: expected current load, type of current (a.c. or d.c.), type of load (inductive, resistive, capacitive, etc.), expected operating voltage, peak make and break current, peak make and break voltage, arc suppressing methods, contact bounce or chatter, contact closing force, contact opening force, horizontal or vertical plane contact action, frequency of make and break, wiping or rotary action, snap action, maximum contact separation, physical dimensions of contacts and backings, material for backings, methods of contact assembly, mechanical wear, foreign matter (oil, dust, other contamination), heat generation and dissipation, surrounding atmosphere, and ambient temperature. There is much to be gained by giving careful consideration to all these factors, plus any special factors that are peculiar to the device that is being designed.

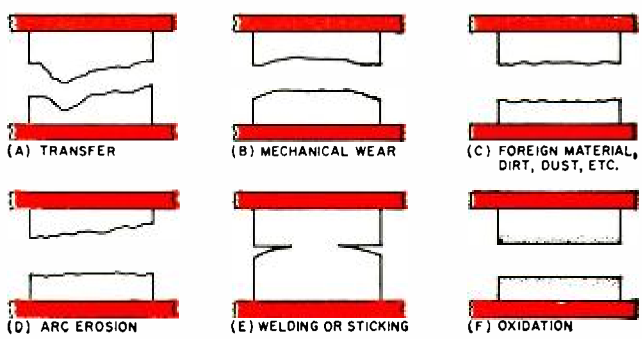
Know Your Contact Materials

In any device electrical contacts are required to perform three basic functions: 1. make the electrical circuit, 2. break the electrical circuit, and 3. carry the contact current required by the particular application. Success or failure of a contact is controlled by the electrical characteristics of the circuit, by the mechanical characteristics of the device, and by the properties of the material itself. Failure of the selected contact material to perform satisfactorily can be recognized visually as indicated in Fig. 1.

Unfortunately, there is no "universal" contact material which answers the requirements of every situation. Such a material would have to function under electrical conditions ranging from dry circuitry to heavy current without welding, overheating, eroding away, or corroding badly enough to cause an open circuit. Each application must be evaluated and a material selected which most closely meets its particular parameters. At best, each material selected represents a compromise of one property for another depending upon the set of conditions for that particular application.

The materials used for this highly specialized function are metals which either in themselves demonstrate desirable properties or when alloyed or combined with others,

Fig. 1. Symptoms of electrical contact failures. (A) In d.c. circuits arc erosion sometimes causes metal to migrate, resulting in a pit or depression in one contact and building a cone on the other. (B) An abraded or deformed appearance on contacts otherwise clean. (C) Irregular pits, roughening or discoloration, often mistaken for oxidation or arc erosion. (D) A roughening or pitting of the contact surfaces usually accompanied by blackening or discoloration, sometimes showing spots actually melted. (E) Overheating may cause contacts actually to weld to each other. (F) A discoloration over the entire contact face, generally black, bluish, brownish, or yellow, accompanied by increased resistance.



assume new compromise properties to suit the need. Important properties for consideration range all the way from the high conductivity of pure fine silver to the mechanical wear and arc-resisting properties of pure tungsten. They include the low contact pressure materials such as the platinum group metals to some of the relatively inexpensive base metals and oxides used in small alloying amounts to achieve selected specific properties.

Table 1 is a listing of the most used contact metals or alloying elements arranged in descending order of electrical conductivity. Also shown are the specific heat, melting point, boiling point, and density of each element—information which is often helpful in considering what material to specify. A comparative cost column is provided to judge the economics involved. It should be noted that although the relative operating forces are not listed, some contact metals, because of their inherent resistance to surface corrosion or contamination, can operate at very low pressures and therefore compensate for a lower conductivity as compared to another metal which has a higher conductivity but reacts with the surrounding environment, forming high resistance oxides or other compounds.

Classification by Groups

All metals, alloys, and powder metallurgy compositions used for electrical contacts may be grouped into the following general classifications:

Refractory Metals. Tungsten and molybdenum are typical of this group. Both have high melting points, low vapor pressures, and high resistance to welding, pitting, and arc erosion. They are usually employed in applications where operation is continuous or very frequent, where closing forces are relatively high, and where there are appreciable peak voltages due to inductance. Although they resist oxidation and atmospheric corrosion at room temperatures, their tendency to form highly resistant oxides at elevated temperatures and under severe arcing conditions is a disadvantage. This, however, is overcome by any one of several methods, such as using higher closing force, a hammering or wiping action, proper arc suppression, or a properly balanced circuit. The advantages of the refractory metals are retained and their disadvantages minimized by combining them with highly conductive metals such as silver or copper.

Highly Conductive Metals. Fine silver has the highest electrical and thermal conductivity of all the metals used in electrical contacts. Although it forms an oxide, the oxide is conductive and decomposes at relatively low temperatures, so that a low contact surface resistance is maintained. The disadvantages of silver are its low melting point, its softness, and its tendency to form resistant sulfide surfaces when exposed to sulfurous atmospheres. However, fine silver is used for a great many contact applications. It is also combined with many other metals, including copper, nickel, cadmium, cadmium oxide, iron, palladium, and others to reduce metal transfer and give greater resistance to sticking, welding, or atmospheric corrosion. Obviously, the less expensive alloying elements also tend to reduce cost.

Non-Corroding Metals. Platinum, palladium, and gold are used in electrical contacts because of their high resistance to corrosion and tarnish, even when subjected to chemically contaminated atmospheres. Contacts of these metals are used in sensitive devices, employing extremely light contact forces, in which clean contact surfaces are essential. These metals are seldom used in their pure state, however. Because of their inherent softness, they are usually alloyed with iridium or ruthenium. For economy, they are sometimes alloyed with silver.

In most applications, the same contact material is used in both contacts of a pair, but sometimes better performance is obtained by making use of dissimilar materials.

Design Factors to Consider

Conductivity. Even though the voltage and current in the circuit may be of only nominal value, the amount of heat energy generated at the contacts often attains startling proportions. The effective conductivity of the operating surfaces, especially after considerable use, is therefore of much greater importance than the nominal conductivity of the material of which the contact is made. Whatever contact material is used, the contact mass and surface area must be ample to conduct the maximum current and provide sufficient heat dissipation. The designer must realize, too, that inadequate removal of heat greatly increases the resistance of any contact material which, in turn, generates more heat.

Arc Erosion. When the potential difference between a pair of operating contacts exceeds certain minimum voltage levels (see Table 2), an arc or electrical discharge takes place. This arc is an electrical path of considerable conductivity whereas the gaseous materials surrounding the contacts, such as air or nitrogen, are normally non-conducting.

The energy released upon the contact materials due to arcing is violent and extremely erosive. This energy is dissipated rapidly by several means: the surfaces where the arc strikes are instantly increased in temperature to the melting point and often to the boiling point; energy is conducted through the metal away from the hot spot by thermal conduction; and energy is dissipated by radiation from the glowing hot spot. If the energy generated by the arc is at a rate that exceeds the rate of dissipation by conduction and radiation, then evaporation of metal occurs.

This evaporation and expulsion of molten metal from the arc area due to the explosive forces released are the principal means of erosion. Other more subtle phenomena also occur. However, it can be seen that the lowest erosion rate for a given arcing condition is obtained from contact materials with the highest boiling point, highest density, and highest thermal conductivity. These properties at once indicate the suitability of metals like platinum, iridium, and tungsten. Again, though, a compromise is often indicated because of other design considerations. In any case, contacts should be designed with sufficient thickness to allow for expected erosion during the life of the device.

Mechanical Factors. The mechanical operation of a current-interrupting device should be made as favorable to the contacts as possible. To maintain low contact surface resistance, every effort should be made in designing the operating mechanism to assure that the contact surfaces remain smooth, clean, and free from contamination.

Troubles arising from dirt on contact surfaces will be minimized if the contacts operate with their surfaces in a vertical plane. Tightly fitting covers over contact mechanisms are also helpful. Rubbing action against insulators is a common cause of dust and this condition should be avoided.

Surface contamination is an extremely critical factor in premature contact failure, especially at dry-circuit and low-duty levels. The search for and elimination of such contaminants has become a very serious and sophisticated function in relay design. Aside from the obvious atmospheric and industrial sources, research has shown that some benign and inert electronic materials are sources of organic and corrosive vapors and insulating films. For example, Teflon, even at fairly low relay operating temperatures, gives off small amounts of acid vapors including minute but corrosive hydrofluoric acid. Another insulating material exudes silicone vapors which under certain conditions react to form a glass-like insulating film on the mating contact surfaces.

Hermetically sealing the entire device has become a fact of life today to insure ultimate reliability. However, a false sense of security is frequently obtained when devices are hermetically sealed. Serious problems can develop, undetected until too late, by careless processing and inadequate seals. Before the mechanism is enclosed and sealed, every precaution must be taken to insure absolute cleanliness. Frequently after a failure such contaminants as lint, dust, metallic particles, flux residues, etc., which could have been avoided, are found inside the device.

Perhaps the most common contaminants in sealed relays are organic materials and their derivatives. One such example is "frictional polymer," a brown amorphous deposit believed formed from organic vapors at the contact rubbing site, especially in the presence of a metal of the platinum-palladium group. Exclusion of organic materials is one obvious solution. Until recently very little was known about this mysterious substance. However, studies now indicate that the contact material itself is the catalyst. The organic or hydrocarbon source can be almost anything: phenolic structural parts, cellulose acetate, polyvinyl chloride, or Mylar insulators. Work being done in several areas suggests certain additive agents will poison the reaction process. However, any source of organic or hydrocarbon contaminants should be questioned and eliminated, if possible.

The inert gas selected for filling sealed devices should have good heat transfer, arc suppression, and other desirable characteristics. Moisture can be a very serious contaminant factor. In most instances dry nitrogen with a dew point below −100°F is used and traces of helium are added to simplify leak detection by mass spectrometer techniques.

Contact bounce is often a significant factor in excessive arc erosion and striking. Bounce is caused by the inertia of the contact masses moving together rapidly and hitting each other with such force as to cause them to deform elastically and then rebound, thus re-opening the circuit. This re-opening of the circuit usually restrikes the arc, often increasing the tendency to stick. This may be minimized by reducing the mass of the contacts or increasing the closing force. A common design approach on sensitive devices, or where the economics of the design allow, is to provide the current a dual, parallel path through which to flow. This is often referred to as a *bifurcated* design.

Bifurcated contact points distribute the current through two pairs of contacts which are somewhat smaller in mass and rarely bounce at exactly the same time or frequency, thus reducing substantially the tendency for either contact pair to open the circuit. Another method of reducing bounce is to close the contacts on an angle, thus reducing the force vector perpendicular to the contact face, and also employing surface friction to slow the movement while the circuit is being made.

The force with which contacts open and close should be carefully established and, in all cases, the closing force must be sufficient to insure good contact and minimum contact resistance.

Element	Conductivity Elec'l. % IACS	Conductivity Thermal (%)	Specific Heat (%)	Melting Point (°C.)	Boiling Point (°C.)	Density (g/cc)	Comparative Cost
Silver (Ag)	106	100	100.0	960.5	1950	10.5	$ 1.293/troy oz
Copper (Cu)	101	94.1	164.5	1083.0	2310	8.94	.36/lb
Gold (Au)	75	71	55.2	1063.0	2600	19.3	35.00/troy oz
Aluminum (Al)	64.9	53	405.0	660.0	1800	2.7	.25/lb
Magnesium (Mg)	38.0	36.7	446.2	651.0	1100	1.74	.37/lb
Rhodium (Rh)	37.4	21	107.1	1966.0	2500	12.44	200.00/troy oz
Molybdenum (Mo)	34	34	115.9	2620.0	3700	10.2	35.00/kg
Iridium (Ir)	31.9	14	57.7	2454.0	4400	22.4	170.00/troy oz
Tungsten (W)	30	39.7	60.9	3410.0	5900	19.3	20.00/kg
Zinc (Zn)	28.6	27	161.1	419.4	907	7.14	.16/lb
Cadmium (Cd)	24.7	22	98.0	320.9	767	8.65	2.75/lb
Nickel (Ni)	23	22	200.7	1452.0	2900	8.9	.85/lb
Ruthenium (Ru)	22.2	—	101.7	2500.0	4900	12.2	55.00/troy oz
Iron (Fe)	17.75	18	240.5	1539.0	3000	7.87	.03/lb
Platinum (Pt)	16	16.5	57.0	1773.5	4300	21.45	100.00/troy oz
Palladium (Pd)	16	16.8	105.0	1554.0	2540	12.0	35.00/troy oz
Mercury (Hg)	1.7	1.96	59.0	38.9	357	13.55	6.58/lb
Graphite (C)	.12	5.7	295.7	3700.0	4200	2.25	1.25/lb

Table 1. Physical properties of materials used for contacts.

MATERIAL	VOLTAGE (in volts)	CURRENT (in amps)
Cu	13	0.43
Ag	12	0.4
Au	15	0.38
W	15	1.0
Pt	17.5	0.9
Pd	15	0.8

Table 2. Minimum arcing voltage and current of common contact materials at room temperature and at 35-60% relative humidity.

AUTOMOTIVE RELAYS	RECOMMENDED	ALTERNATE
Headlight	75 Ag,24.5 Cu,0.5 Ni	Coin Silver
Horn	75 Ag,24.5 Cu,0.5 Ni	Coin Silver
Starter	90 Ag,10 CdO	85 Ag,15 CdO
Vibrator		
Power Contacts	Tungsten	Moly vs Fine Silver
Driver Contacts	90 Pt,10 Ru	75 Ag,19.5 Cu,5 Cd,0.5 Ni
Voltage Regulators		
Voltage Contacts	90 Pt,10 Ru (+) vs W (−)	72 Pd,26.2 Ag,1.4 Cu, 0.4 Ni (+) vs W (−)
Current Contacts	90 Ag,10 Ni (+) vs 97 Ag,3 Pd (−)	77 Ag,22.6 Cd,0.4 Ni (+) vs 97 Ag,3 Pd (−)
Cut Out Contacts	Coin Silver	75 Ag,24.5 Cu,0.5 Ni
AVIATION EQUIPMENT RELAYS		
Light Duty	Fine Silver	90 Ag,10 CdO
Medium Duty	90 Ag,10 CdO	75 Ag,24.5 Cu,0.5 Ni
Heavy Duty	85 Ag,15 CdO	60 Mo,40 Ag
BUSINESS MACHINE RELAYS		
Light Duty	Fine Silver	90 Ag,10 Pd
Medium Duty	90 Ag,10 CdO	90 Ag,10 Ni
Totalizing	Fine Silver	85 Ag,15 Cd
COMMUNICATION EQUIPMENT RELAYS		
Telegraph	Palladium	72 Pd,26.2 Ag,1.4 Cu, 0.4 Ni
Telephone	Palladium	72 Au,26.2 Ag,1.8 Ni
Voice	72 Au,26.2 Ag,1.8 Ni	90 Pt,10 Ru
ELECTRONIC EQUIPMENT RELAYS		
Choppers	90 Pt,10 Ru	90 Ag,10 Au
Computers	90 Pt,10 Ru	92 Pd, 8 Ru
Relays, Photoelec.	Fine Silver	90 Ag,10 Pd
Vibrators, Pwr. Sup.	Tungsten	Moly
IND'L. & POWER EQUIPMENT RELAYS		
Light Duty	Fine Silver	Coin Silver
Medium Duty	90 Ag,10 CdO	85 Ag,15 Cd
Heavy Duty	35 Ag,65 WC	85 Ag,15 CdO
Time Delay	Fine Silver	Coin Silver
RAILWAY EQUIPMENT RELAYS		
Block Signal	90 Pt,10 Ru	72 Au,26.2 Ag,1.8 Ni
Highway Crossing	Fine Silver vs Silver Graphite	90 Ag,10 CdO
Automatic Gate	Fine Silver vs Silver Graphite	85 Ag,15 Cd

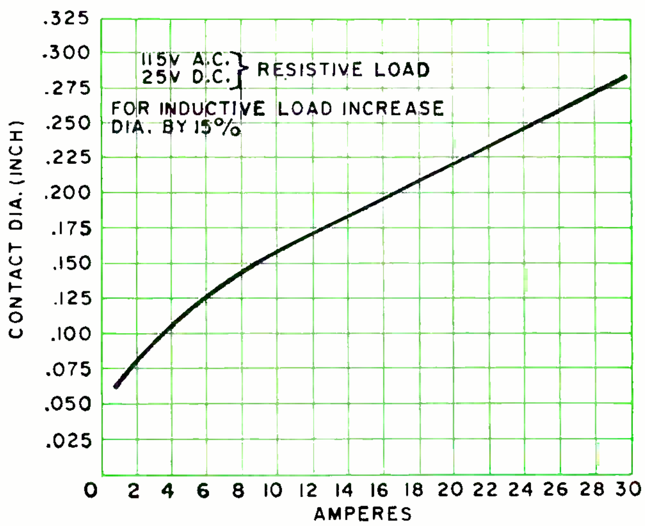
Table 3. Contact material selector chart. Recommendations are intended as guide only. In selecting material, deviations may be required due to circuit or operating conditions.

	CONDUCTIVITY (%IACS)	HARDNESS (Rockwell)	DUCTILITY	CLOSING FORCE
DRY-CIRCUIT AND LIGHT-DUTY APPLICATIONS				
Platinum Alloys:				
90 Pt-10 Ir	7	15T67	Poor	Light
85 Pt-15 Ir	6	15T88	Very Poor	Light
90 Pt-10 Ru	4	15T90	Poor	Light
73.4 Pt-18.4 Pd-8.2 Ru	4	15T90	Poor	Light
Gold Alloys:				
68.8 Au-25.9 Ag-5.3 Pt	14	15T74	Good	Light
72 Au-26.2 Ag-1.8 Ni	14	15T61	Good	Light
Palladium Alloys:				
92 Pd-8 Ru	8	15T91	Very Poor	Light
72 Pd-26 Ag-2 Ni	4	15T82	Very Poor	Light
40 Pd-30 Ag-30 Cu	8	50T81	Poor	Light
72 Pd-26.2 Ag-1.4 Cu-.4 Ni	4	15T85	Poor	Light
MEDIUM-DUTY APPLICATIONS				
Coin Silver	92	15T70	Good	Med-Light
Eutectic Silver	87	15T77	Good	Medium
75 Ag-24.5 Cu-.5 Ni	79	15T78	Fair	Medium
85 Ag-15 Cd	34	15T56	Good	Medium
90 Ag-10 CdO	79	F 50	Fair	Medium
77 Ag-22.6 Cd-.4 Ni	30	15T68	Good	Med-Light
90 Ag-10 Au	47	15T48	Good	Med-Light
97 Ag- 3 Pd	59	15T55	Good	Med-Light
90 Ag-10 Pd	29	15T64	Good	Med-Light
80 Ag-20 Pd	14	15T70	Good	Med-Light
97 Ag- 3 Pt	47	15T56	Good	Med-Light
90 Ag-10 Ni	90	15T56	Poor	Medium
85 Ag-15 Ni	85	15T60	Very Poor	Medium
HEAVY-DUTY APPLICATIONS				
85 Ag-15 CdO	72	F 50	Poor	Med-Heavy
83 Ag-17 CdO	67	F 50	Very Poor	Med-Heavy
80 Ag-20 Ni	81	15T61	Very Poor	Med-Heavy
60 Ag-40 Ni	65	15T75	Very Poor	Med-Heavy
Tungsten-Silver (20-50)	42-65	B102-77	Brittle	Heavy
Tungsten-Copper (20-50)	28-55	B98-70	Brittle	Heavy
Tungsten-Carbide-Silver (50-65)	45-60	B50-89	Brittle	Heavy
Tungsten-Carbide-Copper (35-50)	33-43	B90-105	Brittle	Heavy
Molybdenum-Silver (35-50)	42-55	B92-72	Brittle	Heavy
Silver-Carbon (1-5)	92-60	H 80	Fair	Medium

Table 4. Typical contact materials for various applications.

The required closing force varies with different contact materials. The noble metals (platinum, palladium, gold) and their alloys, highly resistant to tarnish, are generally used with low closing forces. Silver and its alloys require low to medium force, with greater forces at higher current. Tungsten, molybdenum, and *Ag*-refractory materials require medium to high forces, depending upon current, voltage, and contact protection. A safe procedure is to use the greatest closing force which the contact material will withstand without excessive mechanical wear or bounce.

Fig. 2. Current-carrying capacity of a pair of fine silver contacts of various diameters. One contact employed had a flat face while the other contact employed had radius face.



Even under normal operating conditions, contacts often become coated with resistant oxide or sulphide films. This is especially prevalent in low-voltage, high-current circuits where low contact forces are used. A slight rubbing or wiping action as the contacts close will help remove surface films and keep surfaces clean.

The opening force is just as important as the closing force. In general, mechanisms should be designed to open the contacts as rapidly as possible so that there is no lingering arc, and with sufficient force so that the contacts will open even under tendencies to stick or weld.

Arc Suppression. Arcing of contacts may be due to the electrical characteristics of the circuit, the characteristics of the make and break mechanism, or the properties of the contact material. Changing the electrical circuit by the inclusion of protective devices will reduce arcing appreciably, or eliminate it altogether. The protective devices most frequently used are capacitors, rectifiers, or resistors. These devices should be used, however, only after a thorough study of the circuit and actual tests which show the arc suppressor to be of the correct value. A capacitor of incorrect capacity, for example, is often worse than none at all.

Rating Electrical Contacts. How large a contact of a particular shape or material is required to carry a certain current load? This is a natural question, but not easily answered. A review of the many factors influencing contact performance reveals the complex phenomena which occur as contacts make and break a circuit. It is readily seen that one is unable to state definitely, even knowing such fundamentals as operating voltage, contact force, frequency of operation, etc., that a contact of a certain diameter made of a certain material will perform adequately. It is equally impossible to state that a certain size and type of contact made of a specified material will handle the same voltage and current load under all conditions.

However, by reducing the number of electrical and mechanical variables to a very small number, it is possible to obtain some fundamental information concerning the load-carrying capacity and current rating of various sizes of electrical contacts. To this end, extensive tests were made in one contact laboratory under controlled values of voltage and current and under as nearly uniform mechanical conditions as possible, using contacts of various sizes. Fine silver was used as the contact material because of its wide general usage. Solid-headed rivets were used in all tests, the moving contact having a radius face and the fixed contact a flat face. The contact opening force was 10 to 12 oz., the closing force about 1 oz.

All tests were made with 28 volts d.c. or a 115-volt, 60-Hz a.c. supply. From the vast amount of data taken, it has been found possible to establish approximate relations between contact diameter and current rating. This information is presented graphically in Fig 2. It must be understood that this data was taken from tests with one set of conditions and must be used as a guide only for other conditions and materials.

Keep Your Contacts Clean

The elementary rule to follow in cleaning contact materials is to prevent them from getting dirty, oily, or contaminated in the first place. It is a simple procedure to acid clean or vapor degrease an unassembled metallic contact. However, once it is assembled it is another story. Many different materials become involved, some of which are attacked by cleaning solutions. Also, cleaning solutions or solvents are frequently not removed completely especially from small crevices and areas where they are held by capillary action. These, then, become the source of organic vapor contaminants or other corrosive fumes.

The importance of manufacturing cleanliness in the reliability of sensitive devices cannot be overemphasized. Assembly equipment should be kept clean at all times, the assembly area should be free from dust, lint, and gaseous vapor contaminants, and the components should be stored in clean, covered containers.

Select the Best Material

When all of the requirements of a particular application are understood and the properties and design parameters of various contact material classifications known, the designer is ready to consider selection of one specific material. This selection, as stated before, is invariably a compromise to attain an optimum balance of properties which together will provide the performance characteristic required of the device.

