Electronics World

OCTOBER, 1969
60 CENTS

SPECIAL ISSUE

ELECTRONICS AND THE LIVING PLANT

HOW TO MATCH SPEAKERS IN P.A. SYSTEMS

PRINTED CIRCUITS

A ZIFF-DAVIS PUBLICATION

Color or UHF set perfect? Antenna perfect? Then obviously there's a missing link. Check that antenna lead-in cable. Old, worn-out, weather-beaten cable, or the ordinary flat ribbon kind designed for black and white VHF, causes more fuzzy, distorted pictures than you can count. It's your opportunity to upgrade these customers to a cable matched to their particular signal reception situations. One of Belden's Big Four—the link to perfect reception.

FOR CONGESTED AREAS...

8290 SHIELDED PERMOHM®

In congested, in-city areas, stray electrical interference and noise are at their worst. For perfect, all-82 channel reception—color or B/W—replace old cable with Belden's 8290 Shielded Permohm. Its aluminum Beldfoil® shielding prevents pickup of ghost signals and electrical noise by the lead-in. Weather-proof and water-proof. You can tape it right to the mast. Or install it underground, in conduits—even in rain gutters.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100'		Standard Package Lengths in ft.
					mc	db	
22 (7 x 30)	Brown	.305 x .515	69.8%	7.8	57 85 177 213 473 671 887	1.7 2.1 3.2 3.5 5.4 6.6 7.7	50', 75', 100' coils have terminals attached. Available in counter dispenser. 250', 500' spool.
Copperweld, 2 conductors, orange polyethylene insulation and web between conductors, cellular polyethylene oval insulation, Beldfoil shield, stranded tinned drain wire, polyethylene jacket.							

FOR FRINGE AREAS...

8285 PERMOHM®

Antenna cable in uncongested or fringe areas picks up little electrical interference. But does get a lot of weathering, which degrades an already weak signal. These customers need encapsulated cable. Belden 8285 Permohm. Its special polyethylene jacket protects the energy field, regardless of weather conditions. It delivers the strongest signal of any unshielded twin lead under adverse conditions. Requires no matching transformers and connectors. For all 82 channels, color or B/W.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100' mc	db	Standard Package Lengths in ft.
22 (7 x 30)	Brown	.255 x .468	73.3%	5.3	100 300 500 700 900	1.4, 2.8 3.8 4.8 5.6	50', 75', 100' coils have terminals attached. Available in counter dispenser. 250', 500' coils and 1000' spool.

Copperweld, 2 conductors parallel, orange polyethylene insulation and web between conductors, cellular polyethylene oval jacket.

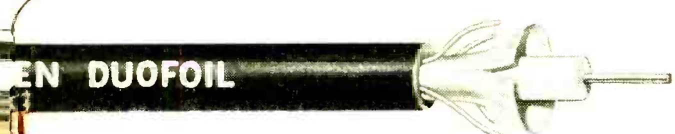
FOR LOCAL BLACK AND WHITE...

8275 CELLULINE®

Cracked, corroded, weathered cable, full of dirt and moisture, loses signal strength; prevents any TV set from delivering a quality picture. Upgrade B/W VHF and local UHF customers to Belden 8275 Celluline. Performance is improved because all possible moisture between conductors has been eliminated. Abrasion-resistant and weather-resistant for a long, long service life. And, it requires no end sealing.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100' mc	db	Standard Package Lengths in ft.
20 (7 x 28)	Brown	.300 x .400	80%	4.6	100 200 300 400 500 700 900	1.05 1.64 2.12 2.5 2.98 3.62 4.3	50', 75', 100' coils in counter dispenser. 250', 500', 1000' spools.

Bare copperweld; 2 conductors parallel, polyethylene jacket with inert gas filled unicellular polyethylene core.



FOR MATV AND CATV...

8228 DUOFOIL® COAX

Got an apartment or townhouse complex in your area? Motels or hotels? Or is CATV coming? Use Belden's new 75 ohm coaxial cable—8228 Duofoil. Shielding is 100%—sweep tested 100%. Spiral wrapped drain wires provide long flex life. Small diameter saves space in conduit installations. Use Duofoil for all coaxial color and B/W VHF, UHF and CATV applications.

AWG & (Stranding)	Color	Nom. O. D. (inch)	Nom. Velocity of Propagation	Nom. Capacitance (mmf/ft.)	Nom. Attenuation per 100' mc	db	Standard Package Lengths in ft.
18 Solid, Bare	Black	.242	78%	17.3	50 100 200 300 400 500 600 700 800 900	1.5 2.1 3.1 3.8 4.5 5.0 5.5 6.0 6.5 6.9	100', 500', 1000' spools.

Don't forget to ask them what else needs fixing.

See your local Belden distributor for full details or to order. For a free copy of the recent reprint article, "Electronic Cable," write: Belden Corporation, P.O. Box 5070-A, Chicago, Illinois 60680.

BELDEN

8-6-8A

CIRCLE NO. 145 ON READER SERVICE CARD

The sensibly priced tape cassette ...from MALLORY.

Just what you've been waiting for. The new Mallory DURATAPE® Cassette.

You get the quality and performance of expensive tape cassettes at a nice, lots-less price. But not the poor performance or the problems of the special-discount cheapies.

And since they're from Mallory — a company long known for quality electronic products—you can expect high fidelity, smooth operation, and long reliability. And get it . . . every time!

They'll fit any cassette recorder, player, cassette-radio. Even the new cassette changers. And you pick the recording time: 30, 60, 90, 120 minutes.

Our DURATAPE® Cassettes are tough but we put them in unbreakable, easy-to-stack containers just for extra protection. Like in the rain or through the mail.

And we make a head cleaner that's perfect for Cassette Recorders, too.

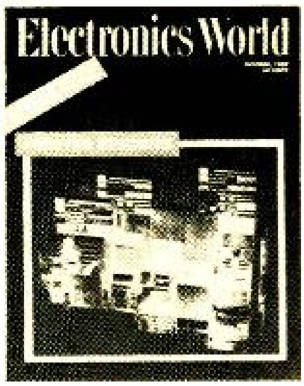
You'll find this great new thing in sound wherever Mallory products are sold.

MALLORY

MALLORY DISTRIBUTOR PRODUCTS COMPANY
a division of P. R. MALLORY & CO. INC.
Box 1558, Indianapolis, Indiana 46206; Telephone: 317-636-5353

Batteries • Capacitors Cassette Tapes Controls • Resistors • Semiconductors • Sonalert® • Switches • Timers • Vibrators • ICs

CIRCLE NO. 121 ON READER SERVICE CARD



THIS MONTH'S COVER shows a grouping of printed-circuit cards that are used as internal circuitry in IBM System/360 computers. The cards have been colorfully lighted in order to produce a rather striking photograph. The cover ties in with this month's Special Section on "Printed Circuits," which consists of eight feature stories dealing with all the important aspects of this interesting topic. The photograph was taken by Charles W. Kelley, Jr., staff photographer, IBM, Endicott, N.Y.

Electronics World

OCTOBER 1969 VOL. 82, No. 4

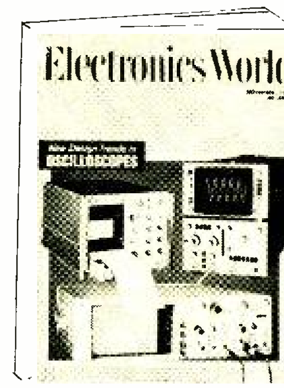
CONTENTS

MONTHLY FEATURES

Publisher
PHILLIP T. HEFFERNAN
Editor
WM. A. STOCKLIN
Technical Editor
MILTON S. SNITZER
Associate Editors
P. B. HOEFER
MURRAY SUNTAG
Contributing Editors
WALTER H. BUCHSBAUM
Prof. ARTHUR H. SEIDMAN
FOREST H. BELT
Art Editor
RICHARD MOSS
Technical Illustrator
J. A. GOLANEK
Advertising Manager
JOSEPH E. HALLORAN
Advertising Service Manager
ARDYS C. MORAN
Associate Publisher
LARRY SPORN

Electronics World: Published monthly by Ziff-Davis Publishing Company at 307 North Michigan Ave., Chicago Illinois 60601. One year subscription $6.00. Second Class Postage paid at Chicago, Illinois and at additional mailing offices. Subscription service and Forms 3579: Portland Place, Boulder, Colorado 80302.

COMING NEXT MONTH



SPECIAL FEATURE ARTICLE:

OSCILLOSCOPES

Like Paris fashions, there are new design trends in oscilloscopes—from those used in service shops to the most sophisticated types used in research and development work. To keep abreast of these changes, don't miss Tektronix James W. Griffin's lead story on New Design Trends in Oscilloscopes. He and his colleagues from Hewlett-Packard, Heath, Honeywell, and Telonics cover the new units in depth.

THE ELECTRONICS OF CORROSION

The role played by electronics in causing and/or minimizing corrosion—especially as related to marine environments—is covered by Dr. William P. Ferren of Wagner College.

MICROSTRIPLINE PARAMETERS

Having advantages of small size and light weight compared to microwave "plumbing," the microstripline technique is used in airborne microwave and radar systems in conjunction with hybrid microelectronics. Leon Sales of Lockheed tells you all about it.

VIDEO TAPE RECORDER DIRECTORY

An up-to-the-minute listing of all the currently available, low-cost VTR's suitable for home and/or industrial applications.

CLOSED-BOX SPEAKER SYSTEMS

So many readers have expressed interest in building their own acoustic-suspension speaker systems that Hugh Morgan of University Sound has come up with the details. Practical information on cabinet structure and proportions are included, along with theoretical considerations.

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

ZIFF-DAVIS PUBLISHING COMPANY

William Ziff
President

W. Bradford Briggs
Executive Vice President

Hershel B. Sarbin
Senior Vice President

Philip Sine
Financial Vice President

Walter S. Mills, Jr.
Vice President, Circulation

Stanley R. Greenfield
Vice President, Marketing

Phillip T. Heffernan
Vice President, Electronics Division

Frank Pomerantz
Vice President, Creative Services

Arthur W. Butzow
Vice President, Production

Edward D. Muhlfeld
Vice President, Aviation Division

Irwin Robinson
Vice President, Travel Division

Furman Hebb
Administrative Vice President

George Morrissey
Vice President

Sydney H. Rogers
Vice President

Editorial and Executive Offices
One Park Avenue
New York, New York 10016 212 679-7200

NEW YORK OFFICE 212 679-7200
Joseph E. Halloran

MIDWESTERN OFFICE
307 North Michigan Avenue
Chicago, Illinois 60601 312 726-0892
Midwestern Advertising Manager, Robert J. Ur

WESTERN OFFICE
9025 Wilshire Boulevard
Beverly Hills, California 90211
213 CRestview 4-0265; BRadshaw 2-1161
Western Advertising Manager, Bud Dean

JAPAN: James Yagi, Ishikawa Mansion,
#4, Sakuragaoka Shibuya-ku, Tokyo 462-2911-3

CIRCULATION OFFICE
Portland Place, Boulder, Colorado 80302

Member Audit Bureau of Circulations

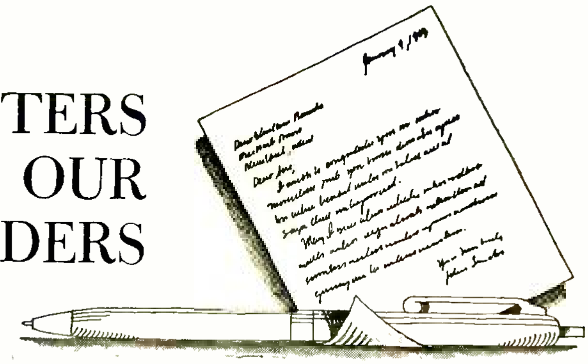
Radio & TV News • Radio News • Radio-Electronic Engineering Trademarks Reg. U.S. Pat. Off.

SUBSCRIPTION SERVICE; Forms 3579 and all subscription correspondence should be addressed to Electronics World, Circulation Department, Portland Place, Boulder, Colorado 80302. Please allow at least six weeks for change of address. Include your old address, as well as new—enclosing if possible an address label from a recent issue.

EDITORIAL CONTRIBUTIONS must be accompanied by return postage and will be handled with reasonable care: however publisher assumes no responsibility for return or safety of art work, photographs, or manuscripts.

ELECTRONICS WORLD (October, 1969, Vol. 82, No. 4). Published monthly at 307 North Michigan Avenue, Chicago, Illinois 60601, by Ziff-Davis Publishing Company—also the publishers of Airline Management and Marketing, Boating, Business & Commercial Aviation, Car and Driver, Cycle, Flying, Modern Bride, Popular Electronics, Popular Photography, Skiing, Skiing Area News, Skiing Trade News, Stereo Review, and Travel Weekly. One year subscription rate for U.S., U.S. Possessions, and Canada, $6.00; all other countries, $7.00. Second Class postage paid at Chicago, Illinois and at additional mailing offices. Authorized as second class mail by the Post Office Department, Ottawa, Canada and for payment of postage in cash.

LETTERS FROM OUR READERS



RECEIVERS FOR CATV

To the Editors:

I thoroughly enjoy Mr. Frye's articles and ordinarily have no reason to doubt the accuracy of his conclusions. In the June issue, however, he strays a little far afield, and I hasten to point out statements entirely accurate in theory but wrong in application.

CATV receivers are simply the last active device in a series. The average receiver on a CATV system is perhaps twenty amplifiers "deep" and, since noise increases 3 dB with each doubling of amplifiers, faces a totally different situation than an antenna-fed receiver.

Practically, we find color receivers demanding levels of +6 to +10 dB for truly "quiet" pictures. As a result, Mr. Frye's statement that noise figure is unimportant on a CATV system is highly misleading. If anything, the CATV receiver requires an improved noise figure.

Again, with a.g.c., solid-state tuners are highly sensitive to overload. CATV systems have been laid out for minimum levels of 1000 μV or "0 dB" but are now being upgraded to minimums of +6 dB for better color. Maximums may easily run +20 dB or 10,000 μV in order to attain these minimums. Without a.g.c. operative over a 30-dB range, Mr. Frye's design would be in serious trouble. "Fully loaded" systems of 12 adjacent channels would cross-modulate badly at about +10 dB or 3000 μV and would be down in the "snow" at −3 dB or 700 μV.

As for sync, it is entirely untrue that sync is unaffected by the amplifiers. The fact is that some "clipping" or "compression" occurs through every active device and CATV receivers must have superior sync stabilizing circuitry.

PHILIP D. HAMLIN, PRES.
Hamlin International Corp.
Seattle, Wash.

Reader Hamlin heads a company that makes special CATV receivers mainly for the Canadian market.—Editors

* * *

OLDEST SERVICE ASSOCIATION

To the Editors:

I take great issue with your paragraph on the "Country's Oldest Service Association" in July's "Radio & Television News" column.