Fine silver is the most important of all contact materials because of its conductivity, ductility, and reasonably good resistance to tarnishing. Tungsten is probably the second most used pure metal because of its wear and arc-erosion resistance. However, between these two extremes there are literally hundreds of combinations from which to choose.

There are few general rules to remember. Any alloying metal added to the base metal usually reduces its conductivity and ductility but probably improves its wear and erosion resistance proportionally. Some materials, notably cadmium oxide, also reduce sticking and assist in quenching the arc. Refractory materials which are not soluble in the more common contact metals retain their own properties in proportion to the percentage used and reduce the effective properties of the other component accordingly.

Table 3 is a list of the more typical compositions available and separated into typical categories of end use. Pertinent electrical and physical properties are shown for comparison and aid in fabrication.

Table 4 is a guide to the material usually recommended for specific applications. In selecting any material, it is important to remember that the design mechanics, electrical parameters, and operating conditions vary from one device to another and consequently such data can only be used as a guide. Contact material specialists are as close to you as the telephone and should be consulted for specific applications. ▲

RELAY TERMINOLOGY

THE contact spring combinations available on a relay are defined in terms of number of poles, number of throws (single or double), normal position (open or closed contacts), and the sequence of make and break. The various combinations have been given form letter symbols, as shown below, to simplify over-all identification.

The abbreviations used to define the exact nature of the contacts are: SP—single pole, DP—double pole, ST—single throw, DT—double throw, NO—normally open, NC—normally closed, B—break, DB—double break, M—make, and DM—double make.

When abbreviations are used to designate a contact assembly, the following order is used: (1) poles, (2) throws, (3) normal position, (4) double make or break (if applicable). Example, SPSTNODM refers to single-pole, single-throw, normally open, double-make contacts.

Single-throw types have one pair of contacts open in one position and closed in the other. The pair of contacts not closed are the NO (normally open) pair, while the closed contacts are the NC pair.

Double-throw combinations have three contacts, one that is in contact with the second, but not with the third in one position, and the reverse in the other position.

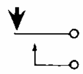
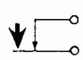
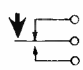
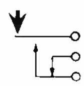
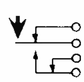
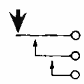
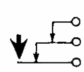
The heavy arrow indicates the direction of operation. Armature contact springs, indicated by the long spring in each example, move downward. In Forms D and E, some electrical discontinuity may be caused by contact chatter.

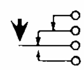
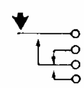
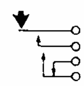
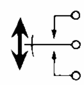
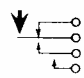
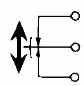
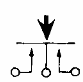
In this table of relay terminology, Form D is often called a "continuity transfer", while Form M is peculiar to MIL-R-5757.

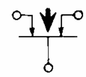
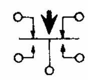
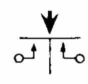
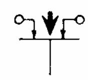
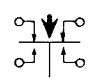
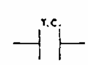
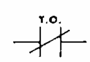
It is significant in the symbolic presentation of contact combinations, that although Form A comes before Form B alphabetically, in a normal relay contact assembly the closed contacts are closer to the armature than the open contacts. This prevents any armature spring tension from going to waste by keeping the back contacts closed with as much pressure as possible. Thus, an order calling for a relay having 1A, 2B, and a 1C contact combination will usually be arranged in the order 2B, 1C, and 1A (unless otherwise specified). If an "early make" is required, it must be specified where an "X" associated with a make combination indicates that the circuit requires one A combination to be preliminary.

It is notable that the 2B, 1C, and 1A contact assembly designation referred to above appears to be simpler and less likely of being misunderstood than the equivalent . . . "one DPSTNC, one SPDT, and one SPSTNO."

The terms "slow" and "fast" are relative, and the degree of rapidity is not to be inferred by the repetition of the symbol on the relay. ▲

Form	Description	Symbol
A	Make or SPSTNO	
B	Break or SPSTNC	
C	Break, make, or SPDT (B-M), or transfer	
D	Make, break, or make-before-break, or SPDT (M-B)	
E	Break, make, break, or break-make-before-break, SPDT (B-M-B)	
F	Make, make, or SPST (M-M)	
G	Break, break, or SPST (B-B)	

Form	Description	Symbol
H	Break, break, make, or SPDT (B-B-M)	
I	Make, break, make, or SPDT (M-B-M)	
J	Make, make, break, or SPDT (M-M-B)	
K	Single-pole, double-throw, center off, SPDTNO	
L	Break, make, make, or SPDT (B-M-M)	
M	Single-pole, double-throw, closed neutral	
U	Double make, contact on arm, SPSTNODM	

Form	Description	Symbol
V	Double break, contact on arm, SPSTNCDB	
W	Double break, double make, contact on arm, STDTNC-NO (DB-DM)	
X	Double make, or SPSTNODM	
Y	Double break, or SPSTNCDB	
Z	Double break, double make, or SPDTNC-NO (DB-DM)	
Spec. A	Timed close	
Spec. B	Timed open	

Operate and Release Times of Relays

Since graduating from the engineering school at the University of Kentucky in 1937, the author has held supervisory positions in just about every production and engineering department at Guardian Electric. From 1960 to 1963 he served as Chief Design Engineer and has been Assistant Chief Engineer since 1963. He is a Registered Professional Engineer and holds many patents on relay, switch, and stepper designs.

By W. WARREN WRIGHT / Asst. Chief Engineer, Guardian Electric Mfg. Co.

Definitions of these important characteristics and methods that are used to modify these parameters.

ALL too often relays are placed in control and logic circuitry without enough consideration being given as to whether or not the relay operational time characteristics will assure proper functioning of the circuit under various operating conditions. A working knowledge of which factors affect relay operating time can give the circuit engineer or technician confidence in his design.

In general, relays are electro-mechanically operated switches, thus there are two items which must be evaluated when considering the time elements of relay function. These are the *electrical* characteristics and the *mechanical* characteristics.

But first, let's define the terms and then consider their relationship to total relay function.

Definition of Terms

The *operate time* of a relay is the time interval from the instant of coil-power application until completion of the last contact function.

The *release time* is the time interval from the instant of coil-power cut-off until the completion of the last contact function. (See Fig 1.) Note that the operate and release times *do not* include contact-bounce times.

When coil power is applied, coil energizing current increases until the magnetic flux is sufficient to move the relay armature and its contact-actuating members. Upon removal of the coil power, magnetic flux *does not* collapse instantly, but decreases for some period of time—depending on the circuit, the coil, and the magnetic structure. When the magnetic flux drops below the "hold-in" value for the particular relay, the armature and its contact-actuating members return to the normal or de-energized position.

With these fundamental characteristics in mind, we can now consider the various relay designs and the effect of circuit characteristics on operate and release times.

D.C. Relays

For d.c. relays, the operate time of a specific relay design may be reduced by three methods. First, we can overdrive the relay. This is done by increasing the control voltage, decreasing the coil resistance, increasing the control voltage and adding a series resistance, discharging a capacitor at an over-voltage charge into the coil, pre-energizing at some value below pickup voltage (the lowest voltage at which the relay always operates), using dual-wound coils—one coil for overdrive, the other to hold the armature in the operated position, using a series resistor shunted by a capacitor, using a positive temperature coefficient resistor in series with the coil, and using a series resistor shunted by an N.C. switch—the switch being operated by the relay being controlled.

Second, we can reduce the pickup voltage of the relay by mechanical means, such as by reducing return spring pressure, reducing the armature gap, or reducing contact pressures and gaps.

Third, we can decrease the mechanical inertia by reducing the mass of the moving elements such as contacts, armature, and contact actuators.

For d.c. relays, the inherent release time of a specific design may be increased by using a parallel capacitor and series resistor, a parallel shunt resistor or switch, parallel diode, or by reducing the residual magnetic air gap.

Relay manufacturers produce many varieties of relays with operate and release times ranging from minimal values of less than one millisecond to some of the more exotic solid-state relays with maximum times of 30 minutes or more.

When specific time characteristics are needed, the relay manufacturer can usually provide relays to match the circuit requirements either from "standard" relays or as "specials" designed for a specific function.

The National Association of Relay Manufacturers (NARM) has not set standards with respect to fast or slow response. In general, relays which have operate and release times under 3 milliseconds are considered fast-operate and/or fast-release. Relays with function times of 50 milliseconds or more are usually considered slow-operate or slow-release. Relays with function times between 3 and 50 milliseconds are medium-operate and release and this is the range into which most general-purpose relays fall. Relays which are purposely designed for slow function time are classified as time-delay relays. These are covered in another article in this special section.

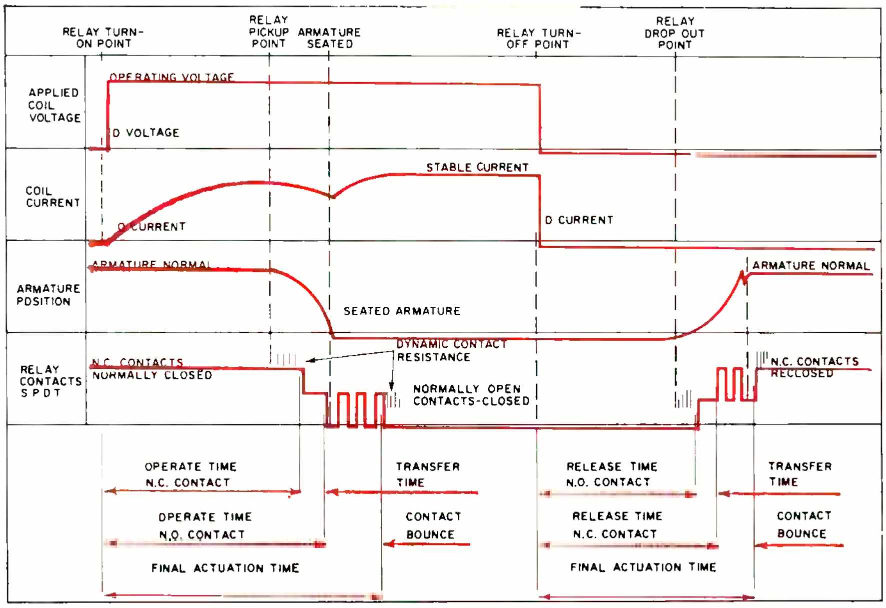
Relay manufacturers produce a bewildering range of relays for use in over a hundred "usage" classifications, with thousands of varieties and modifications in each classification. It is obviously impractical to analyze all of these types, therefore we will only cover some of the most popular general-purpose relays.

The graphs of Figs. 2 and 3 show the effects of ambient temperature changes on the attract and release times of some typical general-purpose, d.c.-powered relays. From this we can see that the attract or operate time increases with temperature and the release time decreases with temperature rise (although circuit components may modify this).

When we consider that relays heat up either under extended energization or repeated cycling, we can expect a relative shift in operating time characteristics, depending upon the frequency of operation.

Relays from different manufacturers, but of the same type, generally have similar operating-time characteristics. It will be noted that some relay types change more with

Fig. 1. Typical d.c. operation of a relay with a resistive d.c. load.



temperature than others—this is inherent in the design of the relay but, in general, the time change is within ± 10% over an ambient temperature range of 0°F to 160°F.

Other factors affect timing, such as changes in operating voltage or current, in which the attract time varies inversely with coil power and the release time varies directly with coil power. Where operation time is critical, the relay should be evaluated in the circuit under the most adverse combination of variables.

Power-supply inductance will increase the operate time of d.c. relays depending upon the L/C ratio of the circuit. Resistance in the power-supply line will tend to decrease the operate time. Relays which are wired in parallel would aggravate these effects. Arc suppressors or coil shunts will increase the release time of relays.

Basically, d.c. relays are reasonably consistent in their timing characteristics under the same operating conditions, but this is not the case with a.c. relays.

A.C. Relays

Other variations in both attract and release times are due to the added factor of the instantaneous (turn-on or turn-off) voltage change. The source voltage varies from zero to peak 120 times per second, thus any voltage from zero to peak may be applied across the coil at the instant of either "turn-on" or "turn-off".

Examination of a typical 60-Hz sine wave will show that most of the time the instantaneous voltage at "turn-on" or "turn-off" will be higher than the pickup voltage of the relay, so that the time characteristics are usually within a reasonable range. Frequently, however, the probability of turning on or off at lesser voltages catches up with us and the operating time suddenly changes. This voltage variation is further complicated by the magnetic flux distribution between two or more functional pole faces. Remember that a.c. relays generally have one core face shaded by a copper ring to cause a phase displacement in the magnetic flux. This phase shift is necessary to provide relay hold-in during current reversal. Thus, we have an operational *time range* rather than a specific operation time. The manufacturer generally specifies the average function time for a.c. relays.

Modification of operational time for a.c. relays may be accomplished in a manner similar to that for d.c. relays, but the actual time of operation will vary because of the sine-wave voltage applied. We must conclude, therefore, that straight a.c. relays should not be used in circuits where precise repeatable narrow-range operational times are required.

The mechanical characteristics which affect operational time apply to both d.c. and a.c. relays and what affects one type will usually affect the other type in the same manner.

Increases in mass, whether it be in contact actuators, the contacts, or armature will slow the operational time. Release time will be increased by minor contact welding or sticking, mechanical wear, and residual magnetism.

We have not attempted to give charts showing precise operating characteristics of relays because the timing is subject to so many variables from relay to relay type, depending upon adjustment, type and number of contacts, voltage variation, source impedance, line resistance, wear factors, etc. Information on timing characteristics is available from the manufacturer and should be used whenever operate and release timing is critical. ▲

Fig. 2. Variations in operate or attract times at various ambient temperatures for six general-purpose d.c. relays.

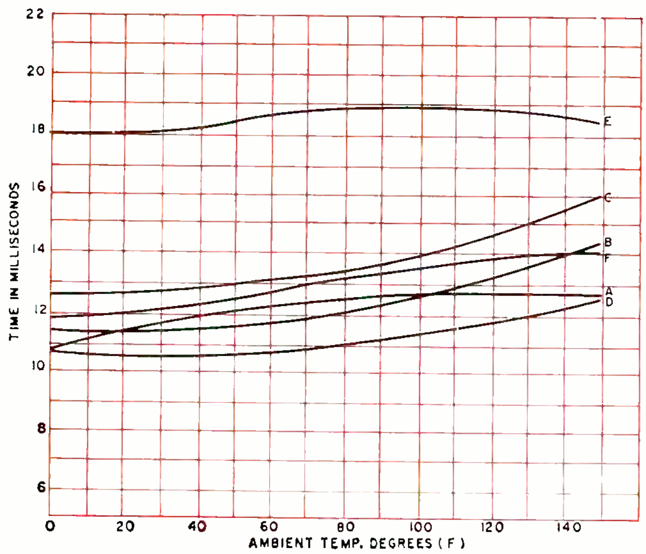
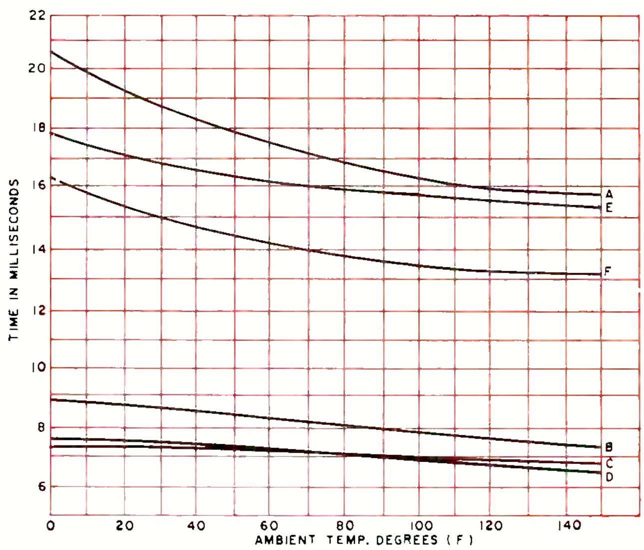


Fig. 3. Variations in the release times at various ambient temperatures for the same six general-purpose d.c. relays.



The author has been with C.P. Clare & Co. for 13 years. He holds a B.S.E.E. degree from the Illinois Institute of Technology, 1949, and is a Registered Professional Engineer in the state of Illinois. He has to date 12 U.S. and many foreign patents to his credit in his field.

Mercury-Wetted Relays

By ARTHUR J. KODA/Senior Development Engineer, C.P. Clare & Co.

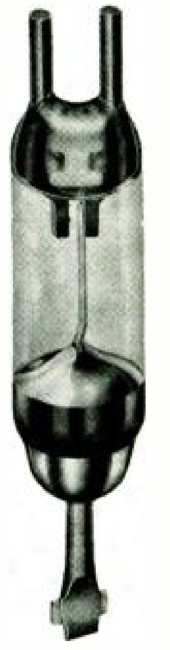
Virtually eliminating contact wear, bounce, and chatter and permitting an almost limitless number of operating cycles, these relays have many important applications.

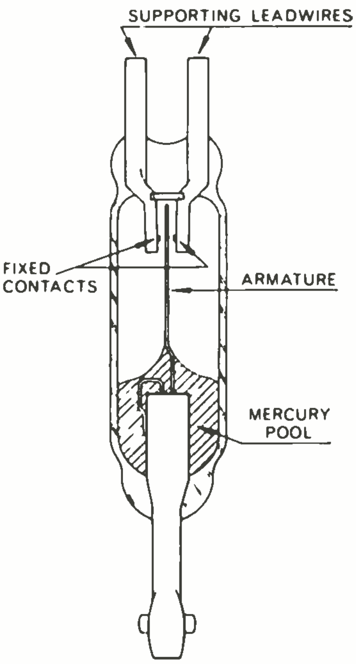
THE mercury-wetted contact relay is an extremely long-lived, highly reliable, and stable relay. The scheme for supporting a thin film of mercury on the surface of solid metal contacts was perfected at *Bell Telephone Laboratories*. It virtually eliminates contact wear. Fault-free life under full-load conditions is extended to billions of operations. Contact bounce or chattering is eliminated and the closed-circuit resistance is fixed at a low level.

When mercury-wetted contacts close, the area of mercury that forms around them is actually larger than that of the contacts themselves. The measured contact resistance is the total for the entire switch assembly. Soldering the contacts together would not reduce circuit resistance.

The mercury-wetted contacts are attached to magnetic conductors which are sealed in a glass capsule. The free end of an armature is arranged to move between the fixed contacts and deliver mercury to them. A mercury reservoir maintains the mercury system. A high-pressure hydrogen atmosphere prevents oxidation, aids in contact cooling, and permits high-voltage gradients to exist within the capsule.

Fig. 1. High-speed mercury-wetted contact switch capsule.





The electrical and magnetic circuits are identical. When the switch is placed in the center of an operating coil, the armature moves in response to the prescribed input current.

The armature feeds mercury from the pool at the lower end of the capsule to the contacts by capillary action. It is a characteristic of two separating wetted contacts that the mercury is drawn into the shape of a thin filament before it ruptures. The surface tension of mercury causes a double break to occur which isolates a portion of the bridge. The bridging mercury quickly snaps into a spherical shape and falls back to the pool. Since the equilibrium of the capillary system has been disturbed, more mercury flows up the armature to replace the amount lost. If the load being switched causes some vaporization of mercury, this amount is also replaced. In either case, it is clear that a new contact surface is presented for each operation of the switch. Since the base metal is never exposed, the life of the contact is independent of the load applied, within the maximum ratings, and contact resistance remains constant within two milliohms.

Incidentally, the configuration of mercury on two wetted contacts that are opening causes an extremely fast break action. The relative acceleration of the two surfaces is estimated to be 1500 G's. No solid contacts approach this figure.

The insulation resistance of the capsule can be 10,000 megohms or more. The stand-off is a minimum of 1000 volts, r.m.s.

Two precautions are necessary when using a mercury-wetted contact relay. First, it is position-sensitive. The mercury will short-circuit the contacts if the switch is inverted, so it is not satisfactory for airborne or satellite applications. The capsule should be mounted within 30° of vertical. Second, the extremely rapid break action causes unusually high voltage transients to be generated. To protect the switch and associated circuitry, a series resistor-capacitor network, chosen for the particular load conditions, must be placed across the contacts.

Two basic switches are available: a high-speed transfer capsule (Fig. 1), rated at 100 volt-amperes; and a larger, heavy-duty switch, employing two "make" and two "break" contacts, rated at 250 volt-amperes. Each is capable of permanent-magnet biasing to operate single-side-stable (always returns to the "break" contact when de-energized) or bistable (magnetically latches to the last position to which it was operated). Both switches are about 5/16 inch in diameter.

There are single and multiple capsule packages for plug-in and printed-circuit board mounting (Fig. 2).

The relays are extremely sensitive. An input power of one milliwatt is sufficient to drive a bistable relay capsule capable of switching a 100-watt load. This represents a power gain of 100,000.

The selling price of such relays starts in the range of $8 to $10, depending on quantity and packaging—a small price to pay for billions of miss-free operations or a single operation after many months of standby service.

The normal operating temperature range is from −38°F (the freezing point of mercury) to 225°F. The relays can withstand shocks of 30 G's and vibration of 0.06 inch or 10 G's, whichever is less, from 10 to 500 Hz.

The relays are ordinarily enclosed in a metal cover which prevents magnetic interaction with adjacent relays. Electrostatic shielding between the coil and the switch is provided to reduce the influence of the coil input signal on the controlled load, when required.

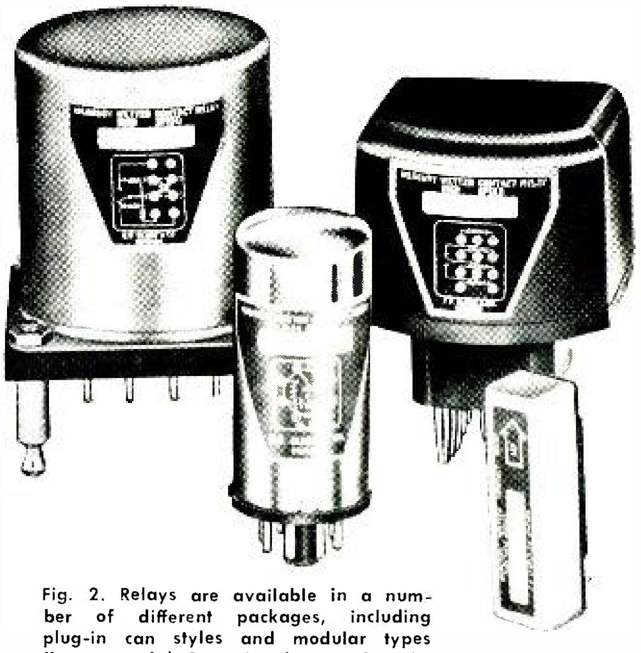


Fig. 2. Relays are available in a number of different packages, including plug-in can styles and modular types (bottom right) for printed-circuit boards.

Applications

Special package forms are available for particular applications requiring low noise generation, high-frequency signal handling, teletypewriter (pulse-code) switching, and permanent-magnet actuation for limit-switch use.

The process of scanning transducers for data acquisition and control requires relay contacts that are fast and free from bounce. Distortion of the low-level signal by thermal or contact noise cannot be tolerated. A two-switch device, in which simultaneous motion of both armatures is necessary, is commonly used for two-wire systems.

A series of coaxial relays, useful at frequencies up to 700 MHz, is available. Most of the popular characteristic impedances and connector styles are provided. Low v.s.w.r., insertion loss, and crosstalk are featured, along with the highest reliability.