I was secretary and vice president of the oldest radio amateur association, the Delaware Valley Radio Association (Trenton, N. J.), for quite a number of years. This association started in 1930 and shortly thereafter the Radio Servicemen's Association (also of Trenton) joined the amateur society—then broke away in 1935 because of the friction between the professionals and the amateur societies (although about half of the servicemen then were radio amateurs).

JOSEPH T. BECK
Beck Radio
Tampa, Fla.

Our column indicated that Associated Radio-Television Service Dealers (ARTSD) of Columbus, Ohio, founded in 1944, was the forerunner of today's service associations. Perhaps our heading should have said "one of the oldest and still in existence."—Editors

* * *

ATOMIC RADIATION

To the Editors:

Many thanks for your series on atomic radiation. There is precious little literature being published on this subject in technical magazines.

Please note the photomultiplier circuit shown on p. 47 in the June issue. This circuit apparently has two errors: (1) The voltage divider network is not grounded. (2) The high voltage seems to be applied incorrectly. According to the way it is shown, the anode will be at the same or lower potential than the final dynode. In either case, the anode will be ineffective in multiplying and collecting current.

WILLIAM C. PATES
Metairie, La.

The schematic diagram shown was only a partial one which is why the ground was omitted. However, it would have been better to show a ground connection. Reader Pates is quite correct in that the point of highest voltage should have been at the anode, rather than at the final dynode.—Editors

* * *

PRE-TRANSISTOR TRANSISTOR

To the Editors:

After many months of searching, I can quiet the nagging in the back of my mind. I have located the reference I needed to comment upon the article "Transistor's 20th Anniversary" which appeared in one of your past issues.

United States Patent No. 1,745,175 titled "Method and Apparatus for Controlling Electric Current" was issued January 28, 1930 to Julius Edgar Lilienfeld of Brooklyn, New York, application for which was filed October 8, 1926. A previous application had been made in Canada on October 22, 1925.

The drawing of the device is remarkable in its similarity to that used in basic texts to explain the operation of an *n-p-n* junction transistor. Included in the application was what would appear to be a four-transistor radio receiver. I wonder what the state-of-the-art might be today if the twenty years for development of this device had not been lost in the shuffle.

ROBERT J. MOHRMANN
Buzzards Bay, Mass.

* * *

TAPE-RECORDER CROSSTALK

To the Editors:

Recently I adjusted the azimuth setting on the record, playback head in my half-track tape recorder. Since then, I note that a recording made on one track comes through on the other track of the tape.

RAYMOND BOYLE
Smithtown, N. Y.

You may have adjusted your azimuth okay but you also probably slightly lowered the record, playback head at the same time. As a result, the fringing magnetic field is spilling over from one track to the other. Try raising the head slightly, using the adjustment screws, without changing the azimuth setting. The height should be such that the top of the head's pole pieces are just a couple of hairs (about 6 mils) below the top tape edge—Editors

* * *

BRITAIN AND THE CONCORDE

To the Editors:

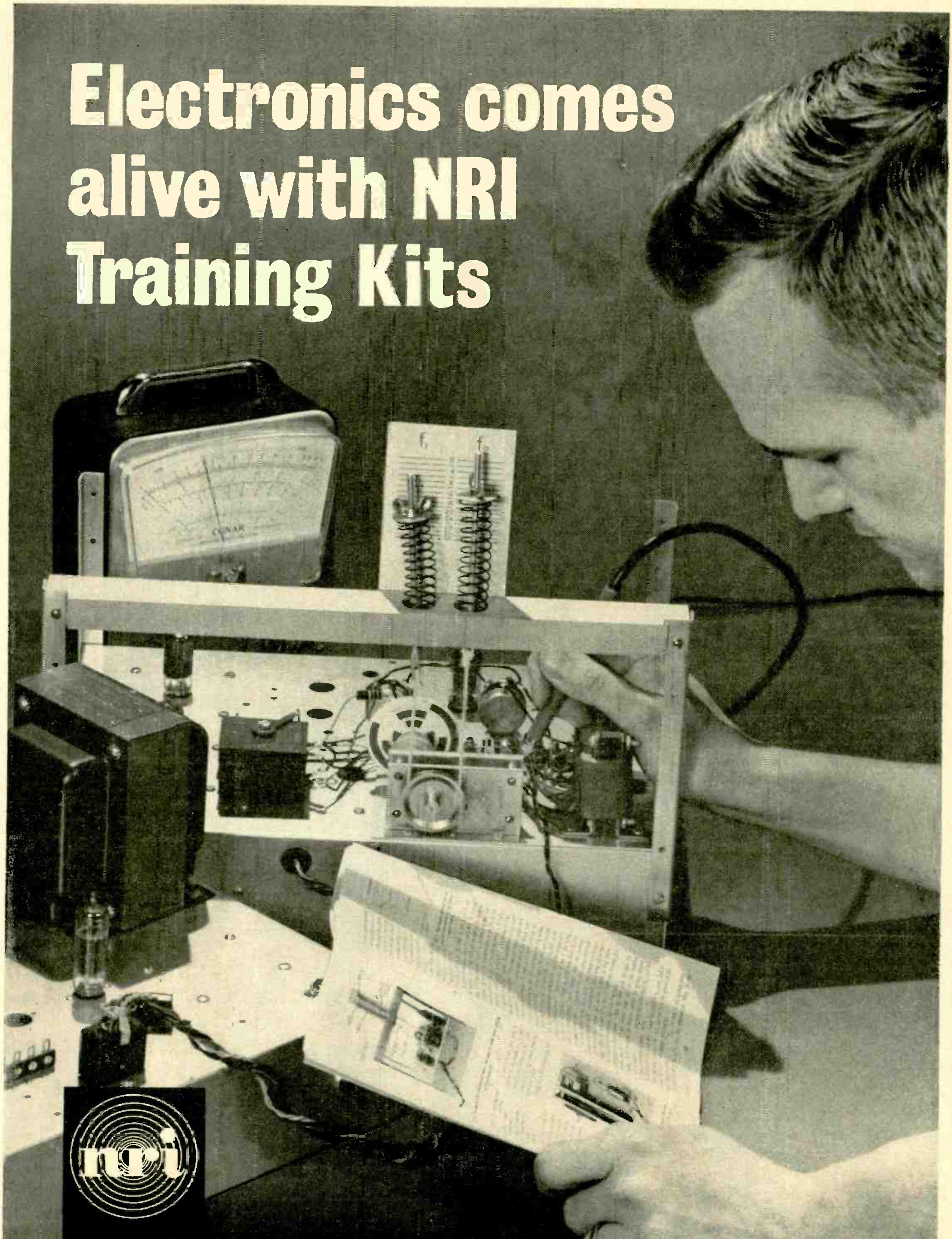
The first item in your "Reflections on the News" column for July appears to contain an error on line 10 regarding Britain's withdrawal from the Concorde supersonic-transport program. To the best of our knowledge, Great Britain did not withdraw from the Concorde program but from the A300 airbus program (*Hawker Siddeley Aviation*). The A300 will be a standard high-density type airbus (not SST) which continues to be developed by *Sud Aviation* and the *German Airbus Company*.

ADRIAN M. ZEFFERT, Supervisor
General Aviation Sales
Bendix International
New York, N. Y.

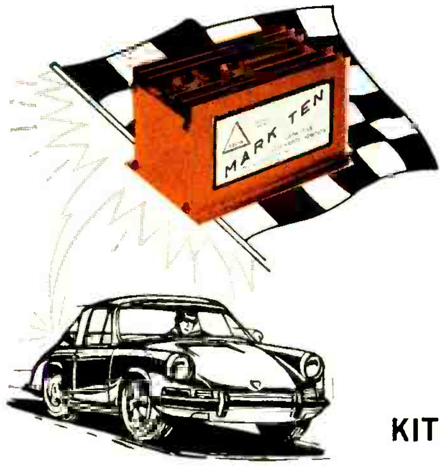
* * *

SENCORE SM152 PRICE

We have been informed by the manufacturer that the price of the Sencore *Model SM152 sweep/marker generator is now $395 rather than $349.50 as given in our August Test Equipment Product Report.—Editors*


Electronics comes alive with NRI Training Kits
nri

DELTA will tell you *everything!*—Complete Specs including schematics!



MARK TEN® SCR

CAPACITIVE DISCHARGE IGNITION SYSTEM

Now discover for yourself the dramatic improvement in performance of your car, camper, jeep, truck, boat—**any** vehicle! Delta's remarkable electronic achievement saves on gas, promotes better acceleration, gives **your** car that zip you've always wanted. Find out why even Detroit has finally come around. In five years of proven reliability, Delta's Mark Ten has set new records of ignition benefits. **No re-wiring!** Works on literally any type of gasoline engine.

- ▲ Dramatic Increase in Performance and in Fast Acceleration
- ▲ Promotes More Complete Combustion
- ▲ Points and Plugs Last 3 to 10 Times Longer
- ▲ Up to 20% Mileage Increase (saves gas)

KIT FORM $29.95 12V ONLY **ASSEMBLED ONLY $44.95** ppd.

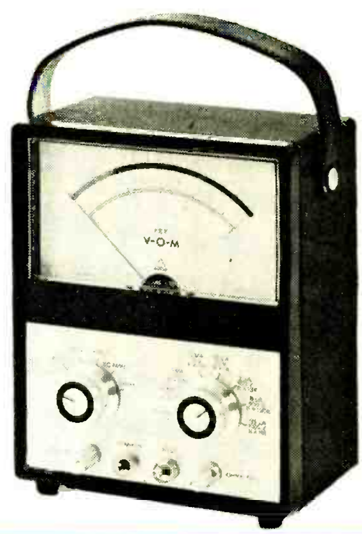
MODEL 3000 FET VOM

ONLY $74.95 ppd.

Delta now offers a compact, versatile, and extremely sensitive VOM which combines FETs and ICs for **extreme accuracy.** Compact (6½"W x 8"H x 3½"D), portable. Wt. 3¾ lbs.

IN KIT FORM: Feedback network with pre-selected components to eliminate all final calibration. **Ready to use when assembled!**

Only $59.95 ppd.



NEW DELTA FEATURES:

- ▲ Mirror scale 200 A D'Arsonval meter
- ▲ Integrated circuit (IC) operational amplifier for extreme accuracy
- ▲ FET input stage with current regulator
- ▲ Two stage transistor current regulator and Zener diode on OHMS for absolute stability and accuracy
- ▲ Voltage clippers for protection of input stage
- ▲ Fully temperature compensated for low low zero drift
- ▲ Ten turns ZERO and OHMS adjust potentiometers
- ▲ Epoxy glass circuit boards and metal case
- ▲ Enclosed switches
- ▲ Uses readily available type AA cells
- ▲ Uses standard test leads for maximum flexibility and ease of measurement
- ▲ 10 Megohms input impedance

DELTA COMPUTACH®

Delta, pioneers in CD ignition who produced the fabulous MARK TEN®, now offer a precise computer-tachometer which obsoletes any type tachometer on the market today! You achieve unbelievable accuracy in RPM readings due to the advanced, solid-state electronic matched components used in the computer, coupled with the finest precision meter in the world. Works on all 2, 3, 4, and 6 cylinder 2 cycle and with 4-6-8 cylinder—4 cycle 12 volt engines.

- ▲ 0-8000 RPM range
- ▲ Perfect linearity — zero paralax
- ▲ Adjustable set pointer
- ▲ Wide angle needle sweep
- ▲ Translucent illuminated dial
- ▲ Chrome plated die-cast housing
- ▲ All-angle ball & socket mounting
- ▲ Use it with ANY ignition system
- ▲ Meter: 3⅛" dia. X 3⅜" deep
- ▲ Calibration kit included, no test eqpt. needed.

*An exclusive computer-tachometer for precise RPM measurement in easy-to-build Kit form! **$29.95** ppd.

KIT FORM ONLY

Write today for complete literature packet

DELTA: Please send me literature immediately.
I am enclosing $________ for items checked.
☐ Mark Ten SCR (☐ Kit ☐ Assembled)
☐ Model 3000 FET VOM (☐ Kit ☐ Assembled)
☐ Computach (Kit only)
Please ship immediately.
Name________
Address________
City/State________ Zip____
*My car is (Model)________ (Year)____
EW

DP 9-8

DELTA PRODUCTS, INC.

P.O. BOX 1147 • GRAND JUNCTION, COLORADO 81501

CIRCLE NO. 138 ON READER SERVICE CARD

Radio & Television news

By FOREST H. BELT /Contributing Editor

Rewards of Apollo

Costly though the Apollo 11 trip and moonwalk were—upwards of $22 billion—home-entertainment electronics benefits indirectly. A heavy technological overflow has bred improvements for earthbound gear.

Ideas that went into a low-light camera for space will improve live-coverage news cameras. Such a camera is needed, too, for CCTV, ETV, and industrial use. S-band communications gear, proven so dependable over 240,000-mile distances, adapts easily to satellite television relay, or even satellite-to-home TV. Field-sequential color transmission, used to send live color from the spacecraft enroute to and from the moon, may turn out to be "the" way to send color television over long distances here on earth, too; converters at each end turn it back into NTSC color to suit U.S. receivers.

The Apollo program may speed up other home-electronic developments. Success with on-board computers in spacecraft contributes directly to the day when home computers take over hundreds of chores —from feeding the cat to reminding you of appointments—from grocery shopping to watering the lawn —from storing recipes to doing the mixing and cooking—from answering the phone while you're out to keeping the kids off it while you're home. All that—and maybe keep your checkbook balanced, too, or at least tell you when you're overdrawn.

You may notice some effect on regular TV programs, too. Network feed for the moonwalk was handled by *ABC*. (The assignment is rotated among the networks.) More than 500 million viewers watched around the world. The deployment of men and equipment surely adds to the ability of networks to handle more smoothly the day-to-day entertainment programming we earthlings have come to take so much for granted. If nothing else, maybe Apollo will give us more dependable TV at home.

Color Movement Continues

Color television has done well this year, despite ups and downs. Since color took off several years ago, sales performance has been all but phenomenal. However its growth began slowing a couple years ago. A few pessimists thought 1969 might see color sales drop off to just a steady year-after-year market.

They guessed wrong. Only one home-entertainment item outclasses color-TV in market growth this year and that is cassette machines. Color sales keep climbing, although not as fast as in prior years. The market is still a battle of the giants. *RCA* leads, with *Zenith* overtaking. *Magnavox* and *Motorola* follow.

Not long ago, a *Zenith* officer predicted his firm would soon take over the lead in color. Interestingly, at about the same time, an *RCA* executive predicted a takeover by his company of the lead in black-and-white TV sales from leader *Zenith*. Thus battle lines at the top are drawn.

Eyeing both segments of the TV market are our overseas friends, the Japanese. Imports of their small-screen receivers, particularly color, have nearly tripled in the last few months. They already have a healthy (for them) chunk of the monochrome portable market. They're introducing a rash of new solid-state small-screen color sets at home, in the 10-inch to 15-inch class. If those find their way over here, they could carve out a 30 or 40 percent niche almost before you know it. Of the 7-million-or-so color sets to be sold in the U.S. next year, don't be surprised if 2 million or more are Japanese.

Search for Cheap Labor

High wages have driven U.S. manufacturers out of the country in a search for less costly ways to build electronic gear. But the gains seem only temporary. The situation in Japan is probably best known. Bargain-priced electronic items don't exist any more. That country has had to face a continuously increasing wage-price spiral. Today, the Japanese find it hard to compete on price.

However, U.S. set-makers never got even a toehold in Japan; the government there has been too restrictive. But they did find cheap labor havens in Taiwan, Hong Kong, even Korea. Within the past year or so, several have put plants in Mexico, too.

But prosperity begets new attitudes among the natives. Hardly have plants been opened and a few dollars injected into the economies of these low-income countries than labor costs start going up. It has gotten so that many formerly attractive spots—particularly Asian areas—have lost their glamor. New localities are taking over, though, so no lasting lesson has been learned. Overseas-oriented U.S. manufacturers are now moving into Singapore, India, and Indonesia. No doubt a lot of dollars will be saved (?) before the inevitable spiral begins in those countries. But it must surely look opportunistic to the rest of the world.

Stereo TV Sound in Japan

Long expected (this column, March 1969) two-channel TV sound started being tested in Japan in August. If tests prove no interference to ordinary TV, regular broadcasting will begin shortly. The original reason for this service was to allow simultaneous English and Japanese sound with telecasts during the Expo 70 World's Fair next year, in Osaka. That still goes, but now concerts will also be broadcast in stereo on the two channels. Moreover, after the Fair is over, if the transmissions have been successful, the system will be continued on a permanent basis in Osaka and Tokyo. It operates on a temporary permit during the Fair.

The second channel is frequency-modulated on a 31.5-kHz subcarrier; 100-percent modulation of the subcarrier is ±10 kHz. The subcarrier deviates the main sound carrier ±15 kHz. Main sound channel deviation is ±25 kHz. A 51.125-kHz pilot signal actuates the converter that must be added to a standard receiver to pick up both channels of sound.

X-Rays Still Simmering

Just when the aggravating issue of color-TV x-rays seemed on the wane, it pops up again as strong as ever. Latest important go-around is with *Underwriters' Laboratories*. They decided to insist that new color sets coming off production lines meet the tough rule of no more than 0.1 mR/hr of x-radiation. This tight limitation was to be expected (this column, September 1969), but not so soon.

The government hasn't made public its own recommendations yet, and a lot of people—especially set makers—think *UL* is jumping the gun. Last we heard before press time, *UL* is thinking of relenting and allowing more time for compliance. That seems the logical thing to do, but the entire ploy seems strangely conceived and oddly timed. Mid-1970 is a more reasonable deadline, or at least after the Bureau of Radiological Health has had time to set standards and stipulate conditions of measurement.

Stereo Cassette Releases Grow

Sure enough, the cassette market is turning into a full-fledged boom. The equipment is selling like hotcakes and the big record companies are hurrying albums and hits into the new format. For example, at one swoop recently, *RCA Victor* introduced 40 new cassette titles and *Columbia Records* brought out 58. Perhaps surprisingly, many of the new releases are classical—which is usually reserved for really "high" fidelity stereo equipment (few cassette machines qualify).

The cassette, before it started booming, looked as if it would be a low-cost medium, suited mostly to young people. With new stereo cassette releases selling at $6.95, $6.98, and $7.95, it isn't really what you'd call a kids' market. The cassette isn't moving into the auto field with any speed, either; 8-track still dominates there. But for portable music, the cassette is winning the race hands down.

Cassette machines aren't all cheap, either—nor simple, as they were at first. As an example, *H. H. Scott* now has the Model 3610 Casseiver. It has a synchronous motor, twin vu meters for recording, sound-on-sound capability, and of course a receiver. The price: $399.95. Not many youngsters will get one of those for rock 'n' roll.

Furniture Look in Hi-Fi

The hi-fi gear that will dominate the 1969-70 season is the compact, followed by components. Yet a couple of companies that specialize in hi-fi have come out with big consoles. One well-remembered name is *Capehart*, known in years past for quality in "furniture" hi-fi. *Electrophonic* is also shooting for big-ticket sales with imported gear that's assembled in the U.S. (cabinets are from Yugoslavia).

We still hear complaints from housewives about hi-fi. The usual one is: "Why can't component hi-fi be made more esthetically attractive?" Not nearly enough manufacturers are doing anything about it, and from conversations we hear among consumers, none has found a real answer yet.

Flashes in the Big Picture

Sales trends suggest that digital clock radios may outsell regular kind within another year or two . . . *Setchell Carlson*, first manufacturer to use modular construction for home TV, quits that business upon being sold to *Audiotronics Corp.*; may continue CCTV. . . . Beginning to appear around country are "Cartridge City" stores owned by *Muntz Stereo-Pak*; saw one in Nashville—very flashy; half-dozen open so far. ▲

Radar Sentry Alarm announces a new powerful way to stop crime . . . "Dialtronic"

Radar Sentry Alarm announces a new powerful way to fight crime. Imagine a security system that automatically and silently delivers any emergency message for which it is programmed. Dialtronic adds a new dimension to your security needs. Advanced concepts in technology and design bring you a new level of security. Providing unlimited application, the Dialtronic uses solid state circuitry to bring help immediately. Use it with existing alarm systems or any other sensing device. Dialtronic is the ideal personal protection for anyone who is vulnerable to intruders. Dialtronic will perform with never a lapse in security . . . You are assured of highly reliable protection.

Also used to protect premises while they are being occupied, the Radar Dialtronic gives push button protection to businesses and home owners alike. This system is triggered by a hidden push button or portable transmitter. Once set into action, it automatically dials the phone—delivering any prerecorded message for which it is programmed without the would-be-thiefs' knowledge. In effect, the Dialtronic gives you a direct line to police, fire departments, in-plant security, key personnel . . . whoever you designate.

Dialtronic's built-in programmer lets you magnetically store "error free" messages on cassette type tape cartridges. Stored information is instantly available to notify proper officials, delivering correct message in each case.

Advantages of Dialtronic Telephone Communicator

- Eliminates costly leased telephone lines.
- Simultaneously stores up to ten separate messages on magnetic tape.
- Automatically dials the right people and delivers the correct message in each case.
- Battery operated (optional) Rechargeable "Nic/Cad" batteries with built-in charger.
- Converts existing local alarm to central station system. Easily and quickly installed.
- Silent "on premises hold up alarm with the ability to get the facts out" instantly.
- Can be used with optional wireless control.
- Home prowler alarm, fire alarm, emergency alarm for invalids. Can be programmed for any emergency.

The Crimebusters Want You! . . . Now!

. . . To make the biggest profits of your career—filling ready-made demand for the dramatic new RADAR SENTRY ALARM systems. Get started NOW as dealer or distributor—step into five-figure income at once, with unlimited potential and wide-open opportunity to grow as you go! MAIL COUPON AT ONCE!

RADAR DEVICES MFG. CORP. EW-109
22003 Harper Avenue
St. Clair Shores, Michigan 48080

☐ Send me the alarming details.

☐ Also send me booklet outlining available dealerships.

Name ....

Address ....

City .... State .... Zip ....

Go on a quality kick

You can afford it with these Outperformers

You give up nothing — except a high price — when you buy these quality performance Pioneer hi-fi units. Designed for the discriminating budget-minded buyer, they contain advanced engineering features and looks that put them in the class of much more expensive stereo components.

SA-500 INTEGRATED STEREO AMPLIFIER — The perfect starter unit for a stereo system, the all solid state SA-500 produces 44 watts of music power. Even at the highest crescendo, distortion is less than 0.5%. Two sets of inputs plus outputs for speakers, tape recording, loudness contour and a headset jack make it tops in versatility. $99.95

TX-500 AM-FM TUNER — All solid state, its multiplex circuitry provides wide channel separation with excellent frequency response. An FET front end, combined with years-ahead design, assures high sensitivity and superb image rejection. Containing advanced features that place it on a par with more expensive units, it is priced at $99.95.

SR-202 REVERBERATION AMPLIFIER — The most dramatic new component in years! No matter what your system is, the SR-202 adds dimension and greater realism to your stereo sound than you can realize. The SR-202 increases the natural quality of your recordings and tapes. Reverberation can be added to an audio amplifier using one or two tape recorders, a record player, or a tuner. In fact, a total of 15 equipment combinations are possible. $95.00

These three Pioneer Outperformers are each housed in a handsome cabinet with brushed chrome facing and Brazilian rosewood end pieces. Hear them in action at your local Pioneer dealer.

PIONEER®

PIONEER ELECTRONICS U.S.A. CORPORATION, 140 Smith Street, Farmingdale, N.Y. 11735 · (516) 694-7720
West Coast: 1335 W. 134th St., Gardena, Calif. 90249 (213) 323-2374 & 321-1076 · *Canada:* S. H. Parker Co., Prov. Ontario

MEMBER INSTITUTE OF HIGH FIDELITY INC.

CIRCLE NO. 117 ON READER SERVICE CARD

Reflections on the news

How High the Sky?

Earth's natural satellite, Moon, was exactly 226,970.9 miles away one evening recently. That's most accurate man has ever measured it. Feat was done at Lick Observatory in San Francisco, thanks to special laser reflector in Sea of Tranquility on lunar surface. It was put there by LM crew of Apollo 11. Scientists shot laser beam through big 18-inch telescope and timed return bounce within fraction of microsecond.

Mariners 6 and 7 A-OK

This is year for fabulous space exploits. Hardly was Apollo pronounced success than two little Mariner spacecraft, with their TV cameras and S-band communications gear, started sending back amazingly clear photographs of surface of Mars. Considering pictures traveled 60 million miles, they were miraculous. Show Martian surface topography similar to that of moon. They convinced scientists that sending man there is feasible. We'll land Surveyor-type package there in 1973.

System-Engineering Airways

More sophisticated approach to planning in store for Federal Aviation Administration. Secretary of Transportation Volpe sees systems approach as only way to ever catch up to mounting problem of airway and terminal congestion. Costly computers and ID/tracking gear are wasted unless *whole* concept is thought out—equipment integrated into comprehensive system. Future operations are complicated by diversity of interests: business and private flying; scheduled passenger service; freight flights; supersonic traffic (soon); military and defense traffic; all and more must be part of planning, *now*.

Electronics on Ice Route

Giant tanker Manhattan has highly advanced *Litton Industries* navigation complex to guide it through ice-covered "northwest passage" across oceans north of Canada. Will test feasibility of route from East Coast through Arctic ice to northern Alaska, to shorten shipping time. Ship has integrated position-finding and navigation setup, with impact/sideslip measurement. Includes Doppler sonar, radar, satellite receiver for Omega navigation, accelerometer, h.f. single-sideband communications, forward-, side-, and rear-looking CCTV, telemetered strain gages, digital computer.

Sonic Holography

Laser holography is established. *CBS Laboratories* has just about perfected sonic holography under water. Creates three-dimensional images by interferometry of sound-wave reflections in water. Result is comparable to underwater radar; works in muddy water or clear. Transducer initiates sonic waves, 20-200 kHz. Reflections are picked up by array of 500 or so hydrophones, each about 1-mm square, on sheet of barium titanate. Interference pattern makes display like hologram on special Lumatron tube developed by *CBS Labs.* Range about 100 yards with small array, can be extended to miles using large receptor and low frequency.

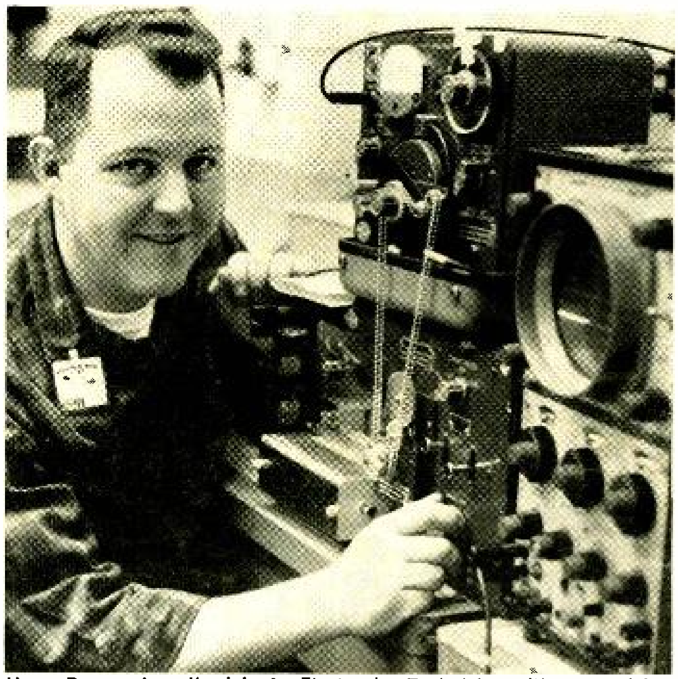
Worldwide Defense Communications

Five new electronic switching centers installed by *Automatic Electric* become part of AUTOVON (Automatic Voice Network) system of global communications. Will eventually link more than a million communicating devices, *via* submarine cable, microwave, tropospheric scatter, and satellites. Connects calls in less than 10 seconds anywhere in the world. Centers use computer-type switching and interfaces with existing equipment of all kinds.

In separate development, Government Accounting Office suggests integrating AUTOVON with other government communicating systems. Decision will be up to National Communications System, which may soon be made part of President's Office of Telecommunications Management. Without interweaving all networks says report on subject, we'll never have truly responsive National Communications System. ▲

One of our students wrote this ad!

Harry Remmert decided he needed more electronics training to get ahead. He carefully "shopped around" for the best training he could find. His detailed report on why he chose CIE and how it worked out makes a better "ad" than anything we could tell you. Here's his story, as he wrote it to us in his own words.



Harry Remmert on the job. An Electronics Technician with a promising future, he tells his own story on these pages.

By Harry Remmert

AFTER SEVEN YEARS in my present position, I was made painfully aware of the fact that I had gotten just about all the on-the-job training available. When I asked my supervisor for an increase in pay, he said, "In what way are you a more valuable employee now than when you received your last raise?" Fortunately, I did receive the raise that time, but I realized that my pay was approaching the maximum for a person with my limited training.

Education was the obvious answer, but I had enrolled in three different night school courses over the years and had not completed any of them. I'd be tired, or want to do something else on class night, and would miss so many classes that I'd fall behind, lose interest, and drop out.