Polar relays that are precisely adjusted for balanced dwell on the fixed contacts and that never require readjustment or maintenance have long been sought for teletypewriter and telegraph application. The mercury-wetted contact relay solves these problems with improved efficiency and reduced size and cost.

It is possible to mount mercury-wetted contact relay assemblies directly in apertured printed-circuit boards. The boards are covered with a vacuum-formed vinyl sheet that provides mechanical protection and excellent electrical isolation. A minimum build-up in size and weight is possible with this configuration. Associated drive circuitry can be placed adjacent to the relay area for improved continuity of design.

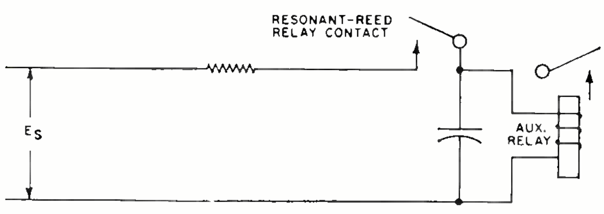
The mercury-wetted contact relay has become the standard switching device for test equipment, check-out systems, and low-frequency pulse generation. It is often used in equipment made to life- and miss-test other types of relays. ▲

RESONANT-REED RELAYS

RESONANT-reed relays permit the transmission of a number of different control signals over a single wire, carrier, or radio circuit. This type of relay is designed to respond to a given frequency of coil input current and consists of an electromagnetic coil that, when energized, drives a mechanically vibrating reed having an electrical contact at its end. When the coil input current frequency corresponds to the resonant frequency of the reed, the reed will vibrate and cause its end contact to touch a stationary contact and thereby close an electrical circuit once each mechanical cycle. Otherwise, the reed will not respond.

Since the vibrating reed closes its contacts only for a portion of each mechanical cycle, it is often necessary to provide an output circuit that will store these pulses long enough to operate a conventional relay. This auxiliary relay, in turn, is used for control purposes.

As shown in the diagram, a sensitive relay is used together with a resistor-capacitor combination to produce a steady closed contact. The supply voltage (E_S) should be approximately three times the normal operating voltage of the auxiliary relay. The auxiliary relay should have a resistance of from 5000 to 10,000 ohms and a sensitivity of better than 50 mW. ▲



METER RELAYS

THESE relays use conventional d'Arsonval meter movements as the actuator for performing the switching function. There are two variations in the method of closure: those in which the meter pointer carries an electrical contact that can be made to engage a stationary contact that is preset to the desired high or low metered levels; and those that use the meter pointer to break a light beam, thus actuating the switcher at either high or low level.

In the contact types, a flexible pigtail is connected to the meter pointer for current-carrying purposes. However, the contact pressure between the meter pointer and the stationary contact is often so small that some auxiliary means is usually provided to exert greater pressure. One way of doing this is to attach a small permanent magnet to the stationary adjustable contact arm which will cause the meter pointer to close the contacts quickly and firmly as it nears the stationary contact. The contacts are released either manually or by some auxiliary means. Another method of quick closure is to add a pair of very light contacts on both arms to energize an auxiliary coil on the meter motor to provide a surge of torque just before the main contacts engage.

The light-controlled switching meter consists of a light source, focussed on a photocell which, in turn, controls the external signal contacts.

Some meter relays (Simpson 332 4XA) use an integral solid-state switcher which in turn controls a mechanical relay. In another type (Beede Optical Meter Relay), a vane mounted on the indicator pointer interrupts a beam of light as the indicating pointer passes the set pointer. This changes the output of a photoconductive cell, triggering an electronic circuit that operates an output relay. ▲

The author has been with Cornell-Dubilier Electronics since 1963. He has made significant contributions as Chief Engineer of Rotors and Relays. Prior to joining CDE, he was with General Electric Co., Technical Programming at the Jet Engine Plant, Lynn, Mass. He is a mechanical engineering graduate of MIT and received an MBA in Business Administration from Harvard University. With his recent appointment as Marketing Manager, Mr. Underwood has assumed responsibilities for product planning, merchandising, and product promotions for the entire line of Fuquay-Varina Products.

Trade-Offs in Relay Selection

By GEORGE C. UNDERWOOD / Cornell-Dubilier Electronics Div. (Federal Pacific Electric Co.)

Understanding design compromises in relay selection can reduce ultimate product costs or represent significant gains in product performance for dollar expended. Here is how the most common pitfalls can be avoided.

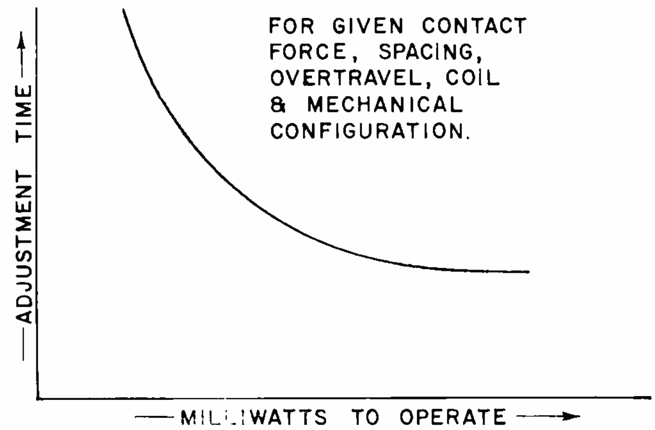
IN selecting relays for a particular application or class of applications you must consider the circuit design and the operating environment as well as the relay. This article is intended as a general guideline in selecting the optimum relay for a particular circuit and thus provide the basis for suggesting circuit changes to gain in relay performance or economy.

Cost and relay sensitivity, switching capability, relay performance, and mechanical arrangement represent the primary trade-offs in relay selection. But the particular application may place a premium upon other considerations that ordinarily would be of secondary importance. For example, interchangeability (standardization or availability when two or more sources of supply must be considered); operating characteristics such as pull-in, drop-out, or the ratio of pull-in to drop-out; operate or release time; and contact bounce may be very important. For appliance design UL or CSA construction may be controlling. Each of these trade-offs should be examined with reference to the parameters that have the greatest influence upon them.

Cost and Sensitivity

Cost is an important consideration in any design but is becoming an even more important factor in relay selection with the advent of inexpensive and widely available solid-state devices and integrated circuits. The cost of a relay is a function of sensitivity (coil watts or milliwatts dissipated to reliably perform the switching function), relay adjustment time, mechanical complexity or enclosure, wire cost, and production volume.

Fig. 1. Adjustment time vs required sensitivity for typical relay.



For a given sensitivity range, a relay type that can be adjusted to operate properly must be selected. Extra cost will be involved if the relay selected is more sensitive than required or if it is required to operate very near its limit of sensitivity. The graph of Fig. 1 shows adjustment time expected for a typical relay *versus* required sensitivity.

Fig. 2 shows two relays designed to operate in different d.c. sensitivity ranges. Note that although the short-frame relay (left) appears less costly, it will be more expensive to produce in the 25-milliwatt class because the relay will be very difficult to adjust to provide reliable operation.

A.c. relays (Fig. 3), when low volt-ampere operation is desired, may require a unit utilizing components specially designed for low core losses or particularly advantageous pole shading arrangements. The relay on the right in the figure, although it is basically more costly, may be the most economical selection where a.c. sensitivity is paramount.

The next most important cost trade-off is coil cost. For a given bobbin, a 10,000-ohm coil always costs more than a 2000-ohm coil. Wire sizes smaller than #43 or #45 usually require special winding techniques. Fig. 4 shows typical coil cost *versus* coil resistance for a given relay bobbin.

It is seldom economical to buy increased impedance by specifying high-resistance coils when other circuit changes would accomplish the same purpose. Relays may often be obtained at a lower cost by specifying a lower coil resistance, provided that the impedance loss can either be made up elsewhere or can be ignored without overheating the coil. In this way operating voltage may often be traded off against the cost of higher coil resistance. The same relay will have a much less expensive coil to operate on 24 volts d.c. than 100 volts d.c.

On the other hand, production volume alone may be traded off against the cost of an otherwise expensive relay.

Use of specially tooled components, automatic winding equipment, and automated assembly techniques will reduce costs. Operator skill in adjusting a particular high-volume relay results in lower costs.

Production volume may be traded off against a complete redesign, tooled specifically for the application. Other trade-offs, *e.g* switching capability, are very important.

Switching Capability

Switching capability is another fundamental circuit consideration. Up to eight-poles, double-throw with isolated contacts are commonly available in various relay types and the need for multi-pole operation must be traded off against cost to perform a given function, with a given interchangeability, reliability, and mechanical configuration. Sometimes several single-pole relays are less expensive than a single multi-pole relay, although this may call for more power and space for the switching.

Performance

Primary performance factors are pull-in and drop-out and the spread between them. Other factors to consider are type, size, material of contacts, mechanical life, use of materials, and noise or hum in a.c. relays.

The absolute amount of pull-in or drop-out current or voltage is closely associated with performance and cost and may be traded-off for each. Performance will be improved by specifying characteristics applicable to the particular relay. A too close ratio of pull-in to drop-out (less than 2/1) or too wide (greater than 8/1) a ratio will result in either increased cost or decreased performance.

When very close ratio or high drop-outs are required, this may be traded off against high contact forces on the normally open contacts. Adjustable residuals or non-magnetic separators to hold the armature a controlled distance from the pole face can be incorporated. The use of these materials usually must be traded-off against higher cost and a loss in performance.

The use of contact material is fundamental to relay performance. Contact trade-offs must be used in the light of three general switching classes: dry-circuit switching, where the current and voltage are so low that practically the same contact performance can be obtained from switching no load; low-power switching from about 100 mA up to 3 to 5 A; and power switching from about 5 A and over.

Dry-circuit switching generally requires precious metals such as gold, palladium, platinum, or alloys of such metals. The use of silver or silver alloys is usually a poor trade-off. Occasionally it is possible to trade-off higher gram pressure, extra contact wipe, short required life, or less severe operating environmental against the higher cost of more expensive contacts. Sometimes contact configuration may be traded for material when it is possible to get localized high pressures. Crossbar contacts are an example—they also help with contact alignment problems and are generally a good trade-off for dry circuits. But the ability to stay clean, to resist mechanical wear, and to exhibit low contact resistance usually overrides other trade-offs for dry-circuit switching. Sometimes the use of gold plating or contacts made by bonding a surface material to a base material may reduce cost without degrading performance.

Low-power switching is more subject to trades because there are so many types of relays available in this class and because such a wide variety of contacts is available. Silver combined with cadmium oxide (usually 90%–10% or 85%–15%) has become popular but fine silver, coin silver, and other alloys should be traded off against cost and tested in the application for performance. Usually the difference in contact cost is such that a contact material compromise becomes a poor trade-off against superior performance.

Power switching requires broader trade-offs when selecting contact materials. Never substitute paralleling poles for heavier contacts or more suitable material. Double-break (or make) may be an excellent trade-off for a heavier contact in single-break, especially for troublesome voltages. It seldom pays to select a relay of a power class not recommended by the manufacturer to trade-off against cost. But a given relay may have several ratings in a voltage class and this can be turned to advantage when very long electrical life is not required.

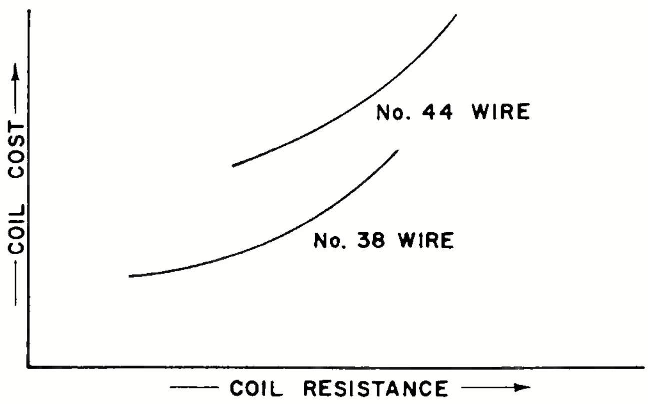
Four times as much a.c. voltage can be switched as d.c. voltage for a given current rating. It may be an excellent trade-off to substitute arc suppression external to the relay but testing should always be done to verify this. Inductive loads and tungsten incandescent lamp loads always require derating of the contacts. Sometimes contact resistance can be traded-off for a short duty cycle in highly inductive loads. For example, very inductive or high in-rush currents can often be switched successfully by tungsten or silver tungsten provided that the load is not left on long enough to overheat the contact or provided that heat sinks are used to dissipate the heat.

Mechanical life affects performance and may often be traded for cost, for electrical life in power relays, and for type of relay. Where very long electrical life is required,

Fig. 2. Typical short-frame (left) and long-frame (right) relays.

Fig. 3. A pair of relays that are designed for a.c. operation.

Fig. 4. Typical coil cost vs coil resistance for given bobbin.



mechanical life is a poor trade-off against cost. For a given expected electrical life, mechanical life will be a better index to reliability than any other parameter provided that a wise choice of contacts has been made. But a very long mechanical life is a poor buy in a relay that can be expected to have a relatively short electrical life in the application.

Mechanical life depends on design, wear, material deterioration with time, manufacturing process control, and adjustment. Spring performance, hinge performance, and judicious use of plastics represent common factors affecting mechanical life. Good design and proper process control can result in mechanical life in the 10^8 operations for proper adjustments and correct applications, even for the fairly inexpensive relay types.

Mechanical Configuration

A wide choice of trade-offs can be made in mechanical configuration. Relays are available in many types, sizes, enclosures, mounting arrangements, and terminations.

When trading cost against mounting style, the total product assembly cost should be considered. A printed-circuit style might be somewhat more expensive than a similar relay with solder lugs, but production volume with wave soldering may justify the trade-off. "Quick-connect" terminals may be traded off in a similar manner.

Relay enclosures (or open styles) provide trade-offs against cost, shipping damage, dust protection, and damage in handling or damage on the production line through solder splash. Plug-in relays are available for faster assembly, less costly replacement or troubleshooting in complicated circuits. The cost of color-coding the enclosures to indicate circuit functions can often be traded against faster assembly.

Sophisticated enclosures and sealing methods are available on all types of relays from the smallest crystal can to the largest stepping switch. The need for hermetic sealing should be traded-off against cost and application requirements and is not usually required in commercial applications.

Other Trade-Offs

A double-throw contact is often required by the circuit. The most demanding switching should be accomplished by the normally open contact whenever possible. This will save sensitivity and adjustment time and provide more reliable operation. Other trade-offs which may be unique to the application might have to be considered. It is important that communications be effective between the relay designer and the circuit designer. It is not difficult to achieve this rapport.

Reputable relay manufacturers will provide the services of their design engineers and field sales engineers at no cost to the customer. They have a vested interest in the performance of their relays and such services make satisfied customers. ▲

CHECKLIST FOR ORDERING RELAYS

By GEORGE C. UNDERWOOD / Cornell-Dubilier Electronics Div. (Federal Pacific Electric Co.)

EVERY engineer, technician, or circuit designer planning a new project that will involve the use of relays must either select standard relays or order special samples. The following checklist is to serve as a guide in requesting samples for prototyping. Some of the information requested herein may not be known or may not be applicable for the particular circuit involved. The circuit may require certain other features and, if so, they should be indicated. Portions of the checklist may be shown as desirable but not required. Emphasis should be placed on the "C's"—Contacts, Coil, Configuration, and Cost. But this checklist or any specification should not be considered as a substitute for personal contact between the circuit designer and manufacturer. In-person consultation can make the job easier for both designer and relay maker. ▲

- ☐ Engineer's name ☐ Company address
- ☐ Customer's part number ☐ Customer's drawing included
- ☐ Number of samples and date required
- ☐ General description of application (when not proprietary)
- ☐ Estimated annual volume (first and following years)
- ☐ Date required for first production shipments

Applicable specifications:

- ☐ Customer specs (include)
- ☐ Military (specify number and sections that apply)
- ☐ Other (UL, CSA, etc.)

Contacts:

- ☐ No. of poles
- ☐ Type of form (double-throw, break-before-make, etc.)
- ☐ Contact rating if known

Switching load:

- ☐ Amount: amps, volts
- ☐ Type: resistive, inductive, incandescent, in-rush
- ☐ Dry circuit: Is resistance important?
- ☐ Electrical life required
- ☐ Special requirements (such as sequence for steppers)

Forces required:

- ☐ Normally closed________. Normally opened________
- ☐ Minimum overtravel
- ☐ Bounce specs
- ☐ Contact gap
- ☐ Vibration specs

Coil specs:

- ☐ A.c. or d.c. (specify a.c. frequency)
- ☐ Coil resistance required and tolerance
- ☐ Coil protection requirements
- ☐ Temp. rise requirements ☐ Continuous duty required

Adjustment:

- ☐ Pull-in between________and________. Nominal________
- ☐ Drop-out between________and________. Nominal________
- ☐ Operate or release time required
- ☐ Over-all size required
- ☐ Other (specify)

Mounting required:

- ☐ Tapped hole ☐ Stud mount and size (anti-turn tab?)
- ☐ Printed circuit (layout specified) ☐ Straps or brackets
- ☐ Plug-in ☐ Attitude of mount ☐ Other

Enclosures:

- ☐ Open
- ☐ Dust covered (removable?)
- ☐ Hermetically sealed?

Terminations:

- ☐ Solder lug
- ☐ Printed circuit
- ☐ Quick connects? Size? Type?
- ☐ Mechanical life required
- ☐ Test procedure that will apply to samples
- ☐ Cost bogey or anticipated range. Can some of the portions above be sacrificed for lower cost?

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Modern electromagnetic relays—mechanical and static—can perform many functions with a high degree of reliability.

A LOOK AT RELAYS

BARNEY was already at work when Mac, his employer, came in and deposited three books on the service bench. Barney, always curious as a raccoon, walked over and examined the titles. "*The Relay Guide* by Auger; *Engineers' Relay Handbook* by the National Association of Relay Manufacturers; and *Static Relays for Electronic Circuits* by Blake," he read aloud. "What brings on this sudden relay kick?"

"As you know, since that bad fire destroyed my favorite cafeteria, I've been taking lunch at Louie's Place, the little restaurant near the relay factory on the north side of town. I figured I'd feel right at home there because it is patronized by many of the engineers and production men from the factory. I even thought—rather condescendingly, I'm afraid—I might be able to give the boys a helping hand with their problems. After all, I'm a hot-shot electronics technician, and a relay is just a simple electrical device whose operation is grasped by any high-school physics student."

"Did they talk about their work?"

"They did, but a fat lot of good that did me. They might as well have been speaking a foreign language. I haven't felt so frustrated and ignorant since the time, shortly after we were married, I tried to buy my wife a complete new-from-the-skin-out Easter outfit as a surprise. Neither I nor those department store clerks have ever completely recovered from that."

"I don't get it. What's so hard to understand about a relay?"

"In the first place, relays constitute a very large family, and these guys called them by their first or second or third names. The word 'relay' was always preceded by something like clapper, bimetal, crossbar-switching, ferreed, telephone-type, plunger, general-purpose, rotary, motor-starting, mercury-wetted, high-speed, miniature, subminiature, high-voltage, sensitive, snap-action, latching, vacuum, polarized, r.f., frequency-sensitive, time-delay, overload, sequential, stepping, marginal, wire-type, thermal, card-pickup, etc.

"You see, there are lots of different ways of describing a relay. While it consists essentially of only two major parts, an actuating motor and a set of contacts, you can talk about it in terms of the type of motor, the signal current applied to that motor, the mechanical linkage between the motor and the contacts, the kind of current it is designed to make and break, the arrangement of the contacts, its basic function, the equipment in which it is to be used, and so forth and so on. This means that the same relay can be called by any one of a dozen different names appropriate to the area under discussion at the moment."

"I see where that could make things sticky. Do the books help?"

"Yes. For one thing, they make me realize that my relay knowledge is strictly pre-World War II. Until then there had been only slight changes in performance and design, and most relays were of the simple clapper or telephone type the word 'relay' still conjures up in my mind. But during the war, spurred by demands of the military who were beginning to grasp what a powerful weapon electronics could be, major changes in the electro-magnetic relay occurred and are still going on."

"What do the fellows at that restaurant talk about?"

"Well, for one thing, there seems to be a continual good-natured hassle going on between a group of the younger engineers and some of the older fellows about the relative merits of static relays and conventional types. A static relay, as a bright boy like you must have already guessed, is a complete entity with no moving parts that performs a switching function in a 'relay-like' manner. Most of these employ solid-state devices such as unijunction transistors, tunnel diodes, unipolar FET transistors, avalanche and punch-through transistors, four-layer diodes, controlled rectifiers, and thyristors."

"What's that 'relay-like manner' bit? I'd think if it performs the switching job that's all there is to it."

"Not necessarily. If it is going to replace a relay, it must provide isolation between the signal and load circuits; the 'off' to 'on' impedance ratio of the controlled circuit must be high; a single signal must permit switching several individual circuits simultaneously with a minimum of inter-circuit coupling; and the switching must be of the snap-action type in which transfer from the high-impedance 'off' to the low-impedance 'on' state occurs without any intermediate impedance appearing at the load terminals."

"That last provision sounds tough. How do they achieve it?"

"In two ways. With devices containing regenerative elements, such as the controlled rectifier, unijunction transistor, four-layer diode, and tunnel diode. the action of the state-changing signal is aided by the regenerative change in the device initiated by that signal. Non-regenerative devices are simply connected in a regenerative circuit such as a blocking oscillator, Schmitt trigger, or bistable multivibrator to produce an abrupt change in impedance across the load circuit."

"How do the arguments go?"

"The young fellows, especially those whose engineering training has been mostly in the electronics field, seem to consider 'mechanical' a dirty word. They want to do everything with semiconductors. They point out that the relay is potentially subject to a host of mechanical failures: a coil can open; springs can break; contacts can burn, stick, or become misaligned; and actuating mechanisms can break or jam. Moreover, the relay's action can be affected by changes in the direction of gravitational pull or by shock and vibration. A corrosive atmosphere can damage the contacts, and even without this a thin film can form over the contacts that prevents their passing a very low voltage a.c. current in what is called a 'dry circuit.' Arcing contacts produce electromagnetic radiation that interferes with radio and TV, and these arcs may ignite explosive atmospheres. Relays are noisy in operation and are incapable of really fast operation in terms of what can be achieved with static relays. Finally, their cycling life is short when compared

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with that of a semiconductor device."

"That sounds like a pretty potent argument."

"Yes, but wait until you hear the other side. Mechanical-relay proponents say that static relays cannot equal the extremely high 'off/on' impedance ratios of mechanical relays. Static relays lack inherent isolation between input and output circuits. (Light-activated switches are an exception that just occurred to me.) Static relays often produce electromagnetic radiation that interferes with other services. All are more or less temperature-sensitive, and many are affected by radiation. Energy requirements of their input circuits vary widely. Multi-pole static relays, generally involving the replication of output circuitry with a common actuating element, are prone to crosstalk problems between circuits.

"Mechanical relays are easier to understand. A defective relay is quickly spotted, even by a person with little technical training. Multi-pole relays can be easily designed to switch several types of circuits simultaneously, or in any desired sequence, with a minimum of crosstalk."

"I've had experience with a couple of those points," Barney offered. "We hams learned that solid-state or vacuum-tube T-R switches designed to transfer an antenna back and forth between transmitter and receiver often are dandy little TVI producers. And my SSB transceiver uses a mechanical eight-pole, double-throw relay to switch eight different circuits containing high- and low-voltage d.c., audio signals, and r.f. currents every time I say 'Boo!' in the mike. And it does it most dependably. But which side are you on?"