The Advantages of Home Study

Therefore, it was easy to decide that home study was the answer for someone like me, who doesn't want to be tied down. With home study there is no schedule. I am the boss, and I set the pace. There is no cramming for exams because I decide when I am ready, and only then do I take the exam. I never miss a point in the lecture because it is right there in print for as many re-readings as I find necessary. If I feel tired, stay late at work, or just feel lazy, I can skip school for a night or two and never fall behind. The total absence of all pressure helps me to learn more than I'd be able to grasp if I were just cramming it in to meet an exam deadline schedule. For me, these points give home study courses an overwhelming advantage over scheduled classroom instruction.

Having decided on home study, why did I choose CIE? I had catalogs from six different schools offering home study courses. The CIE catalog arrived in less than one week (four days before I received any of the other catalogs). This indicated (correctly) that from CIE I could expect fast service on grades, questions, etc. I eliminated those schools which were slow in sending catalogs.

FCC License Warranty Important

The First Class FCC Warranty* was also an attractive point. I had seen "Q" and "A" manuals for the FCC exams,

*CIE backs its FCC License-preparation courses with this famous Warranty: graduates must be able to pass the applicable FCC License exam or their tuition will be refunded in full.

and the material had always seemed just a little beyond my grasp. Score another point for CIE.

Another thing is that CIE offered a complete package: FCC License and technical school diploma. Completion time was reasonably short, and I could attain something definite without dragging it out over an interminable number of years. Here I eliminated those schools which gave college credits instead of graduation diplomas. I work in the R and D department of a large company and it's been my observation that technical school graduates generally hold better positions than men with a few college credits. A college degree is one thing, but I'm 32 years old, and 10 or 15 years of part-time college just isn't for me. No, I wanted to *graduate* in a year or two, not just *start*.

If a school offers both resident and correspondence training, it's my feeling that the correspondence men are sort of on the outside of things. Because I wanted to be a full-fledged student instead of just a tagalong, CIE's exclusively home study program naturally attracted me.

Then, too, it's the men who know their theory who are moving ahead where I work. They can read schematics and understand circuit operation. I want to be a good theory man.

From the foregoing, you can see I did not select CIE in any haphazard fashion. I knew what I was looking for, and only CIE had all the things I wanted.

Two Pay Raises in Less Than a Year

Only eleven months after I enrolled with CIE, I passed the FCC exams for First Class Radiotelephone License with Radar Endorsement. I had a pay increase even before I got my license and *another* only ten months later. I'm getting to be known as a theory man around work, instead of one of the screwdriver mechanics.

These are the tangible results. But just as important are the things I've learned. I am smarter now than I had ever thought I would be. It feels good to know that I know what I know now. Schematics that used to confuse me completely are now easy for me to read and interpret. Yes, it is nice to be smarter, and that's probably the most satisfying result of my CIE experience.

Praise for Student Service

In closing, I'd like to get in a compliment for Mr. Chet Martin, who has faithfully seen to it that my supervisor knows I'm studying. I think Mr. Martin's monthly reports to my supervisor and generally flattering commentary have been in large part responsible for my pay increases. Mr. Martin has given me much more student service than "the contract calls for," and I certainly owe him a sincere debt of gratitude.

And finally, there is Mr. Tom Duffy, my instructor. I don't believe I've ever had the individual attention in any classroom that I've received from Mr. Duffy. He is clear, authoritative, and spared no time or effort to answer my every question. In Mr. Duffy, I've received everything I could have expected from a full-time private tutor.

I'm very, very satisfied with the whole CIE experience. Every penny I spent for my course was returned many times over, both in increased wages and in personal satisfaction.

Perhaps you too, like Harry Remmert, have realized that to get ahead in Electronics today, you need to know much more than the "screwdriver mechanics." They're limited to "thinking with their hands"...learning by taking things apart and putting them back together...soldering connections, testing circuits, and replacing components. Understandably, their pay is limited—and their future, too.

But for men like Harry Remmert, who have gotten the training they need in the fundamentals of Electronics, there are no such limitations. As "theory men," they think with their heads, not their hands. For trained technicians like this, the future is bright. Thousands of men are urgently needed in virtually every field of Electronics, from two-way mobile radio to computer testing and trouble-shooting. And with this demand, salaries have skyrocketed. Many technicians earn $8,000, $10,000, $12,000 or more a year.

Send for Complete Information—FREE

Many men who are advancing their Electronics career started by reading our famous book, "How To Succeed In Electronics." It tells of the many electronics careers open to men with the proper training. And it tells which courses of study best prepare you for the work you want.

If you're "shopping around" for the training you need to move up in Electronics, this 44-page book may have the answers you want. We'll send it to you FREE. With it, we'll also include our other helpful book, "How To Get A Commercial FCC License."

To get both FREE books, just fill out and mail the bound-in postpaid card. If the card is missing, send the coupon below.

ENROLL UNDER NEW G.I. BILL

All CIE courses are available under the new G.I. Bill. If you served on active duty since January 31, 1955, or are in service now, check box on reply card or coupon for G.I. Bill information.

CIE Cleveland Institute of Electronics

1776 East 17th Street, Cleveland, Ohio 44114

Accredited Member National Home Study Council • A Leader in Electronics Training... Since 1934

NEW COLLEGE-LEVEL COURSE IN ELECTRONICS ENGINEERING

for men with prior experience in Electronics. Covers steady-state and transient network theory, solid state physics and circuitry pulse techniques, computer logic and mathematics through calculus. A college-level course for men already working in Electronics.

Cleveland Institute of Electronics
1776 East 17th Street, Cleveland, Ohio 44114

Please send me without cost or obligation:

1. Your 44-page book "How To Succeed In Electronics" describing the job opportunities in Electronics today, and how your courses can prepare me for them.
2. Your book on "How To Get A Commercial FCC License."

I am especially interested in:

- ☐ Electronics Technology
- ☐ Electronic Communications
- ☐ Broadcast Engineering
- ☐ Industrial Electronics and Automation
- ☐ First-Class FCC License
- ☐ Electronics Engineering

Name_______________ (PLEASE PRINT)

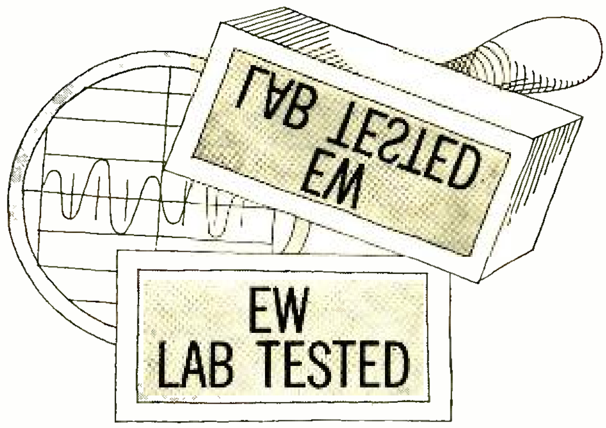
Address_______________

City_______________

State_______ Zip_______ Age_____

☐ Check here for G.I. Bill information. EW-66

CIRCLE NO. 142 ON READER SERVICE CARD



HI-FI PRODUCT REPORT

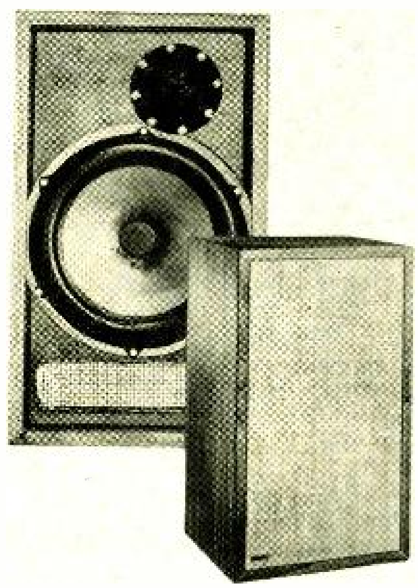
TESTED BY HIRSCH-HOUCK LABS

Dynaco A-25 Speaker System
Shure M92E/M93E Phono Cartridges

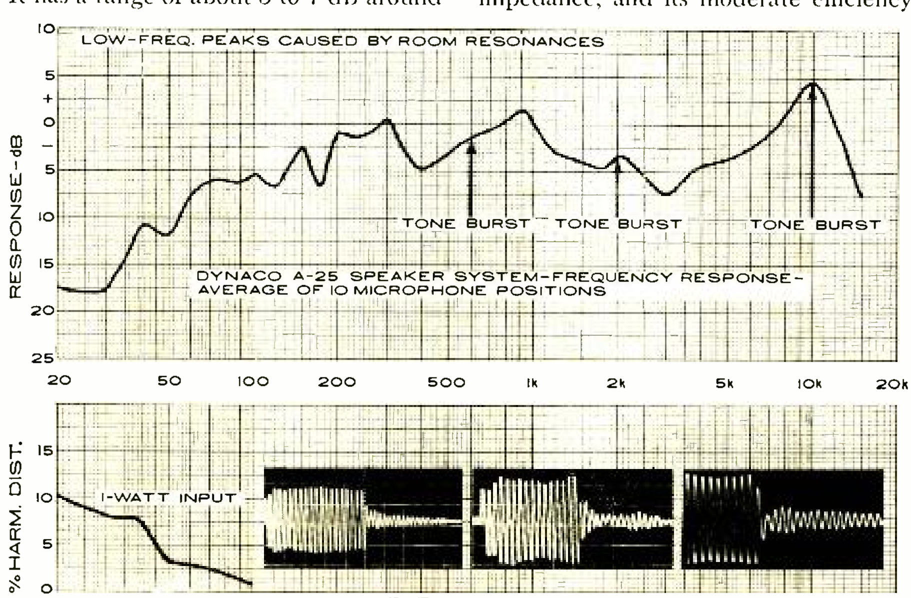
Dynaco A-25 Speaker System

For copy of manufacturer's brochure, circle No. 20 on Reader Service Card.

DYNACO has long been noted for its development of inexpensive components capable of the highest-quality performance. The designs are not changed annually (in fact, some of the decade-old vacuum-tube amplifiers are still sold, in addition to the more recent solid-state models). When a new product carries the *Dynaco* name, we expect it to be a worthwhile addition to the high-fidelity scene. The company's new A-25 speaker system, we are happy to note, lived up to our expectations. The system is referred to as an "aperiodic" design because it is said to be non-resonant.



The A-25 is a true bookshelf speaker in that it measures 20 inches by 11½ inches by 10 inches deep, and weighs about 18½ pounds. Its oiled-walnut cabinet has a slightly recessed back with reinforced keyhole slots to facilitate installation on a wall. Its 10-inch, long-throw woofer operates up to 1500 Hz, at which frequency there is a crossover to a small dome-type direct-radiator tweeter. A five-position switch in the rear permits the high-frequency response of the system to be adjusted to room acoustics. It has a range of about 5 to 7 dB around the "normal" response. The enclosure is ported, but the port is small and heavily damped, giving the system an acoustic characteristic closer to that of an acoustic-suspension system rather than a bass-reflex design. The A-25 has an 8-ohm impedance, and its moderate efficiency makes it suitable for use with practically any modern high-fidelity amplifier or receiver.



In our listening tests, the unit had a remarkably neutral quality. Many loudspeakers have response irregularities that color reproduction of male voices, for example, and leave no doubt in the listener's mind that he is listening to a loudspeaker. The A-25 had less of this coloration than most speakers we have heard, regardless of price. The highs were crisp, extended, and well dispersed. At times, we felt that the bass might be a trifle thin, but when the music contained low bass (under about 70 or 80 Hz), the speaker left no doubt of its capabilities. This led us to conclude that the "thinness" was really a smoothness or lack of accentuation of the mid-bass in the 100 to 300 Hz range.

Having established by listening that this was a very fine speaker system, we were curious to see the results of our laboratory measurements. They contained few surprises. Except for a small peak at 10,000 Hz, the response was within ±4 dB from 60 to 15,000 Hz. There was no obvious region of depressed or elevated response, and the over-all response curve was as flat and smooth as can be when measured in a "live" environment. Below 60 Hz, the output fell off at 12 dB per octave.

The tone-burst measurements also confirmed our listening tests. From 100 to 10,000 Hz, we did not find a single aberration in the transient response of the A-25. In the hundreds of tone-burst measurements we have made, we have found a few instances where a speaker was slightly better than this one at specific frequencies, but nothing we have tested had a better over-all transient response.

The low-frequency harmonic distortion was under 3 percent down to 50 Hz at a 1-watt drive level. It rose gradually to 10 percent at 20 Hz. This, too, is excellent performance, and is topped by only a few speakers among those we have tested.

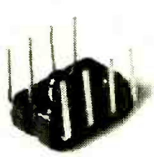
The *Dynaco* A-25 has slightly more midrange output than a number of top-

(*Continued on page 86*)

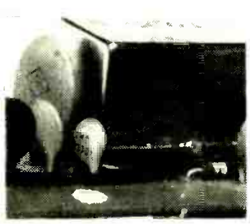
How man's conquest of the moon helped Scott develop the world's most advanced AM/FM Stereo Receiver

The billions of research dollars expended towards America's race to the moon helped foster the development of many entirely new electronic devices. Alert Scott engineers realized that the adaptation of some of these devices could result in significant advances in the performance of high fidelity components . . . a realization that inevitably led to the development of the 386 AM/FM stereo receiver.

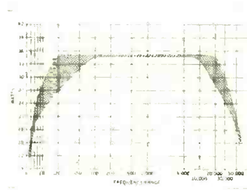
The 386 represents a level of sound quality and performance characteristics that is a giant-step ahead of any stereo component ever before available . . . utilizing entirely new features that help you control incoming signals with a degree of accuracy never before possible . . . incorporating new assembly techniques that guarantee superb performance over periods of time previously thought unattainable.



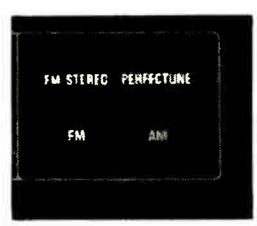
There are 7 ultra-reliable Integrated Circuits in the 386 . . . more than in any other receiver now on the market. These 7 circuits include a total of 91 transistors, 28 diodes, and 109 resistors!



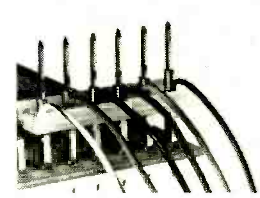
Quartz crystal lattice filter IF section, never before found in a receiver in this price class, ends the need of IF amplifier realignment, and gives very low distortion and high selectivity.



Higher power at lower distortion: The shaded area indicates where competitive receivers tend to rob you of full response in the extreme lows (organ, bass drum) and highs (flutes, triangles, etc.)



Perfectune, a computer logic module, decides when you've reached the point of perfect tuning *and* lowest distortion, then snaps on the "Perfectune" signal light.



Wire-wrap terminal connections and plug-in printed circuit module construction result in the kind of reliability usually associated with aerospace applications.