"Neither, I reckon," Mac hedged. "Those young fellows, though, remind me of my father who, in his 80's, built what he called a 'tractor' from a *Briggs-Stratton* gasoline motor, two old automobile transmissions hooked in tandem, and some automobile wheels. This contraption, with its bewildering choice of speeds forward and backward, was the pride of his life, and he wanted to use it to do everything—scrape snow off the sidewalk, pick up twigs in the yard, mow the lawn, and plow his two-by-four garden plot. Actually, it didn't do any of these things well, but he felt about it as did Dr. Johnson about a dog's walking on its hind legs. It was not that the dog did a really good job of walking, but the marvel was that he could do it at all. Finally Mom balked when Dad wanted to use his tractor to carry a little paper sack of trash back to the alley, and he sulked for a couple of hours.

"Those young fellows who want to use semiconductors for switching, even when a simple relay could do the job easier, cheaper, and better, are acting like Dad with his tractor. On the other hand, I well know static relays far outshine mechanical relays in many places, especially in computers and data-processing equipment. It seems to me a good engineer should maintain an open mind and keep himself well informed of developments in both fields so that he may be able to choose the best type for a particular job."

"Are there any other basic types besides those two?"

Mac grinned as he replied, "They do speak of a 'jackass' type—'hybrid' would probably be a more polite term—in which a transistor, thyratron, vacuum tube, or magnetic amplifier is used to operate a conventional relay. Possibly calling these 'amplified' relays would be more accurate."

"Did you hear them say anything that we can use in our work with relays?"

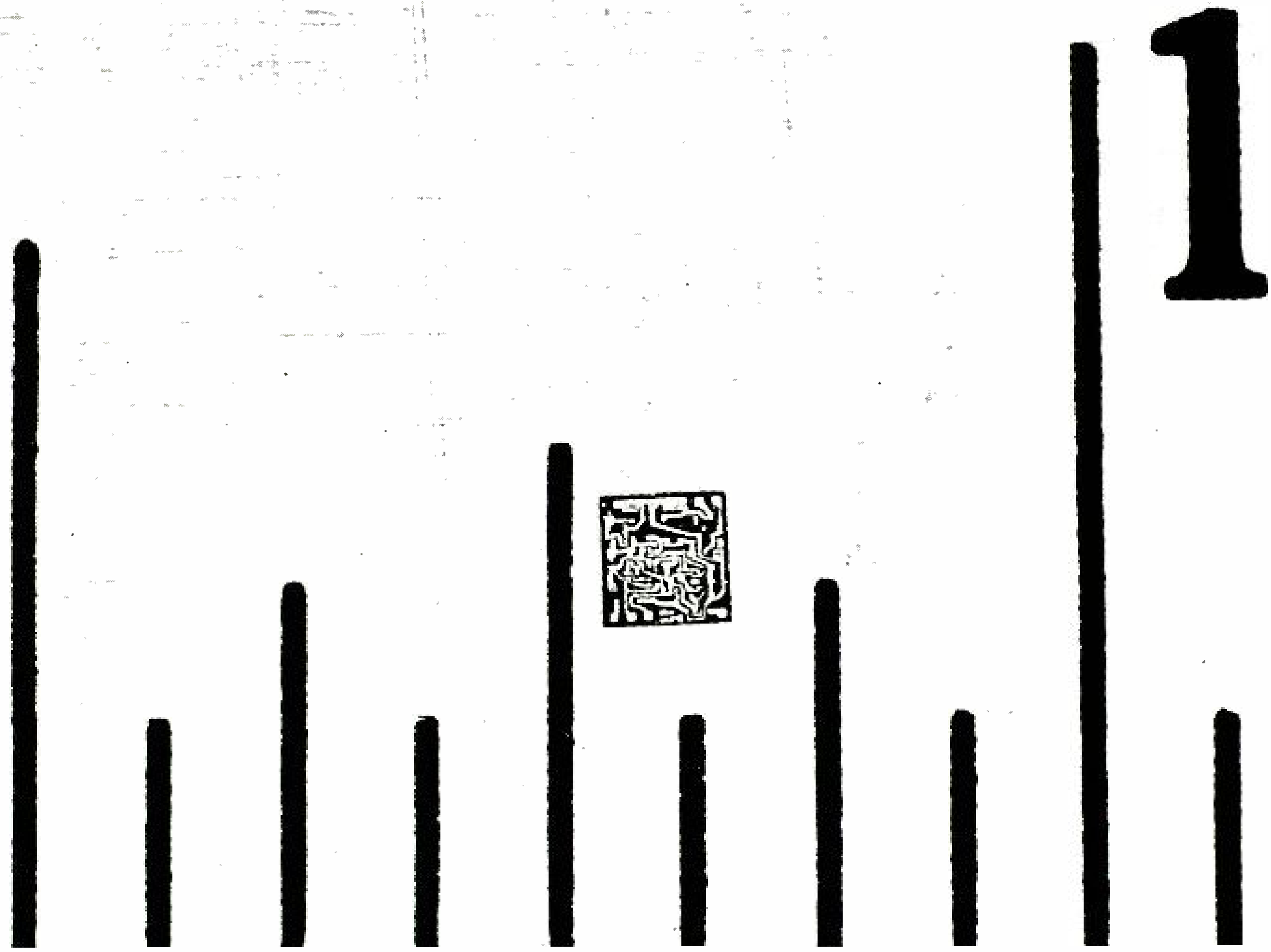
"Yes. I've seen a design engineer practically shed tears over a relay of his that had been returned from the field with twisted and mangled hook-type terminals, with contact points that looked as though they had been filed down with a wood rasp, and with mechanisms bent and distorted by obvious dropping of the unit. They point out that a relay is a precision device and that you should no more consider dropping it or yanking on the terminals than you would think of carelessly dropping your watch or winding it with a pair of pliers.

"A person asks for trouble when he tries to use the wrong kind of relay for a particular job, when he exceeds its maximum ratings, or when he abuses it mechanically or subjects it to a hostile environment in which it is not designed to function. On the other hand, if a good quality relay is carefully selected or designed for doing a specific job in a particular location and is properly installed and treated with respect, it can be expected to provide hundreds of thousands of trouble-free operations."

"I'm convinced this is true," Barney mused. "Think about the things around us that operate dependably year after year with a minimum of attention, such as the electric refrigerator, the furnace controls, the telephone, and the traffic lights. All of these use relays."

"Yes, I suppose they provide a pretty good testimonial to relay reliability," Mac agreed. ▲

"Watch him when I dial in 175 mph!"



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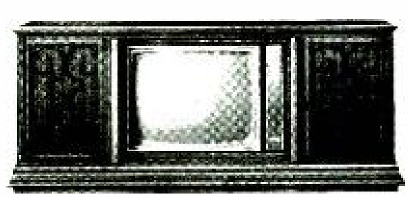

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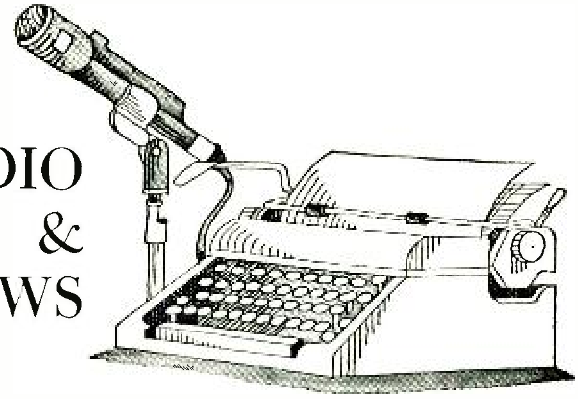

ONE of the most fascinating developments of the past several years has been the hologram method of creating three-dimensional images from a photographic plate, using a laser beam.

Now a scientist at *IBM's* Research Division has developed a method which for the first time permits holograms to be made of a scene illuminated by ordinary white light. In this technique, use is made of a multi-faceted "fly's eye" lens in an otherwise conventional camera. The image from this lens consists of hundreds of tiny individual pictures, each of them showing the scene from a different angle. In this way, the individual lenses sample and record not only the intensity of the light but also the curvature and direction of the light waves coming from every point on the scene. This is similar to the information recorded in a hologram by the former laser process. The fly's eye lens picture is thus a kind of coded hologram.

To reproduce the photographed three-dimensional image, a laser beam is passed through a beam splitter, with the reflected portion acting as the reference beam and the remaining light then passing through the fly's eye lens and through the developed hologram plate. The resultant picture can then be seen in three dimension as in a conventional hologram. (For further information, refer to the article "True 3-D Image from Laser Photography" by Leith and Upatnieks in our October, 1965 issue.)

Electrostatic Salter

It used to be a case of just grabbing a salt cellar and shaking. Now electronics does the job faster and provides an even distribution of salt over the to-be-salted product.

In this new concept in salters, developed for the *Morton Salt Co.*, as the salt drops from a hopper onto a variable-speed roller, it is given a negative charge from a high-voltage (20-kV) source. The salt then passes a controllable positively charged rod that causes it to disperse into the desired salting pattern as the product passes below on a conveyor belt.

The product, having a positive charge, attracts the salt and forms a static bond with it. This causes the salt to cling firmly to the product. The unique bond thus formed makes it possible to salt even cold products while achieving a high uniformity of salting. The initial market is potato-chip producers.

Rare-Earth Glass

Color-TV manufacturers introduced the use of rare-earth phosphors to improve the reproduction of color-TV pictures. Now an optical manufacturer, *Chicago Dial Co.*, has developed "Opticolor," a new glass filter plate for color-TV picture tube faceplates which contain a rare earth. According to the company, when laminated to the viewing surface of the color CRT the filter plate improves the brightness and contrast of the pictures and produces richer colors.

Conventional filter plates are laminated to the CRT to reduce glare and protect the viewer against damage by accidental implosion.

This new filter glass, made in England, contains neodymium oxide, the rare earth that improves the selective absorption properties of glass.

Hot Cable

As a practicing ham with a mobile, we have often worried about what happened to the r.f. signal after it left the transmitter and went through a length of coax to the rear-mounted antenna. The worry was about deformation of the coax interior insulator that could result in changes of impedance along the line with the attendant increase in s.w.r. These worries usually increased in the summertime when the exterior of the car was subjected to considerable heat. It meant occasional checking of the line to make sure all was OK.

Now it appears that in the near future this worry won't exist as the *Electronic Specialty Co.* has just announced a coax weighing one ounce per foot and the diameter of a pipe cleaner that can withstand temperatures up to 1100 degrees without melting. At present, this cable is available only to the military. ▲

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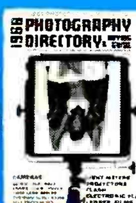

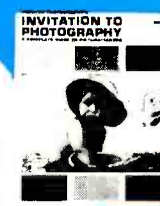

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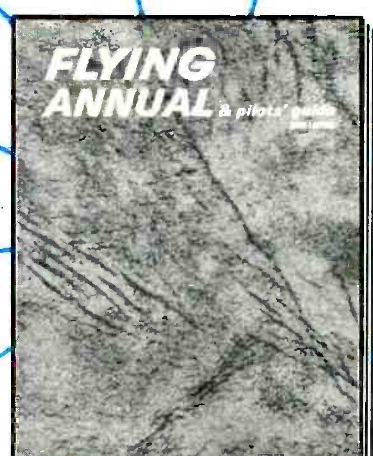

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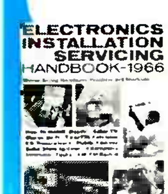

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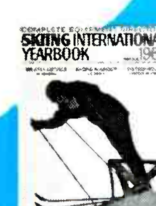

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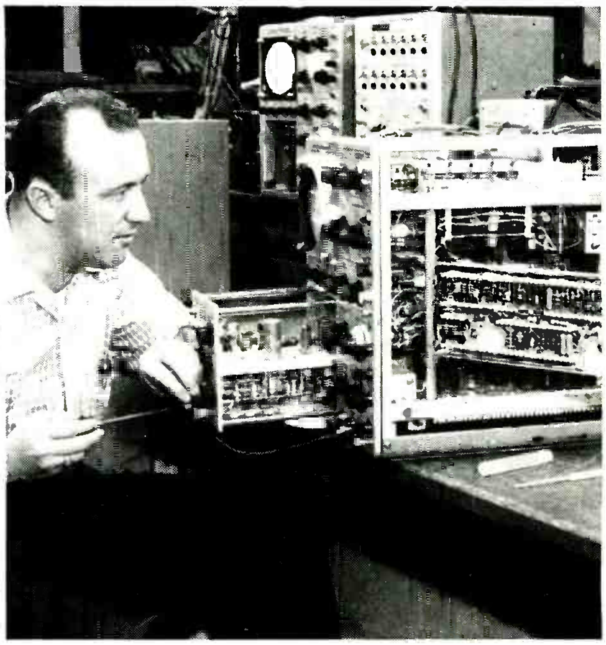

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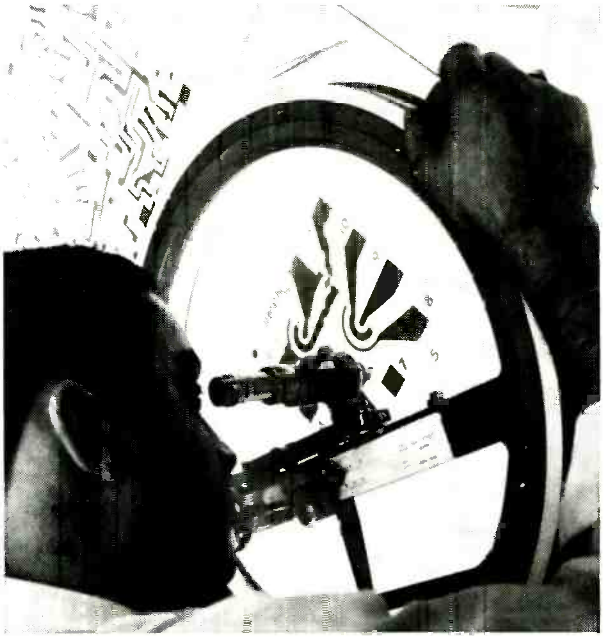

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(Continued from page 36)

of 104 dB. A total tuner gain of 139 dB results and at least 24 dB of limiting is available for even the weakest FM signals encountered.

The larger amount of limiting available results in better weak-signal performance. Changing nothing except the i.f. amplifier/limiter strip in an FM tuner containing a high-quality field-effect transistor front-end improved the IHF sensitivity from 1.7 μV to 1.5 μV. This is shown in Fig. 6.

The over-all circuit diagram of the i.f. amplifier/limiter is shown in Fig. 5 and photos of the integrated-circuit and discrete-component versions are shown in Fig. 7. Under normal conditions, the 1st and 2nd integrated circuits operate as i.f. amplifiers and the 3rd and 4th IC's act as limiters. The wide-band ratio detector, unchanged from previous designs, is the third limiter. The first two i.f. transformers, along with the i.f. transformer on the FM front-end (not shown) provide most of the selectivity.

The i.f. transformer between the first and second limiter IC's provides additional selectivity but has the major purpose of improving capture ratio. E. Baghdadi in the "IRE Proceedings" of January 1955 showed that the use of a phase-linear filter between fast, wide-band limiters actually increases the effective bandwidth of the last limiter-detector combination. Consequently, the capture ratio of the FM tuner was improved from 3 dB to 1¾ dB. This and other performance changes are shown in Table 2.

An improvement in AM rejection results from the use of integrated circuits. Here the small change in circuit phase shift with signal amplitude changes causes a substantially decreased amount of amplitude modulation being converted into incidental phase modulation. Since the amount of frequency modulation is the product of phase modulation and frequency (this incidental phase modulation is a form of distortion), the reduction of high-frequency distortion components also improves the separation of stereo signals, particularly at high modulation frequencies.

Other improvements were also noted with the use of integrated circuits as i.f. amplifier/limiters although the results are difficult to express in numbers. Particularly, pulse noise created by ignition systems, etc. is less objectionable. It is thought that for short-duration, large-amplitude pulses, all i.f. stages act as limiters and that these circuits recover immediately after an overload. A transistor i.f. amplifier, when overloaded, can rectify a large input signal and create a self-bias which decreases its gain. Its recovery from an overload is dependent on the time constants of its bias and "B+" filter networks. The integrated circuits do not change current consumption with overload and the bias supply (a diode in this case) has an extremely low time constant.

Although the number of components in the i.f. amplifier/limiter has been reduced, its cost has increased somewhat. However, the improvement in performance justifies the expense. This subassembly has been incorporated in all current new *H.H. Scott* FM tuners and receivers. The integrated circuit type μA703 is a joint development of *H.H. Scott, Inc.* and the Semiconductor Division of *Fairchild Camera and Instrument Corp.*, and the author gratefully acknowledges their cooperation. ▲

S.W.R. Parameter Table

The table below shows the various related parameters involved in using s.w.r. meter readings. The table includes a correlation between the "return power loss" term used in some antenna specifications and the more popular s.w.r. term. Selected values are shown between the limits of s.w.r. = infinity : 1 and s.w.r. = 1:1. Additional values may be obtained by performing the arithmetical operation indicated at the top of the column. The table was prepared by George A. Philactos of the Installation Engineering Practices Dept. of Western Electric Co.

S.W.R. $= V_{MAX}:V_{MIN}$	V_{MAX} or I_{MAX}	V_{MIN} or I_{MIN} (when V or I = 1.0 for s.w.r. of 1:1)	Forward or Incident Pwr.	Reflected Pwr. $= (V_{MAX}-1)^2$ or $(I_{MAX}-1)^2$	Reflected Pwr. / Forward Pwr. in %	Return Pwr. Loss = Reflected Pwr. / Forward Pwr.
∞:1	2.0	0.0	1.0	1.0	100.0	0.0 dB
5.83:1	1.707	0.293	1.0	0.5	50.0	−3.0 dB
3.00:1	1.5	0.50	1.0	0.25	25.0	−6.0 dB
2.00:1	1.333	0.667	1.0	0.111	11.1	−9.5 dB
1.50:1	1.2	0.8	1.0	0.04	4.0	−14.0 dB
1.222:1	1.1	0.9	1.0	0.01	1.0	−20.0 dB
1.065:1	1.0316	0.9684	1.0	0.001	0.1	−30.0 dB
1.02:1	1.01	0.99	1.0	0.0001	0.01	−40.0 dB
1.006:1	1.00316	0.99684	1.0	0.00001	0.001	−50.0 dB
1.0:1	1.0	1.0	1.0	0.0	0.0	−∞

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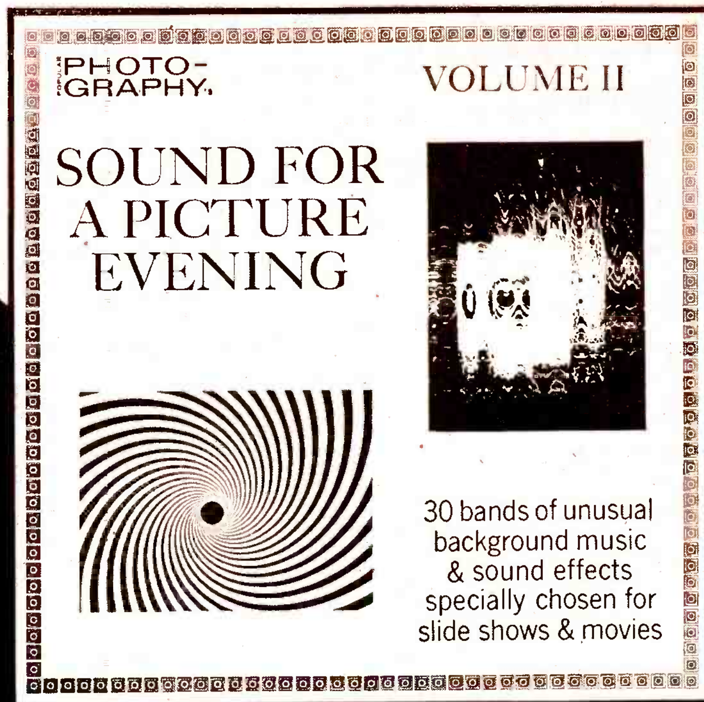

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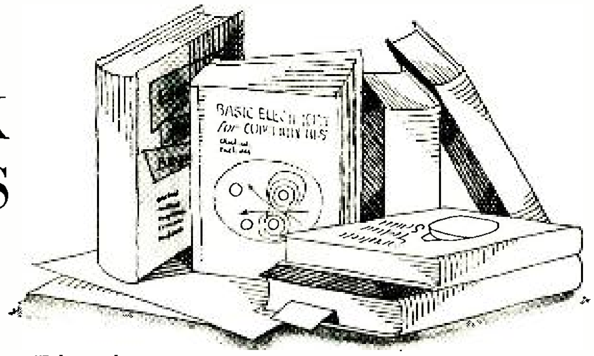
BOOK REVIEWS



"THE INTRUDERS" by Senator Edward V. Long. Published by *Frederick A. Praeger, Publishers*, 111 Fourth Ave., New York, N.Y. 10003. 230 pages. Price $5.95.

Senator Long, who heads the Senate Subcommittee on Administrative Practice and Procedure, has drawn on testimony presented before his committee for the bulk of his text. To the individual American, there is no doubt that Senator Long is "on the side of the angels" and most readers will agree with the Senator that bugging and/or tapping have become so widespread that they must be stopped lest our "right to privacy" disappear entirely.

The author cites innumerable court decisions and actual cases taken from his committee's records. He points out strongly the dangers inherent in eavesdropping, including the possibility of harassment of the innocent by the state, by the police, and by private industry. The book is especially recommended to those who feel they have nothing to hide and that "it can't happen here".

Some of the statements in his chapter on equipment are technically naive, and some of the bugs described are relatively simple and outdated. (For a complete summary of the state of the eavesdropping art, we refer our readers to the article on "Electronic Eavesdropping," which appears on page 23 of this issue.)

These weaknesses, however, do not alter the fact that the Senator is correct in seeking Congressional action to bring such electronic espionage under control so that the "rights" and "wrongs" of such privacy invasion can be established by the courts. Under such an imprimatur and with a forward by Vice President Humphrey and in light of President Johnson's recent pronouncements on the subject, it seems more probable than ever that such legislation stands a chance of passage in the near future, and is less likely to suffer the fate of previous legislation which died in committee or on the floor.

* * *

"ACOUSTICS" by Alexander Wood. Published by *Dover Publications, Inc.*, New York. 575 pages. Price $3.50. Soft cover.

The publication of this book in an inexpensive, easily obtained form should be good news to those seeking comprehensive background material on acoustics. First published in England in 1940, this volume has attained an impressive reputation as an "authority."

Among the subjects covered by the author are wave motion, forced vibrations, resonators, filters, dissipation of energy in sound waves, reflection and refraction of sound waves, diffraction, measurement of sound velocity, intensity of sound, pitch and frequency, the ear and hearing, recording and reproduction of sound, microphones, loudspeakers, and the acoustics of buildings. Since the author's treatment is experimental as well as theoretical, the book can be used as a classroom text for students with the requisite mathematical background.

The spelling and terminology are British and, in most cases, the photographs accompanying the text are of English equipment (*circa* 1940). Since this book is a re-issue of the author's 1940 edition, there are many developments in the field not covered in this text, but since the material covered is basic, this in no way detracts from the value of this volume as a reference work.

* * *

"APPLIED MICROELECTRONICS" edited by C.F. O'Donnell. Published by *America House*, 1001 Vermont Ave., N.W., Washington, D.C. 20005. 265 pages. Price $6.00. Soft cover.

There are five authors of this book with each man contributing a section on his specialty. Under the over-all editorship of Mr. O'Donnell the book maintains a uniformity of style and approach unusual in a collaboration.

This volume is addressed to potential users of microelectronics technology and summarizes for this group the progress achieved thus far. There are seven chapters covering the evolution of microelectronics, elements, digital systems, electromechanical control systems, high-frequency analog circuits, and trends in microelectronics and related technologies.

Although it would be impossible to eliminate all mathematics in treating a subject of this complexity, the authors have done an outstanding job in dealing with their subjects verbally rather than mathematically. Line drawings, partial schematics, tables, graphs, and photographs are used as required to amplify the text.

* * *

"TRANSISTOR SPECIFICATIONS & SUBSTITUTION HANDBOOK" compiled and published by *TechPress, Inc.*, Brownsburg, Indiana 46112. 187 pages. Price $2.95. Soft cover.

This 1967 edition lists over 6000 transistors by manufacturer and JEDEC types with their specifications. In addition, over 18,000 substitutes are included to help those involved in servicing transistorized equipment. Transistor type numbers are also cross-indexed with general-purpose replacement types to speed substitutions.

* * *

"HOW TO BUILD SPEAKER ENCLOSURES" by Alexis Badmaieff & Don Davis. Published by *Howard W. Sams & Co., Inc.*, Indianapolis. 139 pages. Price $3.25. Soft cover.

The authors are enthusiastic proponents of the "do-it-yourself" trend—at least when it comes to building enclosures for favorite speakers. They cover the basic types of enclosures—infinite baffle, bass-reflex, horn-projector, and hybrid—and explain the advantages and disadvantages of each design. Drivers and crossover networks are also included in their analysis.

After initiating their readers to the scope of possible choices, the authors get down to specifics. Instructions and drawings for building the various enclosures are reinforced by practical tips and detailed construction methods. After the enclosure is successfully constructed, the authors explain how the builder can test his job.

Photographs of various installations plus nomograms, charts, graphs, response curves, and construction drawings make this an especially useful handbook not only for technicians, engineers, and hobbyists but for dedicated audiophiles as well.

* * *

"WESTINGHOUSE ELECTRONIC TUBE GUIDE" compiled and published by Electronic Tube Division, *Westinghouse Electric Corporation*, Elmira, N.Y. 182 pages. Price $1.25. Spiral bound.

The 7th Edition of this guide covers both receiving tubes and TV picture tubes as used in communications and industrial applications.

Designed for service technicians, hams, and engineers, this volume contains useful technical information, characteristics, substitution lists, and base diagrams for all tube types. The comprehensive interchangeability lists are especially valuable because they are based on operational rather than static tube characteristics.

An index to the contents of this handy reference work is printed right on the cover for the added convenience of the user. ▲

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ELECTRONIC CROSSWORDS

By JAMES R. KIMSEY

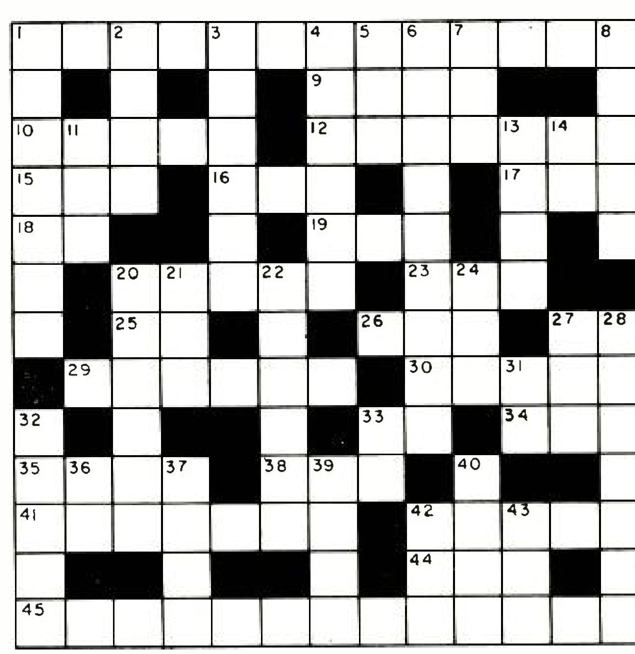
(*Answer on page 98*)

ACROSS

1. Not "in living color".
9. Important element.
10. Rare gas used in some thyratrons and other gas tubes.
12. Five-element vacuum tube.
15. Court.
16. Drop in plate current of a class-C amplifier as its tuned circuits are being adjusted to resonance.
17. Existed.
18. Printer's measure.
19. A type of very sensitive microphone.
20. A crinkly material.
23. Vase.
25. Casual "hello".
26. Beverage.
27. Addition to a letter (abbr.).
29. Pickup unit used in a TV system to convert into electrical signals the optical image formed by the lens.
30. Pertaining to the speed of sound.
33. Rare silver-white element having properties resembling those of sulfur (abbr.).
34. Greek letter that is employed to designate intrinsic impedance, efficiency, or surface charge density.
35. Instrument or means for measuring or testing.
38. Large radio-TV network (abbr.).
41. Switch type capable of sensing acceleration, shock, or vibration.
42. Particle weighing more than an electron but generally less than a proton.
44. Consumed.
45. Circuit or device used to produce one or more gate pulses.

DOWN

1. The cgs unit of magnetic flux.
2. Prefix meaning "millimicro".
3. Unit of luminous intensity.
4. The a.c. component arising from sources within a d.c. supply.
5. Metal-bearing rock.
6. Radar method of determining azimuth and elevation angles simultaneously.
7. Social insect.
8. Peak.
11. Division of time.
13. Four-arm a.c. bridge for measuring self-inductance in terms of capacitance and resistance.
14. East Indian fiber plant.
20. Electrical energy stored in a capacitor or battery or held on an insulated object.
21. Outer edge, as of a turntable.
22. Bolometric vacuum gage for measuring pressure.
24. Old time automobile.
27. Deep hole.
28. Instrument which automatically checks a number of measuring points.
31. Compass point.
32. Storing a component or device until its desired characteristics become essentially constant.
33. Monogram for a Scottish essayist and historian.
36. Indefinite article.
37. One of the "big five".
39. Unit of measure of nuclear cross-sections.
40. Greek letter which designates angles, coefficients, phase constant.
42. Deface.
43. To place a logic storage device in a prescribed state.



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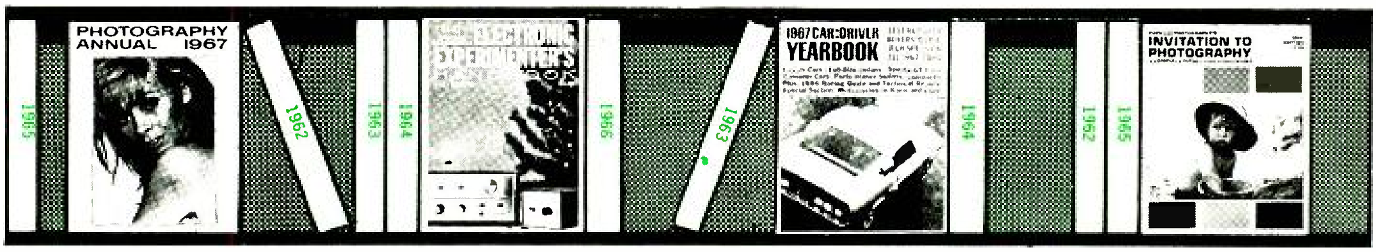

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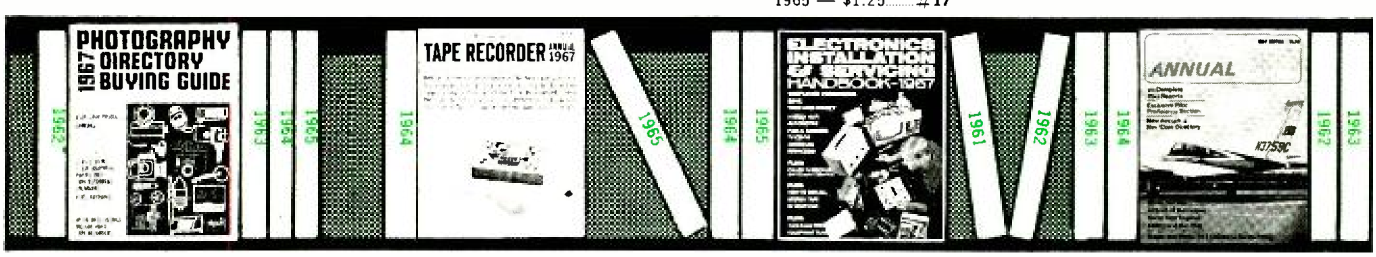

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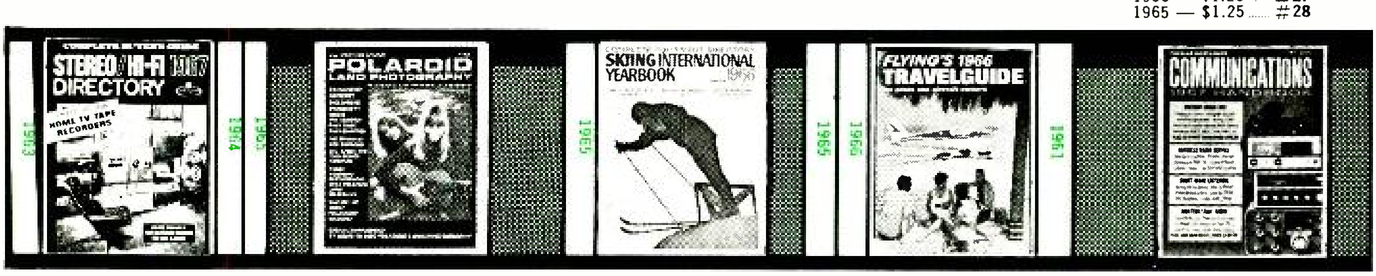

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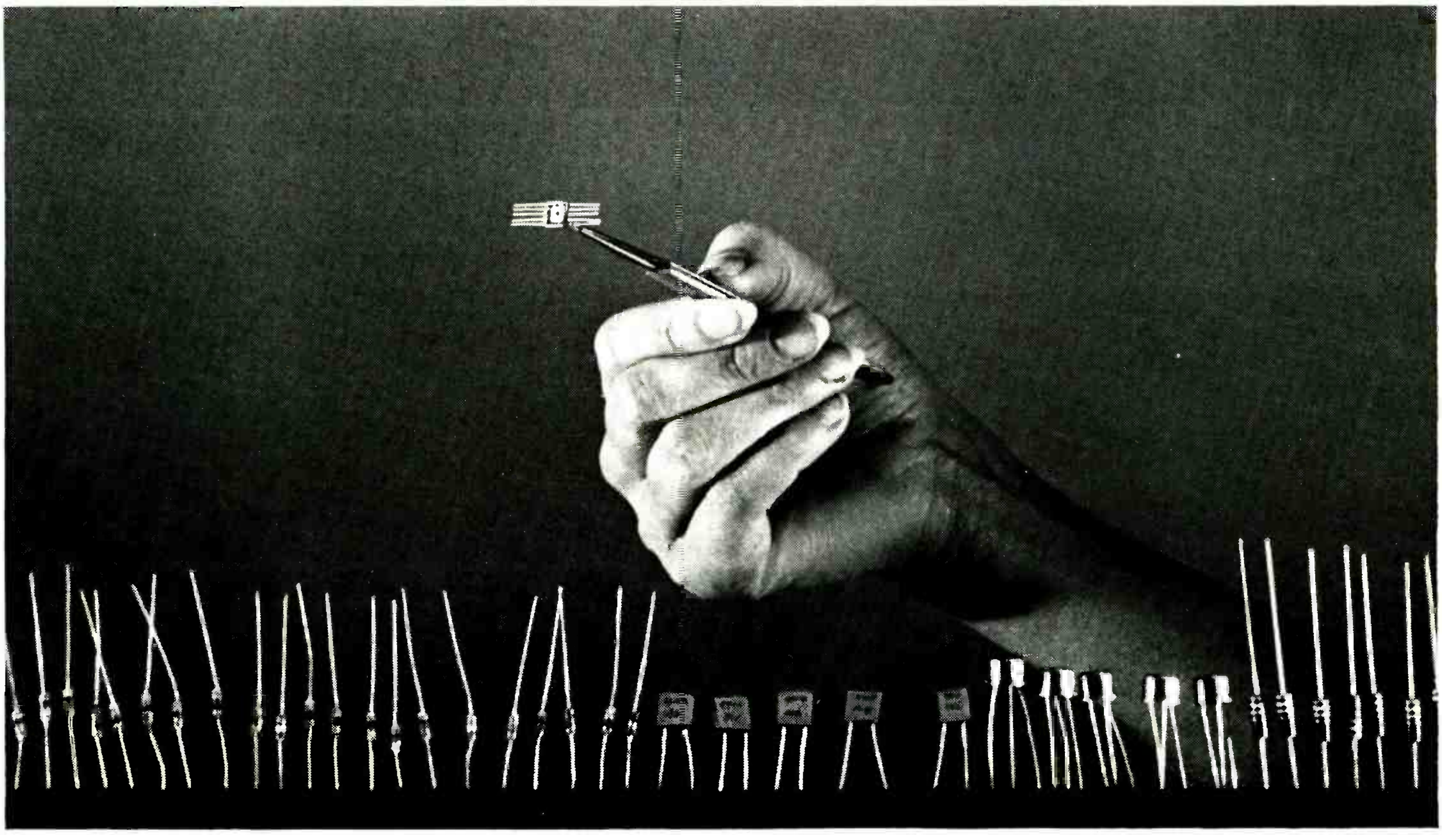


50 functions in a single chip. *The functions of 50 separate transistors, diodes, resistors and capacitors can now be formed by the tiny dot in the center of the integrated circuit held by the tweezers.*

The "Chip"

...will it make or break your job future?

THE DEVELOPMENT OF INTEGRATED CIRCUITRY is the dawn of a new age of electronic miracles. It means that many of today's job skills soon will be no longer needed. At the same time it opens the door to thousands of exciting new job opportunities for technicians solidly grounded in electronics fundamentals. Read here what you need to know to cash in on the gigantic coming boom, and how you can learn it right at home.

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

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

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

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

Miniature Miracles of Today and Tomorrow

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

And this is only the beginning!

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

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

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

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

New Opportunities for Trained Men

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

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

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

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

How To Get The Training You Need

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

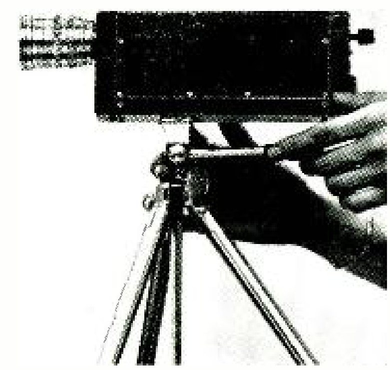
If you do decide to advance your career through spare-time study at home, it makes sense to pick an electronics school that specializes in the home study method. Electronics is complicated enough without trying to learn it from texts and lessons that were designed for the classroom instead of correspondence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

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

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

Always Up-To-Date

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



Tiny TV camera *for space and military use is one of the miracles of integrated circuitry. This one weighs 27 ounces, uses a one-inch vidicon camera tube, and requires only four watts of power.*

Praised by Students Who've Compared

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

Get FCC License or Money Back

No matter what kind of job you want in electronics, you ought to have your Government FCC License. It's accepted everywhere as proof of your education in electronics. And no wonder—the Government licensing exam is tough. So tough, in fact, that without CIE training, two out of every three men who take the exam fail.

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LASER MODULATORS

Although still in the R&D stage, three new light modulators allow a laser to be used as a broadband light transmitter. Bandwidths up to 7000 MHz have been reported for one unit.

LIGHT modulators developed at *Bell Telephone Labs.*, now make it possible to modulate broadband communications signals onto laser beams, using low-level modulators requiring less than one watt of power.

The three devices to be discussed are highly efficient modulators of both pulsed and continuous laser light. The first two work on the well-known principle of polarization in which a light beam is passed through two polarizers. When the two polarization planes are rotated so that they are 90° from each other, no light will pass through. When they are aligned parallel to each other, the light will pass through almost undiminished. By adjusting the polarization planes' relative angle between parallel and 90°, it becomes possible to intensity-modulate the light beam.

Lithium Tantalate

This electro-optic digital transmission modulator system (Fig. 1) has been used in an experimental system for high-speed transmission of pulse-code modulation (PCM) signals. In PCM systems, information to be transmitted (TV, voice, or data) is translated into a coded sequence of electrical pulses (bits), with each bit representing a discrete signal level.

As shown in Fig. 1, pulses of light from the laser are first passed through an initial polarizer that causes the light beam to assume a particular polarization. After passing through the polarizer, the light then passes through the modulator, a thin rod of lithium tantalate crystal (measuring 0.4 × 0.01 × 0.01 inch). The light then encounters the analyzer filter having a plane of polarization 90° different than the polarizer so that the laser light will not pass through the analyzer and be transmitted to the photo-diode detector.

The lithium-tantalate crystal modulates (in this case modulation consists of polarization changes) the incoming light and acts as a high-speed gate. Two electrodes are plated on opposite rectangular faces of the crystal and when the PCM terminal sends an electrical pulse (representing a "1") to these electrodes, it causes the plane of polarization of the light passing through the crystal to shift 90 degrees.

This change allows the light to pass through the analyzer and be detected by the photodiode. If no electrical pulse (representing a "0") is sent from the PCM terminal, the light passing through the crystal is blocked at the analyzer, hence it does not get to the photodiode. The electro-optical modulator uses this coded sequence of high-speed electrical pulses to modulate (gate) an equally fast train of light pulses from the laser.

The speed of operation of this system is about 224 million bits per second. After some re-design of the modulator, it is expected that operational speed will reach 896 million bits per second. This latter rate is equivalent to a bandwidth of about 1600 MHz. It is hoped that future systems, using a solid-state laser having extremely narrow pulse widths, may reach speeds of 5000 million bits per second.

YIG Modulator

This modulator consists of a rod-shaped crystal of gallium-doped yttrium iron garnet (YIG) with a small coil wound around it, and the crystal submerged within a magnetic field. It operates on the principle discovered by Michael Faraday in 1845 that the plane of polarization of a light beam in a magnetic medium rotates along the magnetic lines of force. The application of current to the coil surrounding the doped YIG rod creates a second magnetic field in the crystal, at right angles to the first. If the current flowing through this coil is the result of a vary-

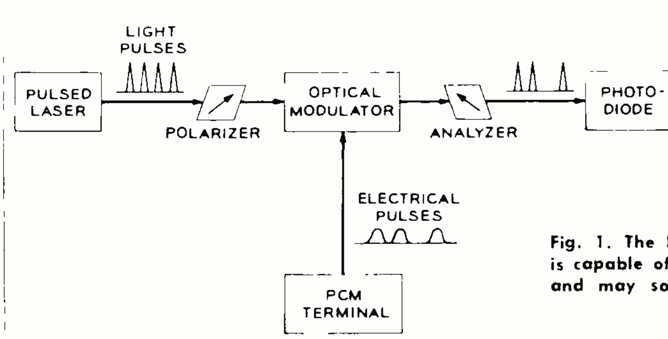


Fig. 1. The lithium tantalate modulator is capable of 896 megabits per second, and may soon attain 5000 megabits.

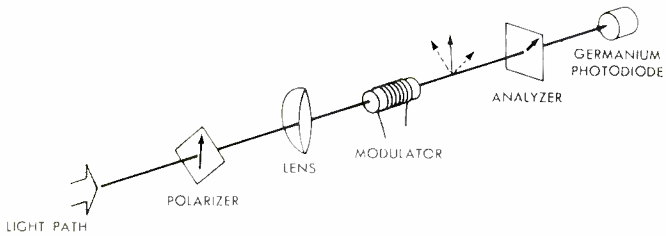


Fig. 2. The YIG modulator can transmit 33 TV programs.

ing signal, the plane of polarization of the light beam passing through the modulator will also vary in accordance with the modulation.

Operation is shown in Fig 2. The light output from the laser is first sent through an initial polarizer that causes the light beam to assume a particular polarization. A lens focuses the light beam through the modulator and onto the analyzer filter. The analyzer has a plane of polarization 45° away from the polarizer.

The modulation current is allowed to flow through the YIG coil, the magnetic field within the YIG varies, thus the plane of polarization of the light leaving the YIG varies, and is allowed to pass through the analyzer at various light levels ranging from no light to maximum light.

This modulator has exhibited bandwidths of 200 MHz (sufficient to transmit about 50,000 telephone calls or 33 TV programs). Another version of the modulator has reached a 400-MHz bandwidth; however, maximum potential bandwidth has not yet been determined.

Gallium Phosphide

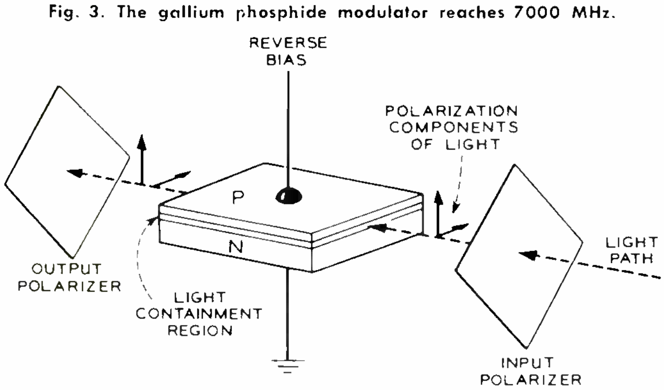
This modulator, shown in Fig. 3, consists of a semiconductor diode *p-n* interface, together with mounting and input/output lenses (not shown). The incoming laser light is divided into two equal components at the input polarizer, then focused on the *p-n* interface. The light passes through the diode and is confined within the *p-n* interface because of the discontinuities in the index of refraction along both upper and lower surfaces.

When reverse bias is applied to the diode, the gallium phosphide in the junction region changes from an optically isotropic (having the same properties in all directions) medium to a medium having different optical properties in different directions. This anisotrophy causes the two polarization components of the incoming light beam to travel at different velocities through the *p-n* interface. This change in relative velocities, in essence, phase-modulates the passing light beam in accordance with the reverse bias (modulating signal) across the junction. Intensity modulation results from passing the phase-modulated components through the output polarizer.

This diode has successfully modulated a laser beam up to 7000 MHz, with optical losses of less than 3 dB.

These approaches show that laser transmission systems to replace microwave relays may not be too far off. ▲

Fig. 3. The gallium phosphide modulator reaches 7000 MHz.



VISTA—A NEW LOOK AT SATELLITE TV

IN 1961, our national capability in space communications was concentrated on the development of small satellites, to prove the feasibility of intercontinental communications using such satellites. One of them, Relay, demonstrated the transmission of conventional TV signals. Using a transmitter power of 11 watts, Relay was designed to work with large ground systems having antenna diameters of 60 to 85 feet, and noise temperatures of 40°K. Although successful in its mission, this satellite did not face the problem of TV broadcasting from space *directly* to home receivers having a minimum of low-cost external equipment to receive these signals.

A number of ideas have been put forth during the past few years covering the requirements for a TV satellite capable of covering about 1.6 million square miles, about half the area of the U.S., with viewers using conventional TV sets and reasonably sized antennas. Unfortunately, the amount of r.f. power required at the satellite worked out to a rather high 107 kW per channel.

Recent advances in our space capability have renewed interest in space telecasting, to the point where *RCA* has suggested its Vista system (*vis*ual-*ta*lking) in which a more realistic satellite power of 3 kW per channel would be used in a satellite stationed in a synchronous orbit, and capable of serving an area of about 500,000 square miles (about 700 miles on a side).

The satellite would receive its signals from a high-powered ground station and retransmit the TV signal on u.h.f. channel 69. A conventional home TV receiver would receive class-2 signals, a picture noticeably superior to that deemed acceptable by the vast majority of viewers tested.