386 Specifications

Total power (± 1 dB) 170 Watts @ 4 Ohms. IHF Dynamic power, 67.5 Watts/channel @ 4 Ohms; Continuous power, both channels driven, 42 Watts/channel @ 4 Ohms, 35 Watts/channel @ 8 Ohms; Distortion < 0.5% at rated output; Frequency response (± 1 dB), 15-30 KHz; IHF power bandwidth, 15-25 KHz. FM usable sensitivity (IHF), 1.9 μV; FM selectivity, 42 dB. Price, $349.95.

SCOTT®

For detailed specifications, write:
H. H. Scott, Inc., 111 Powdermill Road, Maynard, Mass. 01754
Export: Scott International, Maynard, Mass. 01754

CIRCLE NO. 106 ON READER SERVICE CARD

Voltage supply in your city can vary as much as 10%. And even a 2% variation causes a significant tape speed change in tape decks with induction motors and a difference in reproduced sound that is intolerable.

The Concord Mark II stereo tape deck completely ignores fluctuations in line voltage. It is driven by a hysteresis synchronous motor which locks onto the 60 cycle power line frequency and maintains constant speed (within 0.5%) regardless of voltage variation from 75 to 130 volts. So if you're about to buy a tape deck that doesn't have a hysteresis synchronous drive motor, you're liable to negate any other fine feature it might have.

Don't get the idea the hysteresis motor is all the Concord Mark II has to offer. It also has just about every other professional feature. Three high-quality heads: ferrite erase head; wide gap Hi-Mu laminated recording head for optimum recorded signal and signal-to-noise ratio, narrow gap Hi-Mu laminated playback head for optimum reproduced frequency response. No compromise combination heads. The three heads and four preamplifiers also make possible tape monitoring while recording.

The tape transport mechanism assures a fast startup—you don't miss a note. Supply and takeup tape tension arms eliminate startup burble. A special flutter filter eliminates flutter due to tape scrape or cogging action. A cue control provides instantaneous stop and start operation. Other important conveniences: the flip-up head cover permits you to see the head gap position markings for professional editing; 3 speeds; automatic sound-on-sound with adjustable level controls; variable echo control for reverb recording; calibrated VU meters with individual record indicator lights; stereo headphone jack; electronically controlled dynamic muting for automatic suppression of tape hiss without affecting high frequency response. All this, for under $230.

The hysteresis drive Concord Mark III has all of the features of the Mark II plus pressure-sintered ferrite heads for extended frequency response and virtually no head wear. It sells for under $260.

The hysteresis drive Mark IV, the top-of-the-line Concord deck offers all of the performance and conveniences of the Mark II and III including wide gap record, narrow gap playback heads, tape source monitoring, sound-on-sound, echo recording. Plus, a dual capstan tape transport mechanism with electronic automatic reverse, no metal foil or signal required on the tape. Superior recording performance plus the convenience of automatic reverse and continuous play. A superb instrument with the finest performance money can buy, and it's under $330. Audition the new Concord Mark series, the tape decks with the hysteresis synchronous drive motor. For "all the facts" brochure, write: Concord Electronics Corp., 1935 Armacost Ave., Los Angeles, Calif. 90025. (Subsidiary, Ehrenreich Photo-Optical Industries, Inc.) EPOI

For copy of Concord Mark III Instruction book, mail 25¢ in coin

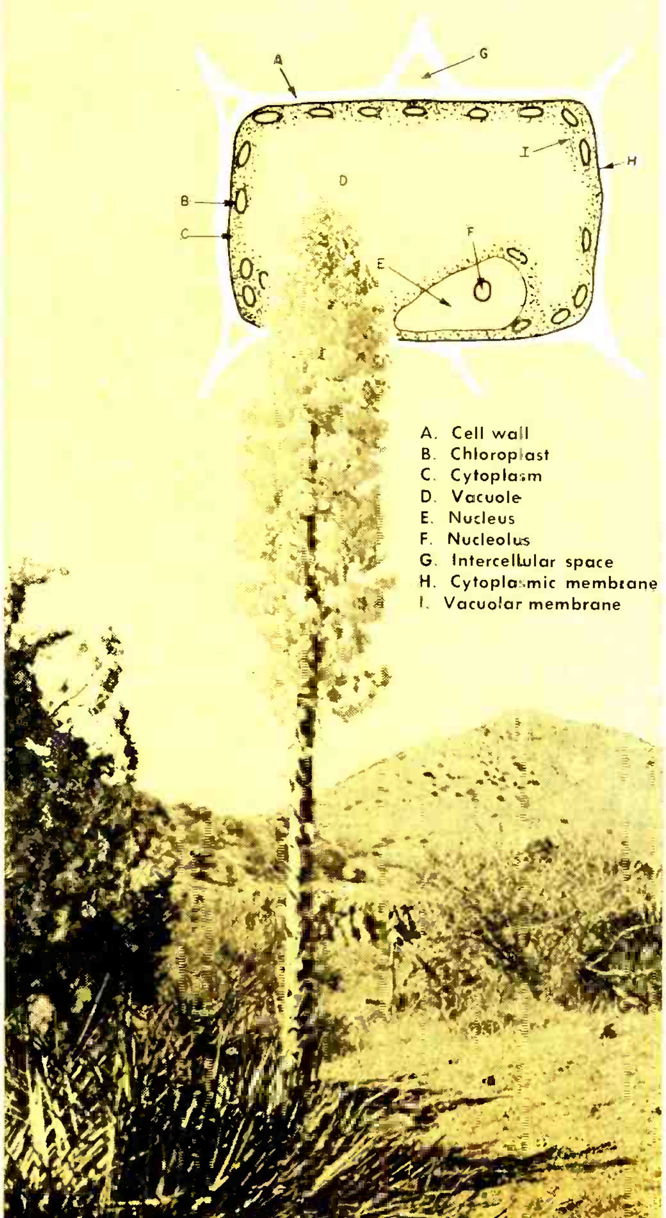
NEITHER AIR CONDITIONERS, TV SETS, WASHERS NOR ANY OTHER ELECTRICAL APPLIANCE CAN KEEP THE HYSTERESIS-DRIVE CONCORD MARK II FROM ITS PRECISELY APPOINTED SPEED.

CIRCLE NO. 141 ON READER SERVICE CARD

ELECTRONICS and the LIVING PLANT

By L. GEORGE LAWRENCE

Can plants be used with electronic equipment for some future exotic sensing and control system? Some investigators, performing unusual experiments, believe they can be.



IT has been known for a long time that plants have electrodynamic properties. Their ability to process complex test currents and to behave in a computer-like "go/no-go" binary mode is unique. But never in all those millenia since the first green leaves poked their heads out of Paleozoic swamps have plants been given more professional attention (other than from botanists) than they have in recent years.

After much initial skepticism regarding plants' semiconductive and general electromotive qualities, here are but a few of the topics that science is speculating about today:

1. Can plants be integrated with electronic readouts to form major data sensors and transducers?

2. Can plants be trained to respond to the presence of selected objects and images?

3. Is their alleged supersensory perception (SSP) verifiable?

4. Of the 350,000 plant species known to science, which family is most promising from an electronics point of view?

Electrical Characteristics

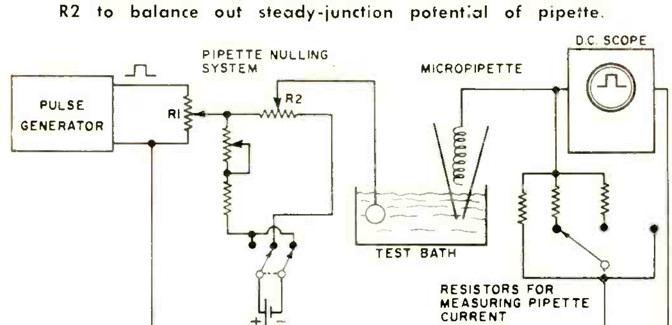
The effect of electrical excitation on plants was noted in the 18th century and described in Dr. Jallabert's book "De l'électricité des végétaux," published in Geneva in 1748. Later, in 1924, Dr. Stern gave an excellent summary in his publication "Die Elektrophysiologie der Pflanzen." Up-to-date findings were described in G. Ungar's work entitled "Excitation" (1963), which also gives a good overview of bioelectric and electrophysical phenomena in general. However, taken together, many schools continue to attach more significance to plant growth hormones and regulators than to electrical phenomena *per se*.

The behavior of a living cell is dramatically complex and unique. There are responses to light, heat and cold, radiation, injuries, and touch. Electrical properties can be investigated with microelectrodes, a sample of which is shown in the test arrangement of Fig. 1.

Microelectrodes usually take the form of micropipettes, consisting of a very-thin glass envelope, a conductive liquid, and a metallic helix or insert for conveying current to external readouts. Their electrical impedance is of the high-ohm type and must be verified frequently by using a special test bath. The d.c.-nulling arrangements and parallel resistances permit investigations of over-all impedance characteristics—which, ideally, should lead to no impairment of pulsing-test currents propagated through the electrode systems. The test bath may be used as an approximate standard, featuring impedance and conductive properties similar to those of biological electrolytes.

Typically, strong electric currents flowing through a plant cell have the effect of causing an immediate contraction of the cytoplasm of a cell (best seen in the *spirogyra* or *elodea canadensis*), from which physiological recovery is impossible. Less intense currents cause either a partial retraction from the cell wall or, after the current has been stopped, resumption of normal cell functions. Upon swarm spores and antherozooids swimming in water, electricity has the peculiar

Fig. 1. Test setup for measuring the electrical characteristics of micropipettes used for data pick-off from micro-organisms. R1 is used to adjust the amplitude of the test pulse, R2 to balance out steady-junction potential of pipette.



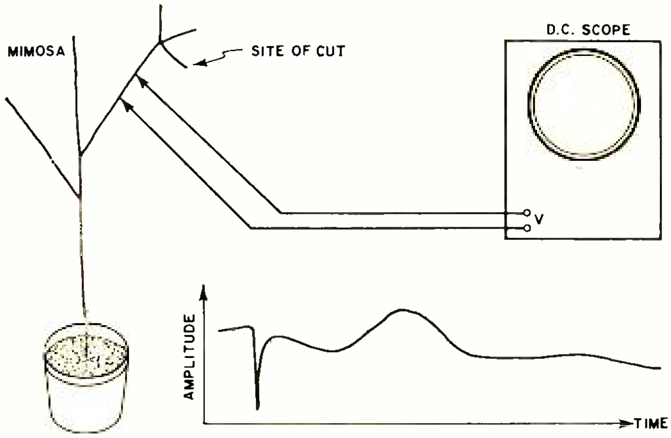


Fig. 2. Characteristic response of mimosa pudica to injury.

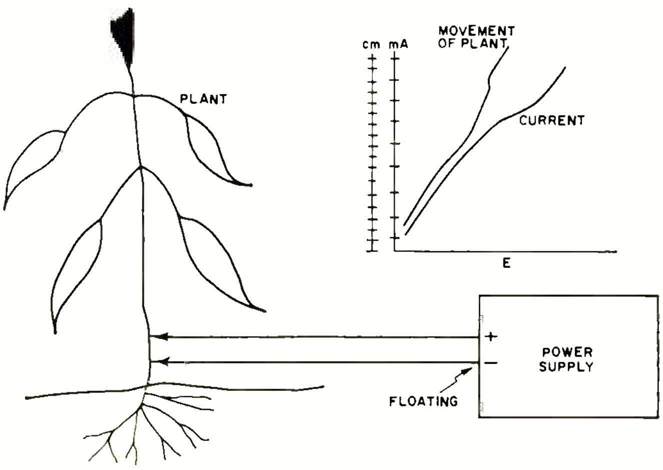
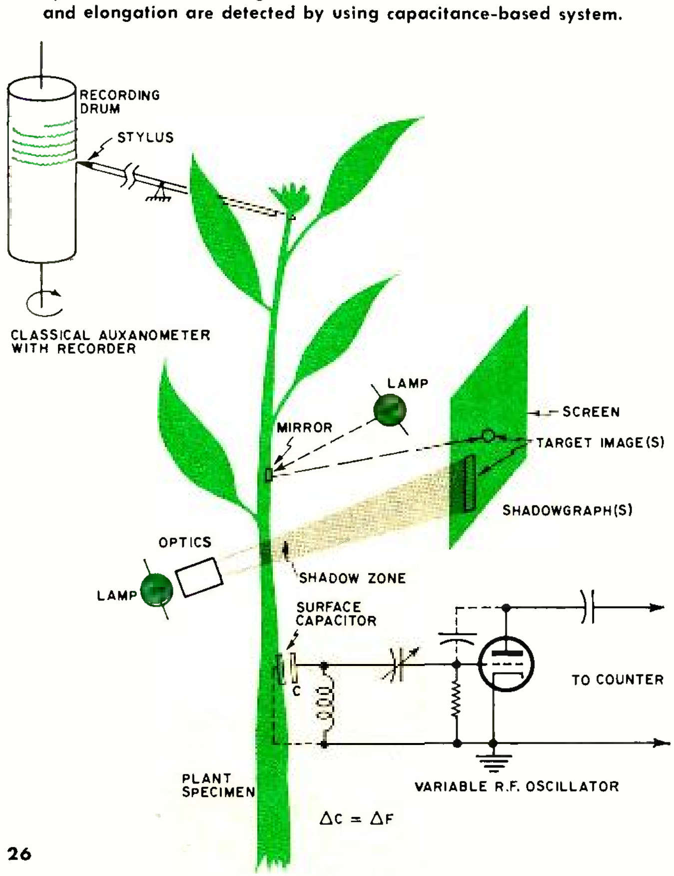


Fig. 3. Response of a small plant to electrical stimuli. The electro-nastic movement of plant versus current is plotted.

Fig. 4. Plant growth is detected by using mirror arrangement, optics, and a recording auxanometer while stem movements and elongation are detected by using capacitance-based system.



effect of *polarizing* them. The one or the other extremity might turn in a definite direction, either with or against the direction of d.c. potentials.

However, a different situation arises when sensitive plants, such as the *mimosa pudica,* experience injury. Fig. 2 shows an experimental setup used for electro-culture work, consisting of a high-gain d.c. oscilloscope as data sensor. If the plant is cut, as shown, a typical current spike will ensue which is indicative of a *nastic* response. The term *electro-nastic movement* is used if, as in Fig. 3, application of current elicits a motive response. In the case of the mimosa, there exists no proportionality between the strength of stimuli and the dimensions of motive reaction. Thus, if a certain current threshold is exceeded, we will notice a total, "all-or-nothing" reaction. The specimen acts like a silicon controlled rectifier in that certain triggering levels must be present to cause action.

Electro-nastic performance is best seen on small plants. For this purpose, various plant-response indicators have evolved, working on different detection principles.

As shown in Fig. 4, simple growth can be detected with a recording *auxanometer*. Mirror arrangements and optics may be employed to verify movements by reflection of light and shadowgraphic methods.