The home receiver would require, besides the capability of receiving u.h.f., an antenna cut to channel 69 having a gain of about 19 dB, feeding a low-noise booster having about 30 dB gain. It is felt, by *RCA*, that such an antenna system would sell for about $50 to $75.

After detailed design studies are completed, launch could occur in 1969 or 1970. The economics of this application of space technology could thus be established by 1970, since the objective of the proposed Vista experiment is to demonstrate reliable, long-lived telecasting by satellite over areas of significant population density as a serious forerunner of operational telecasting by satellite on an international basis. ▲

SPACE ETCH

In this new approach to PC boards, lots of copper is left to act as a heat sink when mounting parts. It also permits the use of drafting machine layouts.

CONVENTIONAL printed wiring considers the wiring pattern as copper conductors of varying lengths and widths. However, a new approach—called "space etch"—has been developed by *RCA* in which the emphasis is on etching the spaces rather than etching the conductors. An example of such a board is shown in Fig. 1A.

The large copper areas of space etch act as heat sinks during soldering thus reducing the probability of damage during board assembly. Normally, space etch is best used for small-sized printed boards where the maximum-conductive area gives good soldering results by avoiding too small component lead termination areas that inhibit solder flow and fillet formation. In addition, too-small conductive areas can readily detach themselves from the board during soldering, particularly with a hand iron.

The inherent increased capacitance effects between adjacent circuit paths must be considered. On space-etched, single-sided boards, capacitance between adjacent areas is approximately 1.5 pF per linear inch or border. The major factor in coupling capacitance between two adjacent printed conductors on a single-sided board is the length of the border, not the spacing or width of the conductors. Therefore, keeping critical conductor paths short is essential in determining the coupling capacitance in a given circuit—this is true in either space-etched or conventional printed boards.

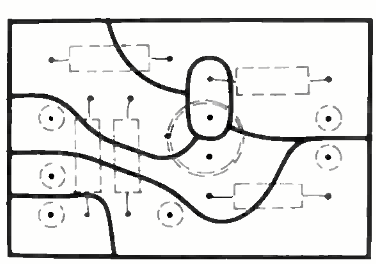
Space etch opens up many avenues of commercial, large-scale application. One is reduction of a complete circuit pattern to digital bits that can be readily placed on a suitable recording medium. The circuit wiring pattern is normally arranged such that the component part lead mounting holes fall on an intersection of the basic grid. With space etch, the spaces can also be correlated with the basic grid by specifying that the space is to be made up of modular incremental horizontal or vertical segments, each of them one grid unit in length and coinciding with the grid lines. For example, the lower left pattern in Fig. 1B can be represented numerically by this approach, and the entire circuit pattern can be converted into digital information. It can then be utilized, for example, as a tape-controlled layout of master pattern artwork, or as a punched paper tape in lieu of a production drawing of the circuit pattern that is required.

The space-etch approach is a simple one, yet has numerous inherent advantages for design, drafting, and fabrication which can reduce time and costs. To realize these advantages requires changes in the engineer's design concept thinking, changes that may well open new avenues for this method of creating printed boards.

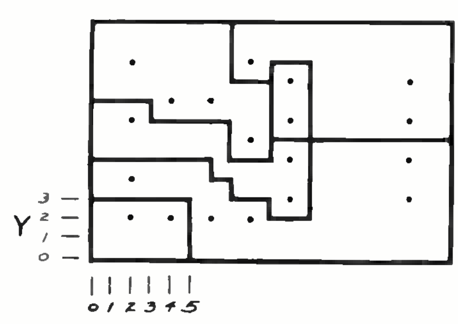
For design layouts, the components are arranged as usual, but instead of using the masking tape to create the conductive patterns (which will remain during the etching process), the masking tape is used to delineate the spaces. In the photography process, the pattern is reversed so that the tapes now represent the areas to be etched away, leaving the rest of the board copper intact.

For breadboard work, the space-etch artwork is simply an engineering sketch in black India ink on paper (such as that shown in Fig. 1A). Dots locate the holes for the component leads, and lines are drawn to represent the spaces which will separate the conductive areas. This dot-and-line sketch is used directly as the negative with the KPR process to produce a printed board, thus reducing the time between component part layout and finished board, and eliminating the cost of additional drafting and photography. ▲

Fig. 1 (A) Simple space-etch artwork. (B) Spaces and holes on X-Y grid allows digitalized circuit pattern. Refer to text.



(A)



(B)

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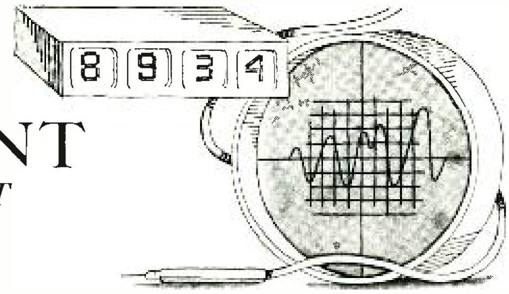

Sencore TR-139 In-Circuit Transistor Tester

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THIS new transistor tester is a simple-to-use unit that checks all transistors, either in or out of the circuit, for accurate a.c. *beta* and I_{cbo} leakage. The tester checks diodes and rectifiers too.

In addition to meeting the needs of the technician in servicing solid-state circuitry, the TR-139 can also serve the designer in the lab as well as the technician doing quality-control checking on production lines.

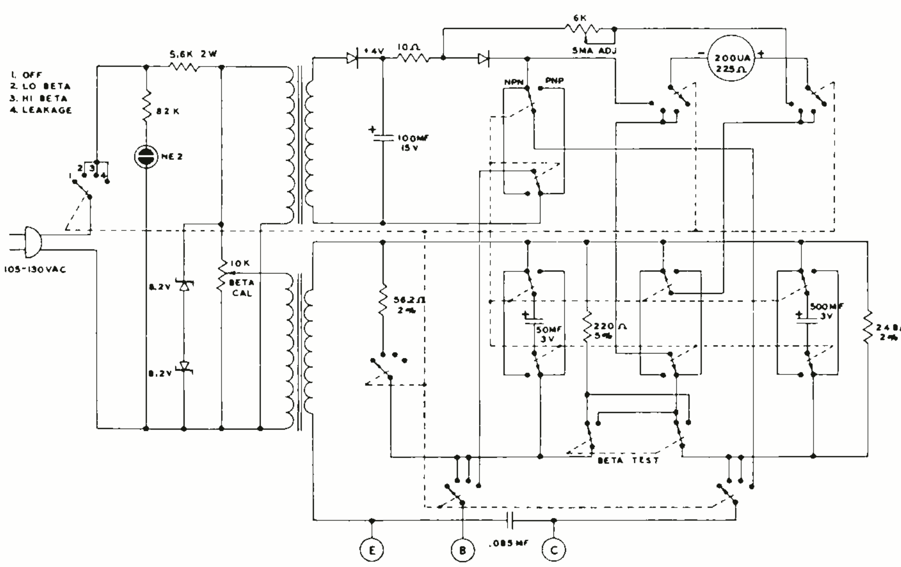
The in-circuit transistor test feature is a time-saver because transistors are checked for a.c. *beta* without unsoldering their leads. In-circuit testing also gives a speedy and positive "go no-go" indication of diode or rectifier conditions.

Beta is read in two ranges on a 6-inch, easily read meter. The meter shows the ratio of a.c. signal on the base of the transistor to that obtained on the collector. On the high scale, the range is from 10 to over 500; on the low scale. the range is from 2 to over 100. The TR-139 will also show an open or shorted transistor in or out of the circuit by refusing to calibrate and by indicating no *beta* reading when the test switch button is pressed.

Leakage current (I_{cbo}) is one of the most important parameters of a transistor. Also called collector cut-off current, it is the current that flows between the base and the collector when the emitter is open. Measurement of leakage current is important because many transistors exhibit a good *beta* reading regardless of age but do not function properly because their leakage currents change or become excessive. Leakage is measured with the transistor out of the circuit by moving the function switch to the proper position, reading the value directly in microamperes on the meter scale. Note that the *beta* and I_{cbo} values of any unknown transistor can be determined without referring to a "setup" book or transistor manual.

When testing diodes out of the circuit, their actual front-to-back conductivity is indicated directly in microamperes. When testing them in the circuit, knowledge of their polarity is not necessary; if the meter reads backwards when connected to a diode, just reverse the leads. The meter will read only if the diode is rectifying. If the diode is shorted or open, the meter pointer will remain still.

The power supply is zener-diode-regulated. A specially designed current-limiting circuit also protects low-powered transistors and diodes against damage due to misconnection of test leads. The tester operates from a 117-volt a.c. source; it weighs 8 pounds and is enclosed in an all-steel, vinyl-covered case measuring 9" x 7½" x 6". Price is $89.50. ▲



Eico "Truvohm" Model 100A4 V.O.M.

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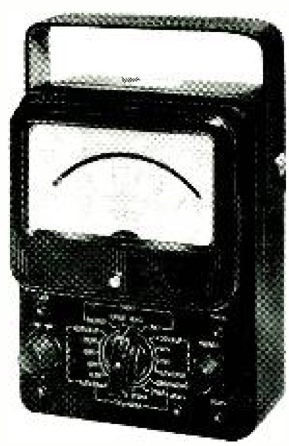
IN spite of increasingly sophisticated test instruments, the simple v.o.m. remains the most widely used and versatile piece of test equipment for servicing and maintenance as well as for design work.

Eico has had two v.o.m. kits in its



line for many years. These were also available factory-wired at an additional cost. More recently, the company has made available a complete line of a half-dozen low-cost, imported v.o.m.'s ranging from a $5.95 pocket tester (Model 1A1) up to the new $34.95 Model 100A4.

This top-of-the-line meter has a d.c. sensitivity of 100,000 ohms/volt and an a.c. sensitivity of 12,500 ohms/volt. Hence, the meter has a resistance of 5 megohms on the 50-volt d.c. range, which is about half that of the usual v.t.v.m. On higher ranges, the v.o.m. has a resistance that is far higher than that of its vacuum-tube counterpart; therefore, there will be little loading on high-impedance circuits.

The Model 100A4 uses a double-jeweled 2% d'Arsonval meter movement with a 4-inch, mirror-backed scale to eliminate meter-reading errors due to parallax. As with most of the recent instruments of this type, overload protection is included for the movement to prevent burnout. In this case, a pair of front-to-back-connected silicon diodes directly across the movement does the job. The carrying handle is stiff enough so that it can be swung under the meter to tilt it up from the bench for easier reading.

The v.o.m. has the usual d.c. voltage, a.c. voltage, d.c. current, resistance, and decibel ranges. Included is a useful 500-mV d.c. voltage range for measurements in transistor circuits. The lowest current range is 10 μA while the highest is 10 A. ▲

Boonton Electronics Model 41A R.F. Microwatt Meter

For copy of manufacturer's brochure, circle No. 159 on Reader Service Card.

THE Model 41A r.f. microwatt meter provides measurements of c.w. microwave power from 0.01 microwatt full scale to 10 milliwatts full scale over a frequency range of 0.1 MHz to 6 GHz, with a maximum sensitivity of 0.001 microwatt.

Because the power detector employs high-frequency silicon diodes rather than thermistors, the instrument exhibits excellent thermal stability; drift is typically less than 0.001 microwatt per hour, and no zero balancing is required on any but the most sensitive range. In addition, the power detector of the Model 41A is more resistant to overload burnout than thermistor types, and an overload of 300 milliwatts will not result in any damage to the instrument.

V.s.w.r. is less than 1.2 to 2.5 GHz, and less than 1.5 to 6 GHz. Accuracy is ±0.5 dB. The meter scale of the Model 41A is calibrated in both microwatts and in dBm. The power detector is equipped with a type-N connector that permits it to be employed in a 50-ohm r.f. system.

Price of the Model 41A r.f. microwatt meter is $695. ▲

Electronic Eavesdropping

(Continued from page 28)

pocket ready for surreptitious installation), the indicator lamp will flash a silent warning that an electronic eavesdropping device is within the premises.

A third, non-tunnel-diode approach is shown in Fig. 8C. Here a conventional transistor audio oscillator is used as the tone source. The output feeds a conventional audio amplifier and loudspeaker. The ground lead of the oscillator circuit is taken through a transistor switch which is normally cut off so that the oscillator does not operate. When an r.f. signal is picked up by the untuned antenna system, it is rectified in the diode, filtered, and then passed to the switch transistor. The positive-going voltage causes the transistor to saturate, closing the ground circuit and allowing the audio oscillator to operate. A commercial version of this was *L. N. Schneider's* "012 Bug Detector," priced at $39.50 (no longer available).

The most widely accepted device today is known as the feedback detector. Nothing more than a tunable, broadband (40 to 300 MHz) receiver with speaker output, the gadget screams with feedback in the presence of a tuned-in room bug. These sell anywhere from $150 to $650 and frequently come equipped with "S" meters to aid in locating r.f. telephone bugs. Interestingly, price seems to have nothing to do with receiver linearity or sensitivity.

The latest craze, however, seems to be in r.f. white-noise generators, suitably souped up for adequate jamming over a wide range of frequencies. (A typical circuit is shown in Fig. 9.) Known as "wiretap traps" (*Zelex Marketing*, New York City) and "antibugs" (*Dectron Industries*, Van Nuys, Calif.), these gadgets can wreak havoc on listening devices, to say nothing of nearby radio and TV reception. Yet they have wide appeal, since they preclude the need for visual and electronic bug detection, which is often quite expensive. Sold in various types of packages, these units cost from $225 to $350. A variation of this design, having an extra r.f. amplifier stage, was recently dropped by a West Coast supplier after the FCC and FAA swooped down on a few users who were unknowingly creating havoc with aircraft radio communications.

The crude spark-gap transmitters of yesteryear, the ultimate in powerful hash generation, are occasionally employed today, although they are not available commercially. Generally planted not far from a speech-sensitive room and powered from dry cells or an auto storage battery, these ancient relics are then remotely controlled from a convenient point in the home or office and are often activated by a wall switch.

At a recent conference, it was stated that it would take $100,000 and a countermeasure man with 10 years experience to insure against electronic invasion of privacy. This may be true in rare instances involving international espionage, but it is also true that the intelligent reader could conduct a fairly thorough investigation himself with a very good chance of coming up with a culprit. The trick is in knowing the enemy and making an approximation of what methods he would be likely to employ.

Exotic Devices

Last year, a hearing by Senator Edward V. Long's Senate Judiciary Subcommittee made public the now-famous martini-olive FM transmitter, that had a maximum range of only 20 feet, thus having very limited application. Likewise, the sugar-cube microphone commonly discussed, is only a microphone—and not a transmitter.

Except for laboratory developments, the smallest commercially available bug contains a single v.h.f. transistor, is powered by a flat hearing-aid battery, and measures 1" × ⅝" × ⅜". Yet it requires an antenna wire and has a maximum range of about 200 feet. As subminiaturization goes, it is expected that this design will continue to be used for some time before becoming obsolete, despite work being done with IC's.

Several electronic companies have indicated success with the creation of physically small antennas, and bug designers have been following these developments avidly.

Some have suggested going to a higher frequency where more efficient antennas could be used. This presents some problems, which are not insurmountable, however. As the frequency goes up, the amount of r.f. power becomes limited, while r.f. absorption by neighboring metal objects (and some types of non-metallic objects) greatly reduces the power that is left, thus again reducing operating range.

One answer is the Gunn-type semiconductors where r.f. power can be raised somewhat to overcome a few of these problems. However, other conditions now enter the picture. Multiple reflections from surrounding terrain and changing antenna patterns with movement of the transmitter or metal objects around the transmitter all contribute to plague the higher frequency unit. It has been estimated that power level advances will not be made until after 1970 at the earliest.

Limited only by the size of the external components required (battery, mike), the introduction of the IC heralds the day of the really small, easy to conceal bug. It only remains for enterprising engineers to solve these problems to match the tiny electronic circuits that can be created.

Of all the exotic devices, the laser-beam eavesdropper is furthest from reality. Experts in laser research and development predict that it will be a minimum of 20 years before any tangible results are realized, although fiction (and often the news) media would lead the public to think it was just around the corner.

Micro-reflectors consisting of Angstrom-thick reflective paint that is not optically visible has been developed, although its use as a window-pane reflector for laser snooping right now is pure sensationalism. Additionally, audio filtering is presently nowhere near the level required for such work.

One problem in the future of electronic eavesdropping lies in working out the flaws in audio-frequency filters and in raising the power levels of r.f. transmitters to something more than the 250 mW of present types. *Miles Wireless Intercom. Ltd.* has already announced that it had developed the ultimate in audio filters, capable of distinguishing and separating voices from typewriter clatter, passing cars, air conditioners, and overhead airplanes. *Electro-Voice* has had, for quite some time, a long-range "shot-gun" mike with specially cut tubes for key voice frequency range response. It should only be a matter of time before practical snooping devices result.

Now that the reader has had a good look at modern electronic eavesdropping, he is urged to use his own judgement in distinguishing between the real and the fictional and to bear in mind that even the most devoted Ian Fleming fans often come from Missouri.

In conclusion, this article has concentrated on the strictly technical aspects of this topic. On the matter of the ethics involved in using eavesdropping equipment, that would require another article even larger than this one. ▲

"He fills in during coffee breaks."

EW Lab Tested

(Continued from page 16)

effortless, "wide-open" sound that we have heard from very few speakers—most of which were far larger and more expensive. Experimenting with the contour control unit convinced us that it can be valuable in the hands of a knowledgeable user, but can be left in its normal, or center, setting without compromising the speaker's performance in any way.

Despite the sonic excellence of the system, we found a couple of minor annoyances in its design. For example, the contour switches rotate clockwise to *decrease* level, in direct opposition to normally accepted human engineering principles. The terminals on the rear of the contour control box are closely spaced and so positioned that it is quite difficult to connect both the amplifier and speaker cables without shorting some of the connections, with possible damage to speaker, amplifier, or both. A slight relocation of the terminals would solve the problem easily.

These minor criticisms cannot affect our over-all judgment of the unit. We consider it among the five or six finest sounding speaker systems we have heard, regardless of size or price. Anyone shopping for a speaker in its price class owes it to himself to listen to it. In fact, hearing the sound of this speaker can provide a useful frame of reference for people who plan to buy a smaller, less expensive system. They face the risk, however, that they may find themselves unhappy with any lesser choice.

Price of *KLH* Model 12 is $275.

Manufacturer's Comments: It is extremely difficult to run a continuous recorded curve of speaker response with a single microphone position for all frequency regions, even when several complete response curves are taken from various positions and subsequently averaged. For effective measurements in the high-frequency region, *Hirsch-Houck Labs'* procedure of averaging response figures from several points relatively distant from the speaker unquestionably is far more accurate than simple on-axis readings or averaged anechoic chamber readings from various mike positions, since it provides a far more telling indication of the total high-frequency energy (reflected energy as well as direct) reaching a listener.

In the region below 500 Hz, however, the same distant microphone placement or placements begins to yield figures that are *so much more a function of the room's characteristics than the speaker's* that the peaks and dips that occur—particularly between 100 and 500 Hz—give virtually no indication of the speaker's actual response. In reality, in any but a grossly deficient loudspeaker, the effective response in this region is remarkably flat, since a speaker is operating well within its area of piston action. In distantly miked room curves, however, the impression of peaks and dips is severe and, even when room effects are mentioned forcefully, the initial and very strong impression of the printed curve is that it represents a *speaker* rather than room behavior. This could only be modified effectively in the reader's mind by reference to curves of several loudspeaker systems at once, in which the similar room-response would be evident. Even here, however, the effect of *very minor* changes in speaker and microphone positions for different reports would tend to indicate speaker differences that really do not exist. (*Editor's Note: We continue to run these curves, all taken under the same conditions, because they do permit just such a comparison to be made.*)

In developing speakers at *KLH*, we begin with slow-sweep sine-wave frequency measurements, with a microphone placed close enough to the speaker to avoid room effects. This, of course, simply gives an indication of point-to-point smoothness and says nothing about desirable balance and over-all sound quality. We then move the microphone back and from several positions measure over-all response by using filtered segments of random noise rather than sine waves to give what we think is the clearest indication of the speaker's response when integrated with room conditions. The filtered noise technique minimizes grossly unrepresentative room effects and enables us to adjust the octave-to-octave response of a basically excellent speaker mechanism by acoustic and electrical means for desirable balance. This is the best way we know of to design a finished speaker system. The octave-to-octave balance is what accounts for the remarkable sonic impression that Hirsch notes in the test of his report—an impression that would be difficult to support in direct references to the response curves he has measured and which appear in this report.

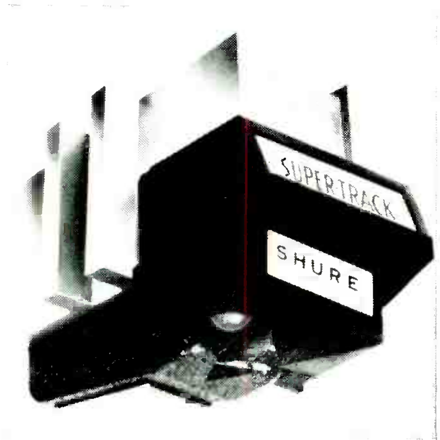
A small point: the reason for the apparently non-standard rotation of the controls on the contour control is that its panel was designed to represent graphically the effect of changing the controls from the "flat" position, so that the listener can see from across the room the relative response position in which he has left the controls. This is done by giving the knobs an arrow shape which tapers to the right and which indicates the elevation of a particular frequency range far more accurately than would a taper to the left, which would be necessary if the control were given the usual clockwise-to-increase rotation. Whatever one's feelings about this arrangement in practice, it was done after considerable thought was devoted by the manufacturer to "human engineering" and usefulness to the listener. ▲

Shure V-15 Type II Stereo Phono Cartridge

For a copy of manufacturer's brochure, circle No. 22 on Reader Service Card.

THE *Shure* V-15 stereo cartridge, first introduced a couple of years ago, incorporated such advanced features as a 15-degree vertical tracking angle, elliptical (or "bi-radial") stylus, and exceptionally high stylus compliance. Its outstanding sound quality earned it a place among the top cartridges of the time. It was difficult to see where any major improvement could be made in its performance.

Nevertheless, *Shure* engineers were not content to rest on their laurels and the result of their efforts is the new V-15 Type II. Recognizing that some heavily modulated records still sounded fuzzy and distorted when played with the V-15 (or any other cartridge),

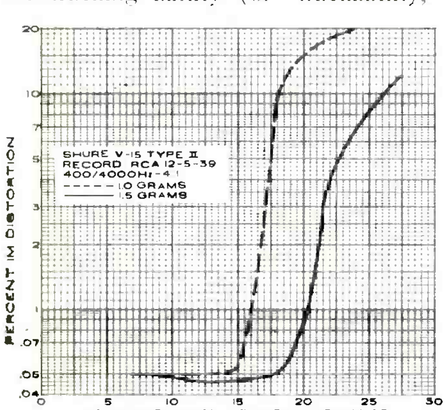


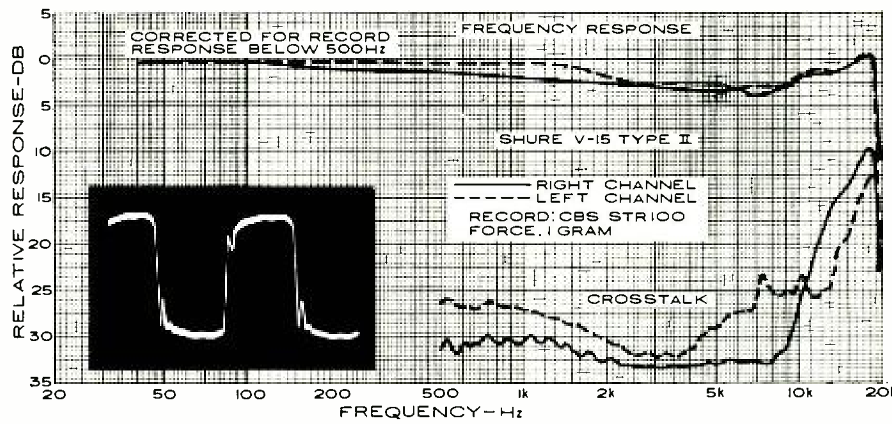
they made an extensive study of the peak recorded velocities encountered at high and middle frequencies. The results, viewed in the light of state-of-the-art cartridge performance, clearly indicated a need for further cartridge development.

At middle frequencies (between 800 and 2500 Hz), velocities as high as 26 cm/sec can occur. The maximum theoretical velocity falls off at about 6 dB/octave above and below these frequencies, but may still attain 6 cm/sec at 10,000 Hz. However, velocities of about 20 cm/sec at 10,000 Hz may occur on some records. This was well above the tracking capabilities of even the best cartridges of the time.

Most test records, even those with velocities as high as 30 cm/sec, are cut at 400 or 1000 Hz. Our measurements have shown that a number of good cartridges can track these records quite well, with acceptably low distortion. Due to our inability to make tracking measurements at high frequencies and high velocities, most good cartridges appeared to be quite similar in frequency response and distortion, and even in their listening qualities. Such differences as could be heard were rather subtle and were more in the nature of slight coloration differences rather than distinct advantages or disadvantages.

Shure's engineers were well aware that even the V-15 could not track the maximum velocities it would encounter at the highest frequencies. Since the tracking ability (or "trackability,"





as *Shure* calls it) of a cartridge is a function of many parameters, including tip mass, record-to-stylus compliance, stylus shank compliance, bearing compliance, and viscous damping, among others, a cut-and-try development program would be lengthy and expensive. Therefore, an electrical analog of the complete cartridge/record system was constructed and an analog computer was used to optimize the design.

Of course, implementing this design involved a great deal of proprietary art, in such areas as stylus shank material and shape, damping material, etc. The manufacturer is understandably reluctant to be specific about these details. The end result, the V-15 Type II, speaks for itself. It is a real step forward in phono reproduction and the improvement over the original V-15, to say nothing of practically all other cartridges, is strikingly audible.

Like the V-15, the V-15 Type II tracks at ¾ to 1½ grams. It has a 15-degree vertical stylus angle. Its elliptical stylus has radii of 0.2 mil and 0.7 mil, compared to the 0.2 mil and 0.9 mil of the V-15 stylus. The cartridge weight has been drastically reduced from 11 grams to 6.8 grams. Its output is also much lower, about 2.7 millivolts as compared to 6.1 millivolts for the V-15 (at 3.54 cm/sec). A swing-away stylus protector is built into the new cartridge. (*Editor's Note: The cartridge tested was one of the earliest ones available. According to the company, current production cartridges are producing 3.5 mV output as an average.*)

Most important, the cartridge, operating at ¾ gram, will track velocities in excess of anything found on modern records. For example, at 10,000 Hz, it will track 20 cm/sec. This virtually eliminates the shattering or raspy quality which occurs when playing a heavily modulated record with a cartridge lacking the necessary tracking ability.

Our laboratory measurements of its frequency response show that the cartridge is flatter and better damped at high frequencies than its predecessor. Over-all it is within ± 1.5 dB from 40 to 20,000 Hz, playing the *CBS* STR100 record. Much of that variation is on the record itself. Channel separation is better than 25 dB from 500 to 5000 Hz and almost 20 dB at 15,000 Hz. The compliance of the stylus is no longer specified, but may be inferred from the fact that the arm resonance in a good turntable is at about 10 Hz.

The 1000-Hz square-wave response shows good damping, with only a single cycle of ringing at about 15,000 Hz. The one measurement which shows the most dramatic improvement is the intermodulation distortion, as tested by the *RCA* 12-5-39 record. The old V-15 had IM of about 1% to 1.5% for velocities as high as 20 to 25 cm/sec (better than most cartridges tested). The new V-15 Type II distortion increases more abruptly at high velocities (about 16 cm/sec at 1 gram or above 21 cm/sec at 1.5 grams), but below these levels it is an insignificant .05%. Not only is this far lower than we have measured on any other cartridge, but we suspect it is the residual distortion of the test record rather than that of the cartridge.

Measurements notwithstanding, the new cartridge can be best appreciated when playing a record—and the more "difficult" or "unplayable" the record, the more impressive is its performance. To convince the user of the superiority of this cartridge, the manufacturer has issued a special record, with recordings of bells, harpsichord, and other instruments at four levels. Most cartridges sound clean at levels one and two. The *Shure* V-15 and other fine cartridges sound good on level three, although many cartridges begin to break up quite badly at this point. Level four produces a shattering, distorted sound from almost any cartridge—except the V-15 Type II. Even when the latter cartridge sounds a little strained on the highest level recordings, it is distinctly superior to the V-15.

We have demonstrated to our satisfaction that many records which were formerly unplayable, or unpleasantly distorted, sound fine when played with the new cartridge. It is truly superb. The *Shure* V-15 Type II sells for $67.50. ▲

NEW PRODUCTS & LITERATURE

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

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

METER CALIBRATOR

A compact instrument which can be used to check a.c. and/or d.c. voltmeters up to 1000 volts and a.c. and/or d.c. ammeters up to 5 amps has just been introduced as the Model 6920B.

The instrument is capable of both constant voltage and constant current output. Its absolute

accuracy of 0.2% + 1 digit for d.c. and 0.4% + 1 digit for a.c., makes it suitable for laboratory or production testing of panel meters, multimeters, and other meters having an accuracy on the order of 1.0% or higher. The calibrator is packaged for bench or rack use. Hewlett-Packard

Circle No. 126 on Reader Service Card

1-WATT ZENER DIODE

A newly designed 1-watt zener diode in which the elements are contained in a smaller body than was previously offered as a ½-watt power-rated diode is now available.

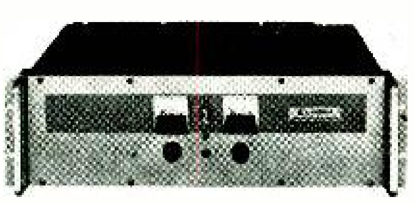
With the new design, the silicon wafer is aligned between two parallel, offset tantalum heat-sink tabs, with gold-plated nickel leads welded to the tabs. The leads do not extrude and the long, bidirectional leakage path assures positive moisture protection. The body is high-pressure molded and has a banded and tapered cathode. Size of the diode body is 0.160" diameter x $\frac{7}{16}$" long. The zener is available in 1%, 2%, 5%, 10%, and 20% tolerance units and in 21 voltages from 2.4 to 16. Schauer

Circle No. 127 on Reader Service Card

REGULATED POWER SUPPLIES

Three new convection-cooled, all-silicon regulated power supplies, with voltages up to 60 volts d.c. and current ratings up to 35 amperes have just been introduced.

Suitable for rack or bench mounting, each of the new power supplies has multiple current ratings for the ambient temperatures most frequently encountered in laboratory, industrial rack applications, and for elevated-ambient operation. The LK-352 model, for example, is rated 0 to 60 volts d.c., has a current rating of 0-15 A at 40°C and 0-14 at 50°C, 0-12.5 at 60°C and 0-10 at 71°C. Current ratings apply over the entire voltage range. Lambda



Circle No. 128 on Reader Service Card

25-AMPERE POWER TRANSISTORS

Six new 25-ampere diffused alloy power (DAP) germanium "p-n-p" transistors are now in production. These new units are specifically designed for high-speed, high-current switching and amplifier applications.

Features of this new B-113000 series are a high collector voltage (−100 to −170), low saturation voltage (−0.5 V maximum at 25 A), high d.c. current gain (60 to 300 at −2 A and −2 V), and low thermal resistance (0.8° C/W maximum).

Mechanical dimensions for these units conform to the JEDEC TO-3 outline. Bendix

Circle No. 129 on Reader Service Card

MOTOR-SPEED/LIGHT CONTROL

The "Knight-Kit" Model KG-201 permits control of the speed of electric drills, saws, sanders, grinders, mixers, and other electrically operated devices. It may also be used to control the brightness of incandescent lamps and photographic photofloods and units with heating elements such as heating pads, coffee makers, and toasters. It can be used with soldering irons (except transformer-type guns) to limit heat for the protection of delicate components.

The solid-state circuit uses a silicon controlled rectifier and two diodes. A calibrated control adjusts the output. In full "on" position the ap-

pliance runs at normal speed. It can be used with any universal-wound a.c.-d.c. motor-driven device with nameplate rating of 7.5 A or less. It is designed for resistive loads up to 900 watts and incandescent lamps up to 500 watts. It will not work with a.c.-only motors.

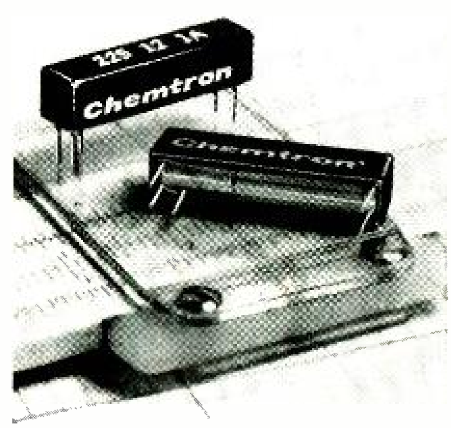
The kit comes with detailed step-by-step instructions for assembly. The completed unit measures only 2⅞" x 4" x 1½". Allied Radio

Circle No. 1 on Reader Service Card

PC REED RELAYS

A new series of printed-circuit reed relays especially suited to aerospace and computer applications has been released as the "Chemtron" 225. With a switching time of less than 0.5 ms (including bounce), the relay is one of the fastest and smallest PC reed relays commercially available today, according to the manufacturer.

The relay measures 0.8" x 0.2" with standard 0.1" pin spacing to simplify PC board layout. Direct PC mounting eliminates the changes in reed characteristics resulting from cutting and bending axial-type leads.



The 225's electrostatic shield minimizes coil-to-reed capacitance for low-loss switching or r.f. or low-level a.c. signals. The s.p.s.t., normally open contact rating is 250 mA at 250 V maximum into a non-inductive load. A 12-volt coil is standard. Self-Organizing Systems

Circle No. 130 on Reader Service Card

PRECISION TRIMMERS

Gold-plated printed-circuit pins or lugs or standard solder terminals are variations available in a new wide-resistance-range series of precision "Relcon" trimmers.

The new CW-90 series units are manufactured in all standard resistance values from 25 to 50,000 ohms, with special 10-ohm units also available. Ceramic mandrels and precious metal wipers are features which make these units especially applicable for precision instrumentation use, according to the company.

A stainless-steel lead screw requiring about 0.625 ounce/inches of operating torque provides for 25 turns with idler protection at both ends of the wiper traverse. Equipped with high-strength Diallyl phthalate housings, ten of the trimmers weigh less than 1 ounce. All units are 1.25 inches long, 0.220 inch high, and 0.312 inch wide. Mounting holes are on 1-inch centers and units equipped with either pins or standard terminals can be stack mounted for maximum space utilization. Bowmar

Circle No. 131 on Reader Service Card

TUNING VARACTOR LINE

A complete new line of tuning varactors that features the DO-7 glass package has recently been introduced. Designed specifically for electronic tuning applications, these units are especially well suited for hand-solder or stripline insertion. They can be used in equipment operating at frequencies up to 3 GHz. The high capacitance ratios, which range up to 6:1, make it possible to design resonant circuits which are tunable over octave bands.

"Q" is up to 400 at 50 MHz, total capacitance is from 5 pF to 30 pF, and breakdown voltages are 120 volts. AEL

Circle No. 132 on Reader Service Card

EXPANDABLE CHASSIS

A new line of patented expandable chassis, which is being offered in brass to permit soldering to prevent RFI leakage, has been announced. Designed for laboratory applications involving experimental circuitry, the chassis is assembled from rails, panels, and bottom plates of the desired size. All seams in the assembled and completed chassis can then be soldered not only preventing RFI leakage but making the internal circuit and components dust-proof and moisture-proof as well.

Available sizes range from 4" x 4" to 17" x 17" in 1", 2", 3", or 4" depths. Seezak

Circle No. 133 on Reader Service Card

VACUUM RELAY

A new vacuum relay which offers the multiple capability of interrupting resistive power and carrying high r.f. currents as well as withstanding high voltage is now available as the RF1D. The new relay weighs ¾ ounce and occupies less than ⅓ cubic inch of space.

Aided by the vacuum dielectric and a new internal design, the RF1D will interrupt 1000 watts of d.c. power for over 100,000 operations at a maximum of 1 A or 2 kV. It will also withstand 4 kV peak test voltage and carry r.f. currents of 4 A r.m.s. at 16 MHz. Contacts are s.p.d.t., contact resistance is 0.010 ohm maximum, operate time is 10 ms maximum, and coil voltage is 26 volts d.c. ITT Jennings

Circle No. 134 on Reader Service Card

MARKER GENERATORS

Two marker generators for superimposing well-defined and precisely crystal-controlled a.c. or d.c. marks on a scope display of response curves are now available as the Models CM-6 and CM-10. The former can be programmed to provide any desired fundamental frequency between 2 and 100 MHz. The CM-10 rack-mounted model has a frequency range of 100 kHz to 100

MHz. At the higher frequencies (20 to 100 MHz), up to the 20th harmonic will be visible and up to the 10th harmonic will be displayed on the lower (100 kHz to 20 MHz) frequencies. Proper choice and proper mixing will provide harmonic and sideband markers across a wide bandwidth.

Full specifications on both the portable and rack mounted models will be forwarded on request. Jerrold

Circle No. 135 on Reader Service Card

MICROMINIATURE FILM RESISTOR

A new microminiature metal film resistor that bridges the gap between available discrete resistors and microcircuitry has recently been introduced as the Type UC. The new unit satisfies the applicable requirements of MIL-R-10509 and is believed to be the smallest commercially available unit of its type.

The resistor measures 0.125 inch long x 0.047 inch diameter and has #30 gold-plated dumet leads. Resistance values range from 50 ohms to 10,000 ohms, with initial tolerances of ± 1, ± 2, or ± 5%. Rated 1/20th watt at 100°C, these tiny resistors can be obtained with temperature coefficients of ± 50 or ± 100 ppm/°C. IRC

Circle No. 136 on Reader Service Card

82-CHANNEL COAXIAL CABLE

A new low-loss, 82-channel coaxial cable for color, black-and-white, and FM-stereo installations is now being marketed as the "Color-Shield 82 Coaxial Colormatch". The cable comes with a 300-75 ohm matching transformer attached. The transformer ties directly to the 300-ohm output of the antenna.

The new cable comes in three lengths: 50, 75, and 100 feet. JFD

Circle No. 2 on Reader Service Card

WIRE MARKERS

A complete line of self-adhering wire markers in convenient pocket-size books is now on the market. Each book contains 420 markers plus

420 single terminal block markers. Nine combinations of letters and numbers are available to cover most marking requirements. Each individual marker is 1½" long.

The wire markers are made of coated vinyl which resists oil and moisture. The imprinted letter and number characters are easy-to-read block letters. The markers won't smudge and can be wiped clean. Thomas & Betts

Circle No. 137 on Reader Service Card

BURGLAR-ALARM KIT

A completely self-contained burglar-alarm kit including all switches, siren, lock-and-key, and all necessary components to protect panel trucks, passenger cars, station wagons, or boats is now available.

Capable of providing protection to the hood, trunk, and all four doors of the vehicle, installation is quick and simple. In normal usage, a protected vehicle is locked and the siren system turned on with the key in the front fender lock. Thus if the vehicle is tampered with, a shrill siren sounds immediately to signal the owner and police. The alarm can only be turned off by the owner resetting the system with his key. The owner can bypass the system simply by turning the key before entering the vehicle himself. On-Guard Corp.

Circle No. 3 on Reader Service Card

H.V. SILICON TRANSISTORS

An expanded line of high-voltage silicon power transistors, designed for use in high voltage inverters and switching regulators, TV deflection circuits, as well as all line voltage switching and amplifier applications are available as MHT 7901-5 and MHT 7907-10.

These 10 amp planar "n-p-n" transistors feature V_{CEO} sustaining voltages from 150 V to 325 V. They are supplied in the TO-66 package and

have a frequency response of 50 MHz and a C_{out} of 150 pF. They are capable of dissipating up to 25 watts at 100° C case temperature. Solitron

Circle No. 138 on Reader Service Card

CONTACTLESS REED RELAY

A contactless resonant reed relay with a life span approaching that of solid-state devices and designed for use in solid-state circuitry has been introduced as the Model S1087A.

The relay, said to be the smallest in the electronic industry. (0.619 inch wide, 0.393 inch deep, and 1.114 inches long plus connecting pins), has a frequency range of 67-3150 Hz and a temperature stability of ± 0.001% per °C.

By eliminating contacts, the life span and reliability of the component has been significantly increased, according to the manufacturer. The unit is designed for use in carrier-current control systems, radio and direct-wire transmission systems. Motorola

Circle No. 139 on Reader Service Card

R.F. LOAD RESISTORS

The Model 8160 "Termaline" dry high-power coaxial load resistors are designed for 50-ohm r.f. line and system termination in any position. The 100-watt model is completely independent of extraneous heat sinks or cooling liquids. Mating it with an axial air flow device in the Model 8161, the radiator permits a safe r.f. power dissipation of 225 watts. Both units operate continuously from −40 to +45 degrees C.

The efficient transfer of heat from the cylindrical resistor is the result of a novel truncated r.f. design on space-age substrate material.

Full specifications and application data are available. Bird

Circle No. 140 on Reader Service Card

REED RELAYS

The new Series 350 reed relay is designed for printed-circuit or plug-in application and is being offered in four different load capabilities from

dry circuit to 15 amps in-rush. Over 100 x 10^6 operations with breakdown voltage of 350 to 1000 V r.m.s. is standard.

The series is offered in three standard coil voltages (6, 12, and 24) and comes with 1, 2, 3, 4, or 6 poles. Electrostatic and electromagnetic shielding are available on special order. Elec-Trol

Circle No. 141 on Reader Service Card

HI-FI—AUDIO PRODUCTS

COMPACT FM-STEREO RECEIVER

The Model S-8600, an all-silicon solid-state receiver, has been designed expressly for compact bookshelf installations in apartments or other areas where space is at a premium.

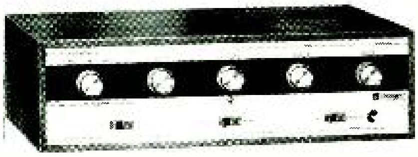
The receiver features front-panel controls for tape monitoring, bass, treble, balance, loudness, tuning, FM/phono, and mono/stereo. A jack is also provided for stereo headphones. Continuous power is 30 watts per channel at 4 ohms and 20 watts at 8 ohms for 1% distortion. FM sensitivity (IHF) is 1.8 μV for −30 dB noise and distortion below 100% modulation. Frequency response is 20-20,000 Hz ± ½ dB FM mono and 20-15,000 Hz ± ½ dB FM stereo.

The Model S-8600 measures 16½" x 12" x 4½". A walnut-grained leatherette case is available at a slight additional charge. Sherwood

Circle No. 4 on Reader Service Card

50-WATT STEREO AMPLIFIER

The new "Knight" KN-960 50-watt stereo amplifier employs all-silicon transistors for maximum circuit stability. The unit provides a full



complement of controls for versatile operation and a separate "on-off" switch. Power is 50 watts IHF, 100 watts peak; output is 17 watts r.m.s. per channel at 8 ohms.

Frequency response is 20-20,000 Hz ± 1 dB at under 1% distortion. Outputs are 4 to 16 ohms, stereo headphones, plus two a.c. convenience outlets. The amplifier is designed for 110-130 V, 60-Hz a.c. operation.

The KN-960 measures 3$^{5}/_{16}$" high x 13" wide x 10" deep. A deluxe oiled walnut case is available as an accessory. Complete specifications are included in Sales Book No. 263 which will be forwarded on request. Allied Radio

Circle No. 5 on Reader Service Card

LUBRICATED MAGNETIC TAPE

An improved lubricated magnetic tape, designed for use in tape cartridges and other endless loop applications, is now available as the "Scotch" brand No. 153. The tape contains improved lubricants designed to increase performance under temperature and humidity extremes peculiar to the automobile stereo tape cartridge field.

The No. 153 is available in 1600-foot lengths on 7" reels and 3600 feet on hubs. 3M

Circle No. 6 on Reader Service Card

CONTINUOUS-LOOP MAGAZINE

The Model 1510 is a continuous loop magnetic tape magazine designed especially for operation on small, battery-operated portable recorders. This device, known as the "Audio Vendor", is only 2$^{5}/_{8}$" in diameter and will work on standard "reel-to-reel" tape recorders which normally use 3" or 4" reels. It is available in playing time cycles (before repeating) of 6 to 10 minutes at 1$^{7}/_{8}$-ips tape speed. It fits easily and instantly over the feed reel spindle of almost any recorder. Orrtronics

Circle No. 7 on Reader Service Card

PORTABLE P.A. SYSTEM

A solid-state, carrying-case public address system which is completely self powered and self contained is being marketed as "The Executive".

The new unit utilizes standard flashlight or alkaline batteries. Featuring a solid-state amplifier and six speakers, the system provides high voltage for either indoor or outdoor amplifications. The special amplifier and sound column construction minimize the possibility of feedback.

The luggage-type carrying case is waterproof and scuff and mildew resistant. A zippered back panel permits easy storage of the microphone, cable, and lavalier cord which come with the system. Hamilton Electronics

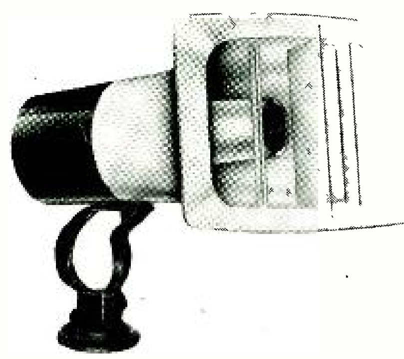
Circle No. 8 on Reader Service Card

PAGING & TALKBACK SPEAKER

The "Cobra" Model COP-8 wide-angle paging and talkback speaker features sectoral diffraction gratings, placed at three positions on the bell of the horn, to eliminate the usual fall-off of energy at the extreme ends of the polar pattern. According to the company, this design concept provides extremely flat, wide-angle dispersion and minimum vertical dispersion.

The speaker can be mounted either vertically or horizontally and its position changed through the use of the firm's "Lever-Lock" bracket. The bell is made from "Implex A", a virtually indestructible material which is impervious to weather.

Frequency response is 250 to 13,000 Hz, power rating is 30 watts, dispersion angles are 120°



x 60°, and microphone sensitivity is —23 dBm. Oxford

Circle No. 9 on Reader Service Card

CB-HAM-COMMUNICATIONS

BATTERY PACK FOR CB

A new, fully self-contained battery pack, especially designed to make all of the firm's solid-state CB rigs completely portable, has been introduced as the "Port-A-Pak" Model PAP-1. It features a rechargeable nickel-cadmium battery and will provide continuous operation on "receive" for up to 8 hours. The unit can be left on trickle-charge continuously to insure ready-to-go operation. It can be recharged while in standby.