The capacitance-based system is suitable for measuring stem movements and elongation. However, a device such as this is critical in that strong oscillator currents and/or d.c. must not act as a stimulus to the plant. This requirement can be met by carefully grounding zero-potential electrodes in the plant's pot and by adequate distance between acting capacitor members. Experimenters normally work with a "center frequency" of given value. If the center frequency is, say, 20 MHz and finally changes to 20.80 MHz while the experiment is in progress, the net value will be 800 kHz. By measuring the distance between capacitor plates (C) with a micrometer, it is possible to plot distance *versus* frequency as a result of growth or movement of the specimen.

Packaged Plant Electronics

The majority of electrical plant reactions occur in the millivolt range and involve long time bases. In electro-culture experiments with bean seedlings, for example, waveforms emanated by roots (Fig. 5) are complex and require careful shielding from industrial interferences. Since it is very difficult to properly "terminate" biological impedance, like a TV antenna, special packaging concepts and designs have emerged to keep plant-generated electrical data as "clean" as possible.

Fig. 6 shows an example of a special packaging concept. The living plant is housed in a quasi-Faraday cage to permit access of light and air. Light is important since the photoreactions of the specimen normally require electromagnetic energy between a wavelength of 2000 and 10,000 angstroms (Å). However, this particular experimental setup is unique in that it permits simultaneous biochemical and bioelectric observations of a plant.

In the case at hand, weak electrical signals are generated by shielded electronics in a special enclosure. These products consist of r.f. below 10 meters and pulsed d.c. Galvanic feedback loops permit immediate stoppage of currents if excitation levels are exceeded. Timing is provided by motor-driven switches beneath the cage, with current normally applied during daylight hours only.

Interest in the plant's chemical behavior is coupled with the above, but is more complex. One of them is the observation of auxins, which are chemicals (plant hormones) which cause distinct growth patterns. One of these substances, indole-3-acetic acid, occurs in minute quantities in growing plant tissue. Thus, in a shoot of the pineapple plant, only 6 micrograms of auxin are found per kilogram of plant material which is comparable to the weight of a needle in a 22-ton truckload of hay. There are other plant hormones and regulators, including gibberellins and cytokinins, that contribute to the electrically stimulated plant's well-being and enable it to deal with a massive set of physical forces. These aspects are of immense complexity and cannot be nailed down in laws and predictive formulas. There is much randomness involved here, which frequently makes a plant's behavorial response just as unpredictable as that of man. However, it is possible to come up with some guidance in the form of statistics and other laboratory data if the plant specimens have a reasonably controlled environment and are fed specific nutrients. A respective feeder can be seen at the upper right-hand side of the cage in Fig. 6.

The Backster Effect

Some ten years ago, in the "Moon Garden" developed by *Republic Aviation* at Farmingdale, N.Y., scientists were able to induce what appeared to be "nervous breakdowns" and "complete frustration" in plants being tested as possible space foods. At East Grinstead, Sussex, England, Dr. L. Ron Hubbard also noted electrogalvanic responses in tomatoes when struck by a nail. Unable to arrive at a reasonable explanation for these "findings" the investigators arbitrarily entitled these reactions "emotion-like" responses in plants.

Three years ago this "emotion-like" response in plants was noted by Clyde Backster, executive director of the *Backster Research Foundation* (N.Y.) and a polygraph (lie detector) expert, when he connected one of his instruments to a *draena massangeana* plant while it was taking up water. The specimen's psychogalvanic reflex (PGR) reaction pattern was strange, for it appeared to be similar to that of a human being undergoing emotional stimulation. Attempting to further test the plant's reaction, Backster decided to take a match and burn the leaf carrying the polygraph electrodes. At the moment this thought entered his mind a dramatic change was reflected in the PGR tracing—the graphic recorder suddenly drew a waveform of great amplitude. This totally unexpected reaction suggested to Backster that somehow the presence of this destructive mental image set off a chain of events, not obvious to the human senses, that triggered the plant into what seemed to be an emotion-like response. Later, in an attempt to substantiate his previous findings, Backster devised a complex experiment involving the dumping of live shrimp into boiling water. The experiment was executed at a random time by machines and, what was most significant, without Backster's presence. Again the plants selected for this experiment seemed to register what could be construed as a profound emotion-like response at the precise moment of the shrimps' death.

The basic equipment inventory required for verification of what is called the Backster Effect is shown in Fig. 7. The apparatus consists of the plant itself as the prime "data sensor," a differential d.c. preamplifier, and the graphic recorder. In a typical test situation, the amplifier is brought into close proximity to the plant (Fig. 8) and connected by shielded lines to the leaves. Fig. 9 shows two additional methods of connecting the leaf through the d.c. amplifier to the recorder. The recorder itself, set up remotely, requires little else but multiple-speed drive trains in order to obtain good trace resolution at various paper speeds.

However, it is only fair to point out that working with the Backster Effect involves much more than the mere ability to construct top-quality electronic equipment. There are certain qualities involved here which do not enter into normal experimental situations. According to those experimenting in this area, it is necessary to have a "green thumb" and (most important) a genuine *love* for plants.

Plant Conditioning

Experiments, such as the one shown in abstract form in Fig. 10, have been performed to demonstrate that plants can be conditioned to react to certain events. Those investigating this possibility feel that these life forms have memories and,

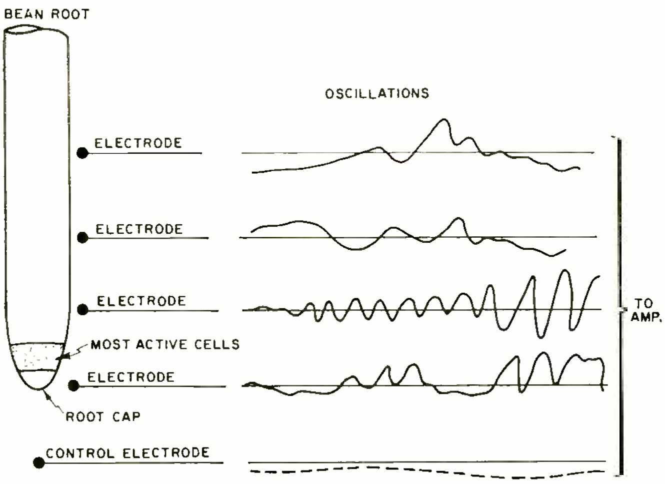


Fig. 5. Oscillatory electrical phenomenon of bean root gives complex waveforms that require shielding from interference.

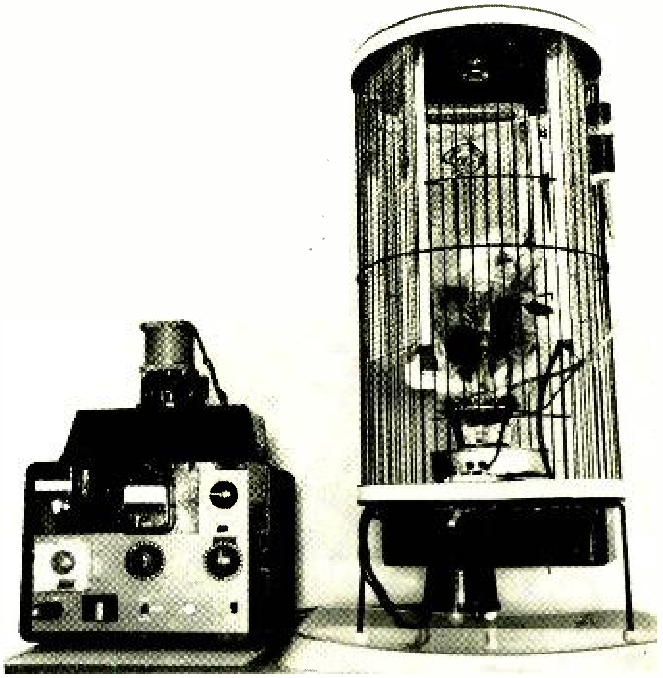


Fig. 6. Quasi-Faraday cage, used to perform simultaneous biochemical and bioelectrical plant experiments, permits entry of air and light. Nutrient feeder is at upper right, timer at bottom. Electronics are in separate package (left).

Fig. 7. Principal arrangement for testing plant's emotion-like response (Backster Effect). Mere thought of threat to the plant appears to elicit a dramatic electrical response.

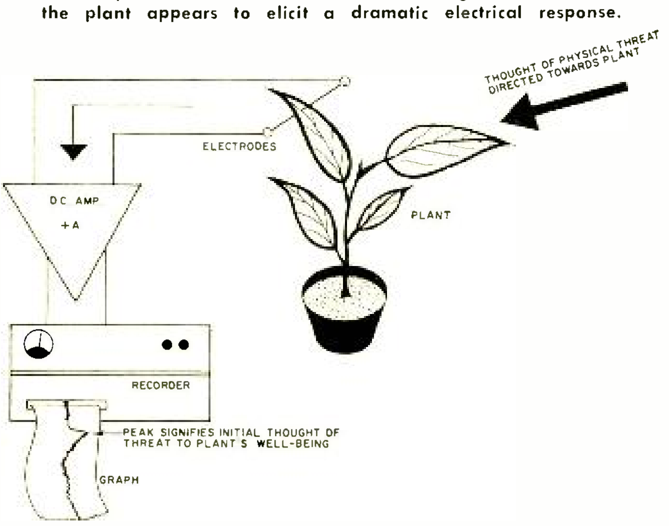


Fig. 8. Indoor arrangement for testing Backster Effect. The d.c. amplifier is at left, connected by shielded line to the leaf and set-up potentiometer. Nutrient feeder is in the pot.

Fig. 11. The d.c. galvanometer and packaged electronics devised for testing the emotion-like response of yucca plants outdoors. The plant shown in the lead photo indicates size.

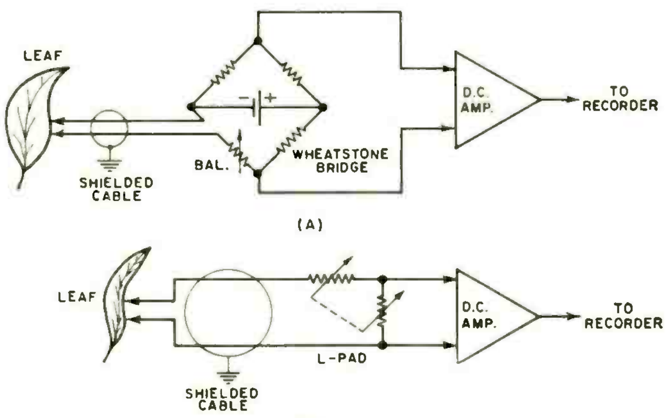
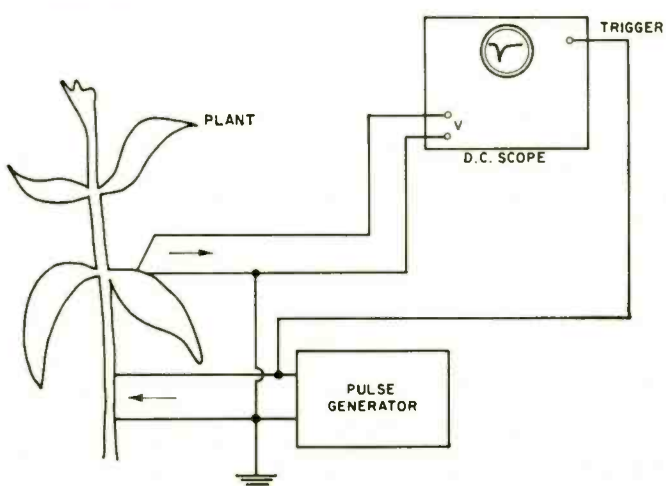


Fig. 9. Two additional methods for connecting the leaf of a plant to the recording equipment. (A) Equipment for checking changes in electrical resistance (Feré Effect) of plant organics and (B) equipment for checking difference in electrical potentials (Tarchanow Effect) generated by the plant.

Fig. 10. Pulsing and monitoring setup used with Pavlovian and Skinnerian principles to condition plants to repetitive events.



being living systems with many sensory capacities, are capable of being trained by Pavlovian and Skinnerian conditioning techniques. Unfortunately, unlike experimental situations involving dogs (Pavlov) and pigeons (Skinner), no specific reward systems—such as food—have as yet been worked out with plants; but experiments are under way.

Attention, of late, has also been given to larger plants as well. The yucca plant is a representative example of a plant too large to be examined indoors. The equipment shown in Fig. 11 was devised to test its responses.

The instrumentation revolves around a high-gain d.c. amplifier and a d.c.-excited Wheatstone bridge. A galvanometer serves as an "emotion" readout, being calibrated in statements such as "Decrease" and "Increase."

This article has given a fair sample of what has been and can be done in this new and exceptionally promising field. The almost human-like sensory and response characteristics attributed to plants by Clyde Backster and other investigators in the field are too unique to be ignored.

(Editor's Note: Although some of the items discussed may be controversial, we believe that our readers will find the story both interesting and stimulating. We would also like to mention that the Backster Effect, dealing with the electrical response of plants under "emotional" stress, was recently demonstrated on nationwide TV. The effect was also demonstrated "live" to one of our editors.) ▲

REFERENCES

Berry, L.J. & Hoyt, R.C. "Polarization and Stimulation of the Onion Root by Direct Current." Plant Physiol. 1943. 18:372-396

Clark, W.G.: "Electrical Polarity and Auxin Transport," op cit, 1937, 12: 409-440

Hollaender, A. (ed): "Radiation Biology, Vol. III", McGraw-Hill, 1956

Loehr, F.: "The Power of Prayer on Plants," New American Library, Signet Books, 1969

Lund, E.J.: "Bioelectric Fields and Growth," University of Texas Press, Austin, 1947

Machlis, L. & Torrey, J.G.: "Plants in Action—A Laboratory Manual of Plant Physiology," W.H. Freeman Co., San Francisco, 1956

McGraw, W.: "Plants are only Human," *Argosy*, pp. 24-27, June, 1969

Purvis, M.J. et al: "Laboratory Techniques in Botany," Butterworths, London, 1964

Sinyukhin, A.M. & Gorchakov, V.V.: "Role of the Vascular Bundles of the Stem in Long-Distance Transmission of Stimulation by means of Bioelectric Impulses," Soviet Plant Physiology, 15:3, pp. 477-487, May-June 1968

Suckling, D.: "Bioelectricity," McGraw-Hill, 1961

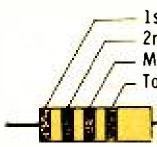
Thomas, J.B.: "Electrical Control of Polarity in Plants," Rec. Trav. bot neerland, (Holland), 1939, 36:373-437

Ungar, G.: "Excitation," C.C. Thomas, Springfield, Ill. 1963

Went, F.W.: "The Experimental Control of Plant Growth," California Institute of Technology, 1957

COLOR CODE CHARTS

COLOR BAND SYSTEM



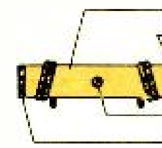
Resistors With Black Body Color Are Composition, Non-Insulated.
Resistors With Colored Bodies Are Composition, Insulated.
Wire-Wound Resistors Have The 1st Digit Color Band Double Width.