The battery pack will operate over a temperature range of —30 to +140 degrees F. It cannot be overcharged when used with the companion "Charge-A-Pak" battery charger. The unit comes complete with collapsible antenna, case, rechargeable battery, battery meter, charging connector, mounting hardware, microphone bracket, and shoulder strap. Courier Communications

Circle No. 10 on Reader Service Card

PORTABLE SNAP-OUT TOWER

A new concept in high-capacity portable towers for communications purposes has been incorporated in a super-compact, triangular snap-out tower. The 300-foot tower can be completely installed without power hoist equipment in just 7 hours. Dismantling of the tower takes 6 hours. The complete tower can be housed in a 4 x 6 x 10 foot shipping container.

The tower consists of 3-foot sections, weighing only 26 pounds each. Sections snap out and lock into place, one on top of the other, without the use of special tools or loose parts. Up-Right Scaffolds

Circle No. 11 on Reader Service Card

FOUR-BAND S.W. RECEIVER

The "Space Ranger" Model 711 is a four-band short-wave communications receiver which is available in both kit and assembled form. The receiver measures 6" high x 13½" wide x 9" deep and weighs 17 pounds.

The superhet tunes 550 kHz through 30 MHz

and includes the popular 160, 75, 40, 20, 15, and 10 meter ham bands. The unit has a built-in ferrite rod antenna and provision for an external antenna. A professional-type "S" meter indicates when the receiver is on-station. Pinpoint accuracy of tuning is obtained with electrical bandspread tuning. SSB and c.w. transmissions are covered with the integral variable b.f.o.

The headphone jack makes private listening possible while the built-in audio system uses a 4-inch PM speaker. Modern printed-circuit board construction makes the kit easy to assemble. Eico

Circle No. 12 on Reader Service Card

V.H.F./FM PERSONAL PORTABLE

The "Minivox" is a v.h.f./FM personal portable two-way radiotelephone with an r.f. output rating of more than 1 watt. It will operate on any frequency within the 147-174 MHz band and employs 16F3 (narrow-band FM) modulation.

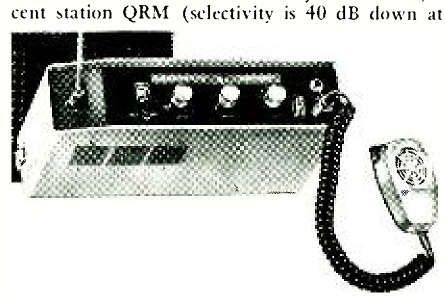
The transceiver is housed in a ruggedly constructed die-cast metal case. It operates from self-contained mercury, nickel-cadmium, or alkaline batteries. Its all-solid-state circuitry employs 28 transistors and 12 diodes. Three different types of antenna are available: a telescoping, a 4-inch or 5-inch spring type for use where the telescoping antenna might prove to be an eye hazard, and a handle antenna of the type used by many railroads.

The unit may be used for man-to-man communications or for communicating with base stations and mobile units. Unimetrics

Circle No. 13 on Reader Service Card

TWO-METER PORTABLE/MOBILE UNIT

The HA-144 is a two-meter transceiver designed for portable, mobile, or fixed-station use. It is fully solid-state (18 transistors and 7 diodes) and features a selective 144-148 MHz tunable dual-conversion superhet receiver with 1-μV sensitivity for 10 dB signal-to-noise ratio. The 10.7-MHz mechanical filter effectively reduces adjacent station QRM (selectivity is 40 dB down at



30 kHz). A series gate limiter automatically suppresses bothersome noise. The push-pull, high-level modulated transmitter delivers over 1 watt of r.f. output power for 2.5 watts input. There are 5 internal and 1 front-panel switched crystal positions. It may be used with standard 8-MHz crystals or external v.f.o.

The unit comes with a leather carrying case, shoulder strap, whip antenna, mobile power cable, mobile mounting bracket and 10 "D" size batteries. It measures 12" wide x 7$^{1}/_{8}$" high x 3" deep. Shipping weight is 10 pounds. Lafayette

Circle No. 14 on Reader Service Card

POWER & POLARITY CONVERTER

A power and polarity converter, the "Power-Match", converts any automobile voltage to the 12 volts required to operate the firm's solid-state CB two-way radios and other transistorized equipment.

It has a heavy duty transformer which powers equipment operating from 12 volts and handles loads up to 30 watts of power drain. The unit is 4½" long x 3½" wide x 2" high and provides 12 volts-to-12 volt polarity inversion, permitting negative-ground-only equipment to be operated from a 12-volt positive-ground battery system. Applications cover both foreign and domestic car power systems. It will also convert 12-volt systems to 24 volts and 6 volt systems to 18 volts for unusual equipment requirements. Pearce-Simpson

Circle No. 15 on Reader Service Card

MOBILE V.H.F. RADIOTELEPHONE

The 960AR "Comtron" mobile v.h.f. radiotelephone is equipped with a compact, four-channel-operation cradle telephone set which can be located in the passenger compartment while the transceiver is mounted in the vehicle's trunk.

The user of this 30-watt unit may choose channels linking him with mobile telephone service (MTS) operators in four separate geographic locations within driving range or all channels can be assigned to operators in the same area. The unit can be supplied with less than four sets of crystals if desired.

The instrument's busy lights show when a channel is available. With the equipment control switch in the "receive" position, the call light will flash on when a call is received during absence from the vehicle, remaining in that position until the user's return. The call can then be traced by contacting the mobile operator.

The telephone set is available in a variety of colors to match automobile color schemes. The equipment may be purchased or leased for periods up to 3 years. Du Mont Mobile

Circle No. 16 on Reader Service Card

MANUFACTURERS' LITERATURE

ELECTROLYTIC CONDUCTIVITY

A new 36-page illustrated catalogue (No. 30) on the company's entire line of process electrolytic conductivity equipment is now available. Instruments described include "Solu Bridges," "Solu Meters," conductivity controllers and recorders, electrodeless systems, and dissolved oxygen analyzers.

Also included are a number of epoxy-dip, flow-type, gate-valve, and screw-in conductivity cells. Beckman Instruments

Circle No. 142 on Reader Service Card

SOLID-STATE TIMERS

Described and illustrated in a new 4-page brochure is a complete line of transistorized timing devices. Technical information on the 20 models covered in the booklet is presented in the form of a handy chart, and cross references to bulletins offering more detailed data are provided. Syracuse Electronics

Circle No. 143 on Reader Service Card

ADHESIVES WALL CHART

A newly revised edition of the "Eccobond" adhesives wall chart has been released. Products with similar properties, such as liquids, powders, pastes, and solders, are grouped together on the illustrated chart. Mix consistency, pot life, lap shear strength, service temperature, thermal expansion, and dielectric strength are shown for each adhesive listed. Emerson & Cuming

Circle No. 144 on Reader Service Card

MERCURY SWITCHES

A new 16-page three-part mercury switch instruction manual (No. AS-1) has been published. Section I contains information on handling factors and horsepower ratings as well as a glossary of mercury switch terminology; Section II covers types of mercury switches and such parameters as resistance, load vs life, differential angle, temperature, and tilt rate; while Section III describes mounting and installation. Micro Switch

Circle No. 145 on Reader Service Card

ADJUSTABLE-SPEED DRIVES

Information on a complete line of "Speed-a-matic" SCR adjustable-speed drives is contained in a new 8-page illustrated brochure. The booklet discusses the company's special design measures to assure electrical, environmental, and thermal protection. Also described are fully enclosed solid-state controllers, conventional and internally geared motors, and single and double reduction motors. U.S. Electrical Motors

Circle No. 146 on Reader Service Card

POWER RELAYS

Information on the new RCP-22 Series of d.p.d.t. heavy-duty power relays is contained in a new illustrated data sheet (Bulletin RCP-22). Applications include starting motors up to 1 hp, elevator controls, machine tools, and voltage switching. Relay and Control

Circle No. 147 on Reader Service Card

TWO-WAY RADIOS

Information on a line of all-transistorized business/industrial two-way radios and accessories is contained in a new 6-page illustrated foldout brochure. Included are a hand-held transceiver, an interchangeable unit for base-station, portable, or mobile use, and a field kit containing two portable transceivers, optional antennas, battery recharging unit, and carrying case. Amphenol Distributor Div.

Circle No. 17 on Reader Service Card

ANECHOIC CHAMBERS

A new 4-page folder, sixth in the New Designs series, describes and illustrates seven recently built "Eccosorb" microwave anechoic chambers. Emerson & Cuming

Circle No. 148 on Reader Service Card

ACIDITY MEASUREMENT

A new 44-page illustrated booklet (Bulletin 4074) on the company's line of process pH analyzers, ORP analyzers, electrodes, electrode chambers, and accessories has been published.

Featured in the booklet is the firm's newest addition to its line, the Model 900 pH analyzer. Also included are sections on pH operating theory and industrial applications as well as a bibliography of reference material on the theoretical and practical aspects of pH measurement. Beckman Instruments

Circle No. 149 on Reader Service Card

HEATING ELEMENTS

A revised 20-page illustrated brochure (Bulletin 74-3) on electric heating elements has been released. Included are strip heaters, cartridge heaters, tubular heaters, lead pots, hot plates, and control thermostats.

In addition, the publication supplies heating formulas, conversion table data, and specific heats for solids, liquids, gases, and vapors. Trent

Circle No. 150 on Reader Service Card

SILICON POWER TRANSISTOR

A new 8-page engineering data sheet on the company's B-5000 plastic-encapsulated silicon power transistor is now available. The leaflet discusses cost, mounting techniques, and performance and lists five applications together with suggested circuitry. Bendix Semiconductor Div.

Circle No. 151 on Reader Service Card

INSTRUMENT RENTAL

Information on renting more than 13,000 electronic, industrial, and electrical instruments of every make through the company's Schenectady Instrumentation Service is contained in a new 16-page instrument rental catalogue (Bulletin GEC-1551B).

Also outlined in the booklet are the calibration, repair, and measurement services offered by the company. General Electric

Circle No. 152 on Reader Service Card

DIGITAL READOUTS

A new 12-page illustrated booklet describing the company's line of optimum-contrast illuminated digital readouts has been issued. Covered in the brochure are display and equipment features, reliability, and test results.

In addition, the publication contains a presentation of the operating principles of the seven-segment bar readout plus a chart of the characters produced. Tung-Sol

Circle No. 153 on Reader Service Card

INSTRUMENT CATALOGUE

A complete test instrument line of semiconductor test systems, digital voltmeters, oscilloscopes, and components is presented in a new 16-page condensed catalogue.

Products listed include test equipment for transistors and IC's; special-purpose oscilloscopes, oscilloscope cameras, and accessories; and differential and operational amplifiers. Fairchild Instrumentation

Circle No. 154 on Reader Service Card

ELECTRICAL INSULATION

A new 30-page glossary for engineering students entitled "Electrical Insulation Terms and Definitions" has been published. Prefacing the booklet is a 7-page illustrated section which describes the various subdivisions of insulating materials, including vulcanized fiber, flexible tubing and sleeving, treated flexible cloth, laminated plastics, and mica products. Insulating Materials Div. of NEMA

Circle No. 18 on Reader Service Card

QUICK-ERECT TOWER

Information on the company's new quick-erect tower is offered in a recently issued brochure. The tower, which can be built within four hours with the services of five men, features all-aluminum, all-welded construction and is completely self-contained, carrying its own power source, lights, and all tools and equipment necessary to effect operational status in the time designated. Andrews Towers

Circle No. 19 on Reader Service Card

MILITARY SWITCHES

A new 32-page illustrated catalogue of military, aerospace, and commercial aircraft switches has been published. The booklet (No. 52) lists a wide variety of mechanically and manually operated devices, and complete technical specifications and dimensions are provided for all products covered. Micro Switch

Circle No. 155 on Reader Service Card

ELECTRONIC COMPONENTS

Described and illustrated in a new 16-page condensed catalogue is a complete line of electronic components. Included are electrolytic, foil, ceramic, and variable capacitors; linear and non-linear resistors; and a number of speakers and control knobs. Amperex

Circle No. 156 on Reader Service Card

TEST EQUIPMENT

A new 4-page illustrated product brochure (No. 338) describing six test instruments that have recently been added to the company's line is now available.

Included are two standard color-bar generators, an FM-stereo multiplex generator, an in-circuit transistor tester, a mutual conductance tube tester, and a combination v.t.v.m./v.o.m. Sencore

Circle No. 20 on Reader Service Card

COMPONENTS CATALOGUE

A wide variety of capacitors, EMI filters, rectifiers, diodes, and integrated circuits are described and illustrated in a new 28-page electronic components catalogue (No. 67). Erie

Circle No. 157 on Reader Service Card

VOLTAGE-SENSING DEVICES

Two new technical bulletins on two "Trimpot" voltage-sensing devices are now available. One booklet covers the Model 3910 d.p.d.t. voltage-sensing relay, while the other describes the Model 3917 voltage-sensing module.

The 4-page bulletins include specifications, application notes, special features, and diagrams. Bourns, Trimpot Div.

Circle No. 158 on Reader Service Card

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Answer to Puzzle
appearing on page 76

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

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

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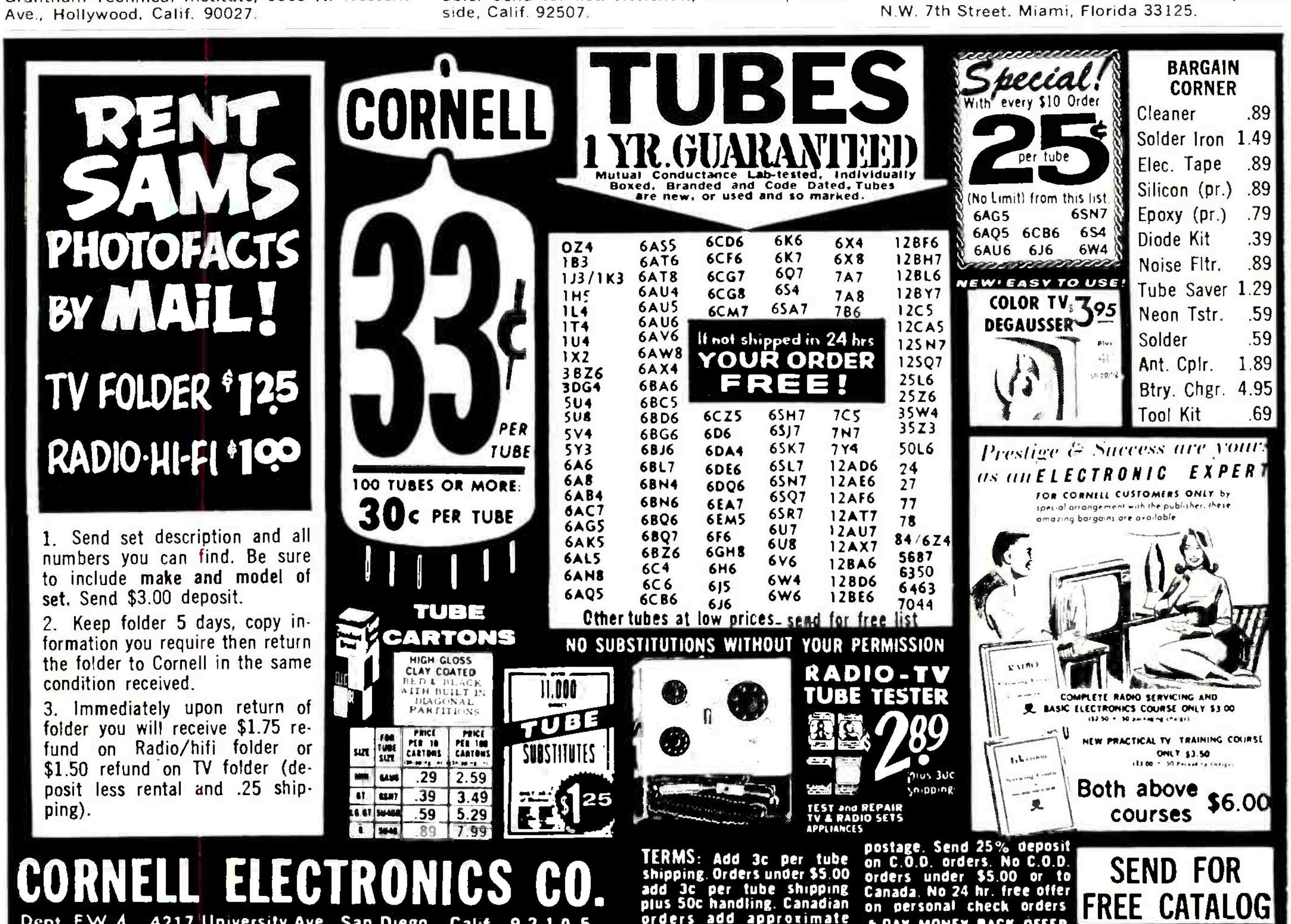
R.F. CONVERTERS World's largest selection. Also CCTV cameras, etc. Lowest factory prices. Catalog 10¢. Vanguard, 196-23 Jamaica Ave., Hollis, N.Y. 11423.

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

FREE ELECTRONICS (new and surplus) parts catalog. We repair multimeters. Bigelow Electronics, Bluffton, Ohio 45817.

DETECTIVES! Free brochures! Electronic Surveillance devices. **SILMAR ELECTRONICS,** 3476 N.W. 7th Street, Miami, Florida 33125.



CIRCLE NO. 89 ON READER SERVICE CARD

SURVEILLANCE EQUIPMENT—NEW HIGH PERFORMANCE SUBMINIATURE MODELS. ELECTRONIC COUNTERMEASURE DEVICES TO PROTECT PRIVACY. FREE DATA: SECURITY ELECTRONICS-EW, 15 EAST 43RD STREET, NEW YORK, N.Y. 10017.

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ELECTRONIC Ignition Kits, Components Free Diagrams. Anderson Engineering, Epsom, New Hampshire 03239.

NEW supersensitive transistor locators detect buried gold, silver, coins. Kits, assembled models. $19.95 up. Free catalog. Relco-A22, Box 10563, Houston, Texas 77018.

INTEGRATED CIRCUIT Experiment Kit, $6.95. Others. Catalog 10¢. Kaye Engineering, Box 3932, Long Beach, California 90803.

UNIQUE relay to build variety of remote controls, model railroads, liquid level control, weather detector, burglar alarm, games, trick circuits. 20 design ideas included free. $3.95 prepaid. Dept. C, Alco, Lawrence, Mass. 01800.

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

RADIATION from billion Stars **CONVERGES** everywhere causing gravitation. Copyrighted Theory, $1.00 Refundable. Carnahan, 1413 Yorkshire, Austin, Texas 78723.

TUBE TESTER $9.00. Shell model 102 tester panel, 7"0-1ma meter, 102 sockets, vibrator tester, 18" wide x 16" high. **EVEREADY** battery tester, $4.00. Money back guarantee. Kirby, 3606 Delmar Road, Indianapolis, Indiana 46220.

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MESHNA'S Transistorized Converter Kit $5.00. Two models converts car radio to receive 30-50mhz or 100-200mhz (one mhz tuning) Meshna, No. Reading, Mass. 01864.

SUDYMONT acoustic baffles. Plans $5.95; Baffle $26.95; with cabinet from $39.95. Send speaker size. **SUDYMONT,** 120 Liberty Str., NYC. 10006.

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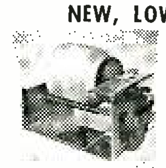

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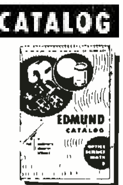

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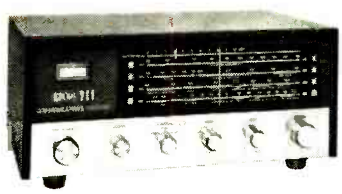

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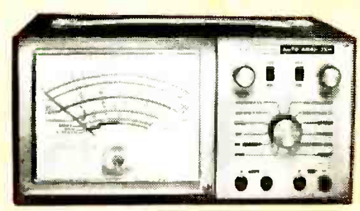

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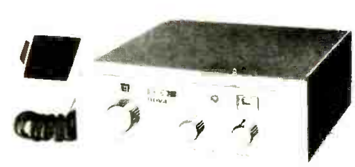

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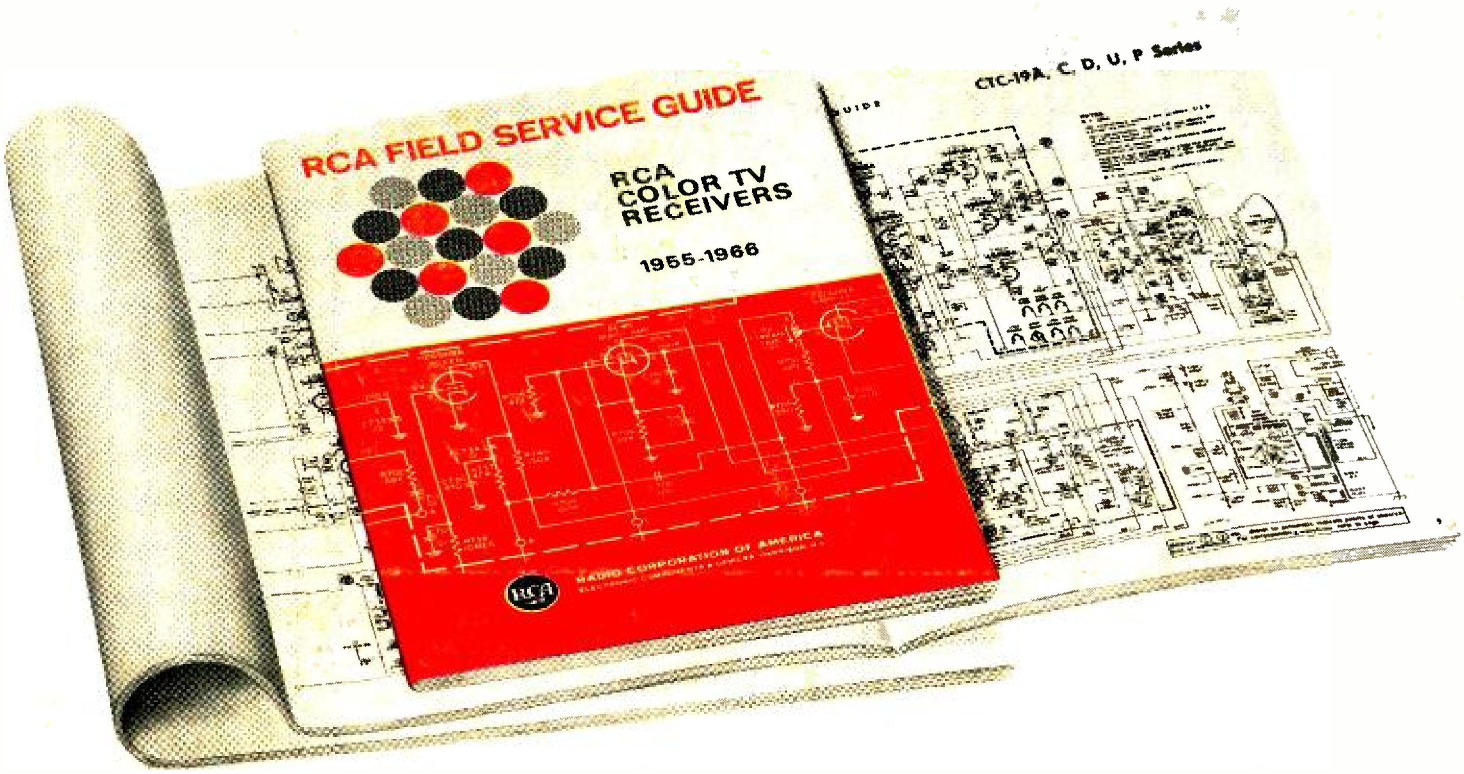

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