RESISTOR CODES (RESISTANCE GIVEN IN OHMS)

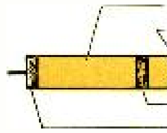
COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	±20%
BROWN	1	10	±1%
RED	2	100	±2%
ORANGE	3	1000	±3% •
YELLOW	4	10000	GMV•
GREEN	5	100000	±5% (EIA Alternate)
BLUE	6	1000000	±6%•
VIOLET	7	10000000	±12 1/2%•
GRAY	8	.01 (EIA Alternate)	±30% •
WHITE	9	.1 (EIA Alternate)	±10% (EIA Alternate)
GOLD		.1 (JAN and EIA Preferred)	±5% (JAN and EIA Preferred)
SILVER		.01 (JAN and EIA Preferred)	±10% (JAN and EIA Preferred)
NO COLOR			±20%

•GMV = guaranteed minimum value, or -0 + 100% tolerance.
±3, 6, 12 1/2, and 30% are ASA 40, 20, 10, and 5 step tolerances.

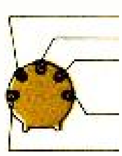
BODY-END-DOT SYSTEM



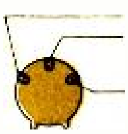
BODY - END BAND SYSTEM



DISC CERAMICS (5-DOT SYSTEM)



DISC CERAMICS (3-DOT SYSTEM)

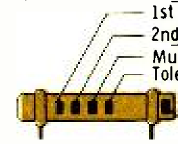


CERAMIC CAPACITOR CODES (CAPACITY GIVEN IN pF)

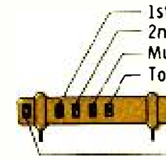
COLOR	DIGIT	MULTIPLIER	TOLERANCE 10 pF or LESS	TOLERANCE OVER 10MMf	TEMPERATURE COEFFICIENT PPM/°C	EXTENDED RANGE TEMP. COEFF. SIGNIFICANT FIGURE	EXTENDED RANGE TEMP. COEFF. MULTIPLIER
BLACK	0	1	±2.0 pF	±20%	0(NPO)	0.0	-1
BROWN	1	10	±0.1 pF	±1%	-33(N033)		-10
RED	2	100		±2%	-75(N075)	1.0	-100
ORANGE	3	1000		±2.5%	-150(N150)	1.5	-1000
YELLOW	4	10000			-220(N220)	2.2	-10000
GREEN	5		±0.5 pF	±5%	-330(N330)	3.3	+1
BLUE	6				-470(N470)	4.7	+10
VIOLET	7				-750(N750)	7.5	+100
GRAY	8	.01	±0.25 pF		+30(P030)		+1000
WHITE	9	.1	±1.0 pF	±10%	General Purpose Bypass & Coupling		+10000
SILVER							
GOLD					+100 (P100, JAN)		

Voltage ratings are standard 500 volts for some manufacturers, but 1000 volts for other companies.

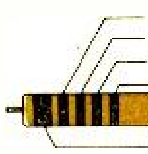
HIGH CAPACITY TUBULAR CERAMIC INSULATED OR NON-INSULATED



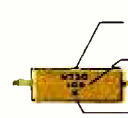
TEMPERATURE COMPENSATING TUBULAR CERAMICS



MOLDED-INSULATED AXIAL LEAD CERAMICS

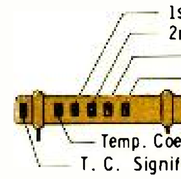


TYPOGRAPHICALLY MARKED CERAMICS

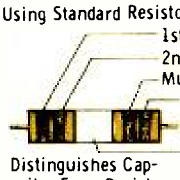


JAN LETTER	TOLERANCE 10 pF or LESS	TOLERANCE OVER 10 pF
C	±0.2 pF	
D	±0.5 pF	
F	±1.0 pF	±1%
G	±2.0 pF	±2%
J		±5%
K		±10%
M		±20%

ENTENDED RANGE T.C. TUBULAR CERAMICS

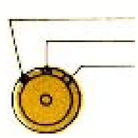


MOLDED CERAMICS
Using Standard Resistor Color-Code



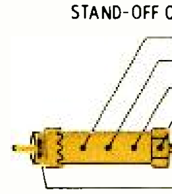
Distinguishes Capacitor From Resistor

BUTTON CERAMICS

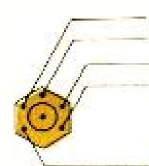


Viewed From Soldered Surface

STAND-OFF CERAMICS



FEED-THRU CERAMICS



MOLDED MICA CAPACITOR CODES
(Capacity Given In pF)

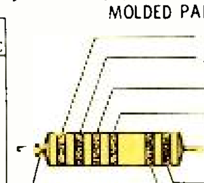
COLOR	DIGIT	MULTIPLIER	• TOLERANCE	CLASS OR CHARACTERISTIC
BLACK	0	1	20%	A
BROWN	1	10	1%	B
RED	2	100	2%	C
ORANGE	3	1000	3%	D
YELLOW	4	10000		E
GREEN	5		5% (EIA)	F(JAN)
BLUE	6			G(JAN)
VIOLET	7			
GRAY	8			I(EIA)
WHITE	9			J(EIA)
GOLD		.1	5%(JAN)	
SILVER		.01	10%	

Class or characteristic denotes specifications of design involving Q factors, temperature coefficients, and production test requirements.
All axial lead mica capacitors have a voltage rating of 300, 500, or 1000 volts.
•or ±1.0 pF whichever is greater.

MOLDED PAPER CAPACITOR CODES
(Capacity Given In pF)

COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	20%
BROWN	1	10	
RED	2	100	
ORANGE	3	1000	
YELLOW	4	10000	
GREEN	5	100000	5%
BLUE	6	1000000	
VIOLET	7		
GRAY	8		
WHITE	9		10%
GOLD			5%
SILVER			10%
NO COLOR			20%

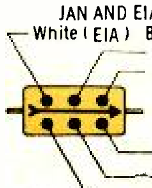
MOLDED PAPER TUBULAR



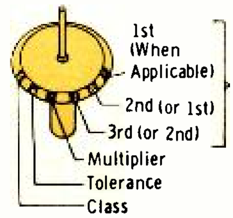
Indicates Outer Foil. May Be On Either End. May Also Be Indicated By Other Methods Such As Typographical Marking Or Black Stripe.

Add Two Zeros To Significant Voltage Figures. One Band Indicates Voltage Ratings Under 1000 Volts.

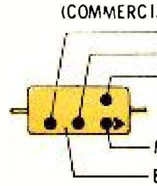
CURRENT STANDARD JAN AND EIA CODE



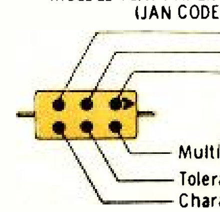
BUTTON SILVER MICA

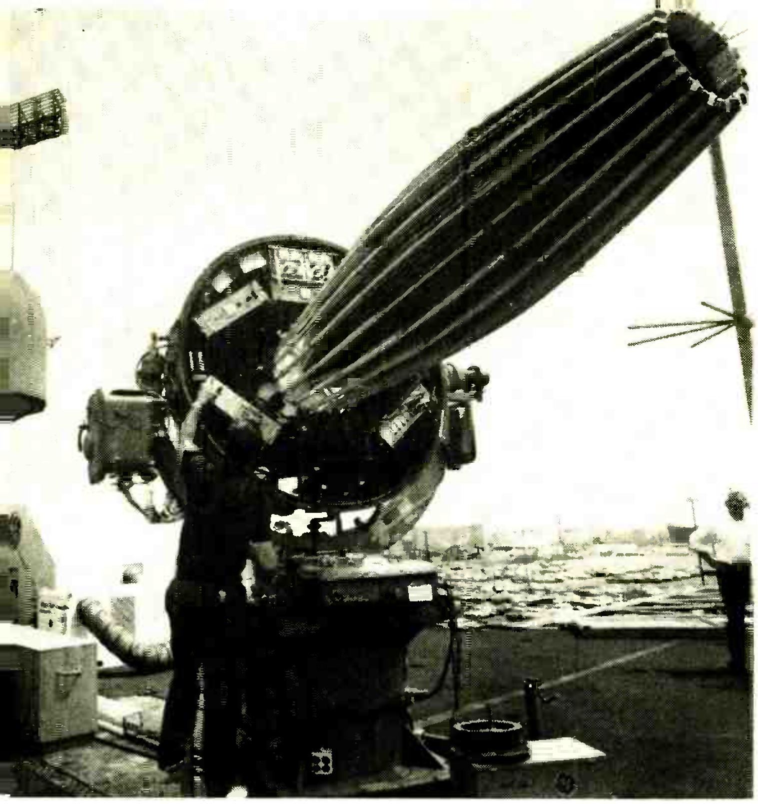


MOLDED FLAT PAPER CAPACITORS (COMMERCIAL CODE)



MOLDED FLAT PAPER CAPACITORS (JAN CODE)





RECENT DEVELOPMENTS IN ELECTRONICS

Antenna Beams Apollo Splashdown. (Top left) No, this is not some kind of ray gun or cannon, but it is a closed-up parabolic reflector. Just after this photo was taken the reflector was opened up into a 15-foot dish. The antenna was used by Western Union International to beam live color coverage of the Apollo 11 splashdown to a Comast communications satellite some 22,300 miles over the Pacific. From the satellite the signals were routed by earth stations and other satellites to TV stations in 49 countries around the world. The antenna is mounted on its gyro-stabilized platform located on the deck of the USS Hornet, and maintains unerring aim on the satellite so as to transmit a steady signal, regardless of the ship's motion.

TV Computer System Checks Eyes. (Center) A patient, seated in front of a modified television set, undergoes a field of vision examination at the University of Texas Southwestern Medical School in Dallas. Dr. Priscilla Berry, ophthalmologist, administers the test from the console of an IBM data-processing system. Using a re-wired portable TV set and the computer system, eye specialists at the medical school developed a unique testing technique designed to detect in early stages those diseases which cause blindness. The patient covers one eye and focuses the other eye on the center of the TV screen. The examiner feeds punch cards into the system and these cause white dots of light, of various sizes and intensities, to appear momentarily at different locations. As the patient sees a spot, he moves a lever below the TV screen toward the spot's position. Speed and accuracy of response are measured and the system then produces a detailed map of the patient's field of vision. By studying the maps that are produced, eye specialists will be able to diagnose diseases, such as glaucoma, and to evaluate the effectiveness of their treatment.

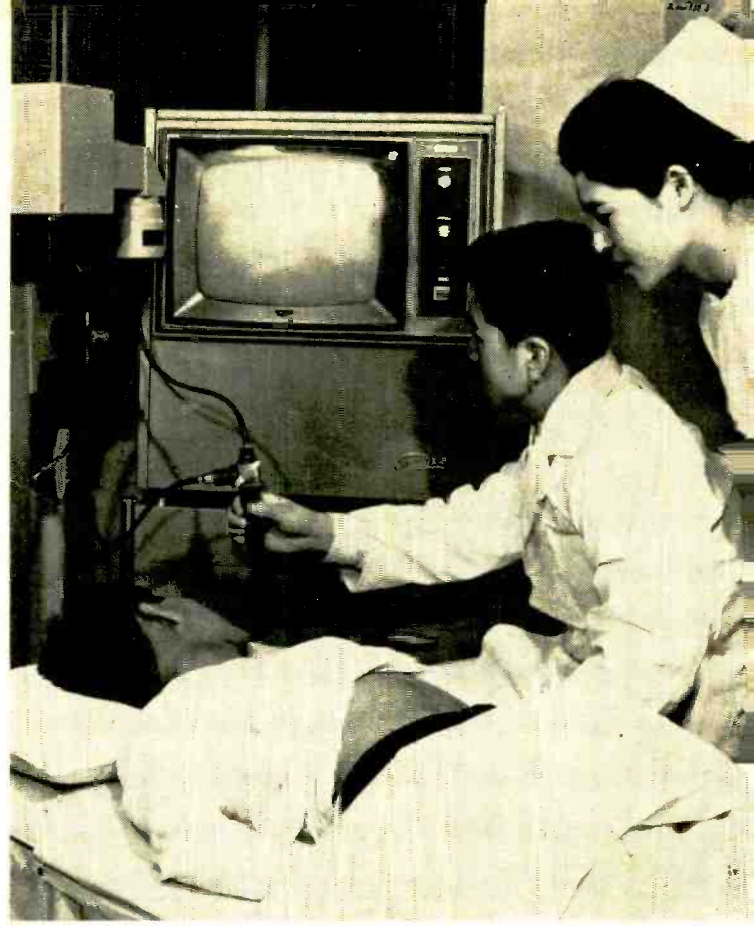
Inertial Navigation for Superjet. (Bottom left) The primary long-range navigational aid for pilots flying the first 362-passenger Boeing 747 superjets next winter will be three separate inertial-guidance units. Five times more accurate than standard methods of navigation, these units have been flight tested in 707's and during the first transatlantic flight of the 747 on June 2, 3. During this flight, the inertial system was coupled to the autopilot and actually flew the plane a distance of 4000 nautical miles over, and most of the distance on the return trip. The flight deck on the superjet is similar to that of the 707. The front instrument panel (1) faces pilot and co-pilot while the flight-engineer panel (2) contains the dials, gages, switches, and indicator lights to monitor the plane's vital systems. The close-up photo (left) shows instrument console between seats of pilot and co-pilot with the inertial-navigation system at (3). Audio controls, v. h. f. radio controls, and the autopilot controls are in the foreground. The inertial system, which is called the "Carousel IV", has been designed and built by the AC Electronics Division of General Motors Corp.

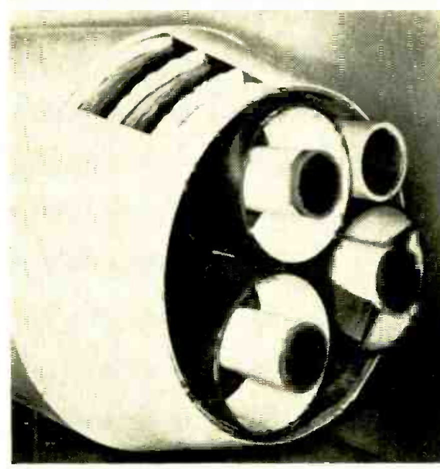
Color-TV Looks Inside Patient. (Top right) More accurate than an x-ray, this system combines color-TV with fiber optics to give doctors an inside view of their patients. A flexible fiber scope can be passed into the patient's stomach, for example, and can transmit an image to the color set of a tumor as small as 2 mm. An entire medical team can observe the enlarged image on the TV monitor. A field-sequential color system is used in the instrument, a tele-endoscope, which is being introduced to U. S. medicine by Toshiba International Corporation.

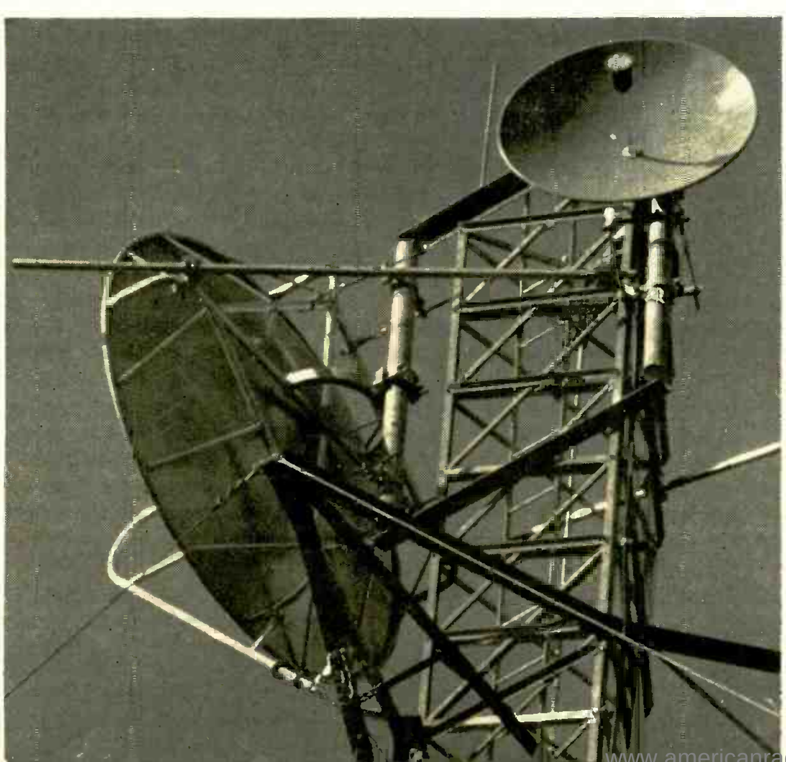
Superconductive Cable for Underground Power. (Center) This 20-in cable is able to carry 25 times more electrical power than is possible today using conventional types of underground power lines. The three coax pipes have their facing surfaces coated with ultra-pure niobium, which is a superconductor having little or no resistance at cryogenic temperatures. The fourth pipe carries liquid helium, the refrigerant, which maintains temperature at −452° F. Layers of insulation keep the temperature low. Studies are being made on such a system by Union Carbide for the electric power companies trade association.

1000-Mile R. R. Microwave System. (Bottom left) The Illinois Central Railroad inaugurated a 1000-mile private communications network between New Orleans and Chicago. The system has 44 towers (one of which is shown here) and relay locations and can handle 420 messages simultaneously. Data on train movements, railway business, and telephone messages can now be carried on the company's own microwave radio system rather than on leased lines. Contractor was Lenkurt Electric.

"Speed Listening" for the Blind. (Bottom right) An electronic device that permits "speed listening" of recorded speech at rates comparable to reading has been produced by the American Foundation for the Blind. The device makes it possible to reproduce the human voice at double speed without altering the pitch and without producing the gibberish that would ordinarily occur. Taped speech is fed into the system and recorded on tapes or discs at four times the original speed, then it is played back at half-speed to achieve the end result of double the original rate. Some 36 bandpass filters are used to separate the speech into its different frequency components. Then 36 frequency dividers are employed to halve the frequencies of the narrow-band signals from the filters. From the dividers, signals proceed to networks that remove distortion and combine the half-frequency signals into a single output. This "harmonically compressed" signal is recorded on tape, which can now be used to make tape or disc recordings of magazines for the blind. Principles for the system were developed by Bell Labs.







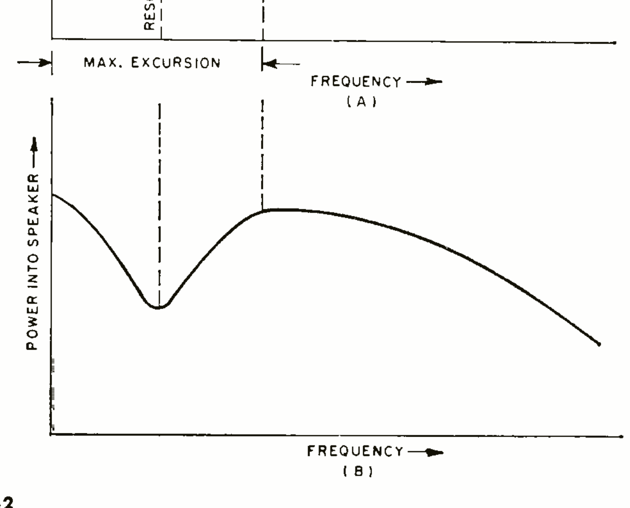
Speaker-Matching Problems in Public-Address Systems

By ABRAHAM B. COHEN, ISC/Telephonics
Division of Instrument Systems Corp.

Part 2 of a series on modern p.a. sound-system practices covers various methods that are used to interconnect loudspeakers to the p.a. amplifier, including impedance matching, use of transformers, constant-voltage system.

LAST month's article, "New Developments in Public Address Systems," concluded that the output of the p.a. amplifier could be connected directly to the loudspeakers on a matched-impedance basis if the number of speakers is small. Where there are a large number of speakers, the transformer method of coupling to the output of the amplifier is more common and easier for the technician to handle. This article will establish the general basis for the choice of one system over the other and will go into the methods of interconnecting loudspeakers.

Fig. 1. (A) Variation of speaker impedance with frequency. (B) Variation of power that is applied to the loudspeaker.



Speaker-Impedance Characteristic

The speaker is a physically moving device when it is operating; it behaves essentially as a motor. Its impedance may be separated into two distinct parts as indicated in Fig. 1A. It has a "motional impedance," which is the result of the voice coil vibrating in its magnetic field in the general area of resonance of the speaker and producing a back-e.m.f. which cuts down on current getting into the voice coil. The driving amplifier, finding it harder to force current into the voice coil, sees a high impedance at the loudspeaker terminals. Since the speaker cone vibrates most energetically at resonance, the impedance is highest at that point and, in many instances, it will be several times higher than the rated impedance of the loudspeaker.

After the area of resonance is passed, the voice-coil excursion "quiets down" and the speaker impedance reaches a trough before it begins to rise again. *It is at this trough area that the rated impedance is specified.*

The voice coil exhibits the characteristics of a choke. The impedance rises with frequency and thus the impedance shown in Fig. 1A indicates a climbing characteristic trend with frequency. This high-frequency impedance is far higher than the rated impedance. It is obvious, then, that what the amplifier will deliver to just a simple speaker is not a straightforward matter of E^2/Z for Z (impedance) is not constant. How, then, can one adjust groups of speakers on a line for power distribution on an impedance-matching basis if impedance is so inconstant?

System Performance Affected

The technician who is involved in installing or specifying a sound-distribution system, even if only one patio hi-fi extension speaker or two high-quality speakers in an auditorium, may rightly question the effect of this variation in the speaker impedance. Fig. 1B indicates the power into the speaker with a constant-voltage amplifier. This would result in a poor frequency response as it stands, not only for hi-fi but for p.a. distribution systems as well.

The low-frequency peak in impedance is readily corrected by proper damping of the speaker by its acoustic enclosure. Where p.a. horn projectors are used, low-frequency excursions of the diaphragm are very severely damped by the acoustic loading of the horn. The rise in impedance at the high end of the spectrum is not so easily handled.

While the low frequencies are important for providing a good "bottom" for hi-fi sound reproduction, the middle and high bands of frequencies are of far more importance. Stereo perception is made possible only by the wide-angle dispersion of the middles and highs. These frequencies determine the direction from which the sound appears to come. In the case of the p.a. system, we may not be interested in stereo, but we are interested in getting the message across. The success in getting an audience to clearly understand the speaker system is to make sure that there is a high degree of articulation from the system. Understandable articulation and intelligibility are the result of good, clean middle and upper frequencies.

Almost all modern amplifiers are of the constant-voltage type; hence the simple speaker impedance characteristic results in a loss of high-frequency power to the speaker.

Impedance Correction

Speaker-impedance characteristics may be corrected so that the impedance presented to the output terminals of the amplifier will look more constant, and permit more constant power to get into the reproducer. This is done by adding other speakers to the single-speaker system.

Most p.a. technicians and hi-fi installers know that it is possible to extend the high-frequency range and raise the level of the system by the addition of a tweeter in a home installation or by using high-frequency projectors in p.a. systems. The method by which this performance change is effected is worth examining in terms of its affect upon the impedance that the amplifier sees.

The impedance of a tweeter or high-frequency projector is usually chosen to be equal to that of the low-frequency unit. This is true whether we consider the case of a simple home speaker system or a high-power horn system used to cover large areas. The tweeter is of course not tied directly across the line feeding the low-frequency unit. A crossover network is a "must" in such a dual-unit system, or at the very minimum a high-pass filter is required to tie the tweeter to the line. Let's examine this last, the simplest type, and the minimum type of crossover used (see Fig. 2A).

The capacitor serves one obvious purpose in this configuration; it keeps damaging low frequencies from getting into the tweeter which is not designed to handle low frequencies. However, the degree to which the tweeter is protected is dependent upon the value of the capacitor. At low frequencies C acts like an open circuit, at high frequencies it acts like a very small series impedance, small compared to that of the tweeter. At the very high end, the capacitor inserts very little impedance into the tweeter branch and very soon the actual circuit looks like two 8-ohm impedances in parallel. Hence, the amplifier sees 4 ohms at high frequencies and 8 ohms at low frequencies. The resultant power into and out of the speaker system produces an improvement in high frequencies, as in Fig. 2B.

How then can we make the speaker system present a more constant impedance to the amplifier? We can add a choke in the woofer circuit, as in Fig. 3A. In this case the low-pass filter, the inductor, will prevent high-frequency energy from getting into the woofer. The woofer choke will electrically "open" up the woofer circuit for high frequencies; just as the capacitor opened up the tweeter circuit for low frequencies. In effect, then, a much more uniform 8-ohm impedance is presented to the terminals of the amplifier, with better utilization of audio power.

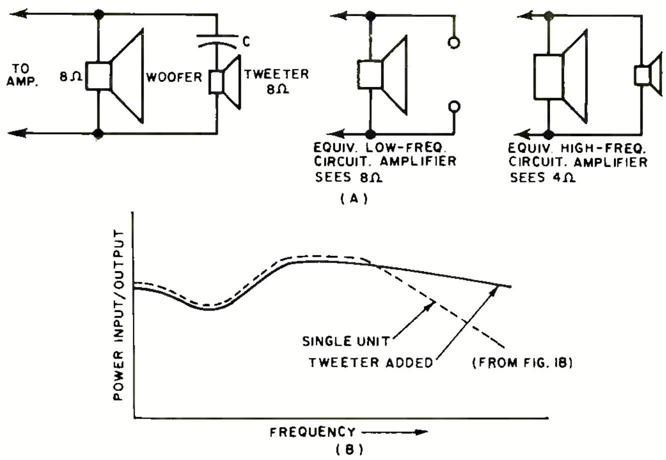


Fig. 2. Use of simple high-pass filter with tweeter or high-frequency projector improves highs but upsets load impedance.

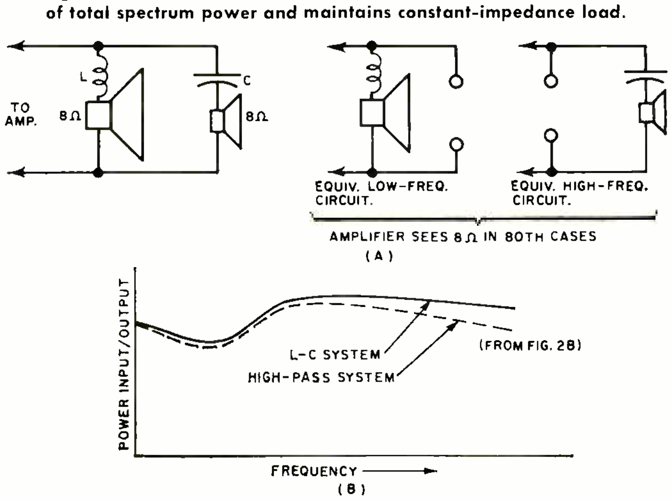
Amplifier Matching Impedance

The advent of the transistor amplifier has made it possible to provide direct-coupled transformerless output circuitry for the loudspeaker distribution system.

Long before the transistor amplifier, and even before the widespread use of the transformer constant-voltage distribution system with conventional tube amplifiers, systems were laid out on a matched-impedance basis. But now, we are going to slay the "sacred cow" of impedance matching. We have been taught to terminate an amplifier in a matched impedance, that is, the speaker or speaker system has to match the *rating* impedance of the amplifier. Not so at all! This condition is necessary only when it is desired to get *maximum* power transfer from the amplifier to the loading system. The actual amplifier impedance may be very low, as low as 0.1 ohm (depending on the feedback characteristic) for a *rating* impedance of "8" ohms.

An amplifier, like any power generator, has some degree of internal resistance (Fig. 4). The current from the amplifier must travel through this internal resistance. There will be a corresponding voltage drop across this internal resistance, which will be in proportion to the current being drawn and the magnitude of the resistance. Obviously, the smaller this internal resistance can be made, the less will be the loss in output voltage at the terminals for a given current delivered to the load. With the present feedback-circuit designs, amplifier internal impedances can be kept quite low so that it is not at all unusual for the difference between no-load output voltage and full-load to be well under 3 dB.

Fig. 3. An LC crossover network provides maximum utilization of total spectrum power and maintains constant-impedance load.



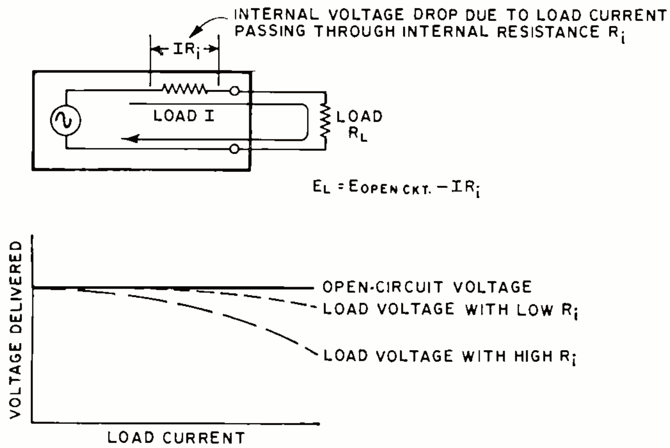


Fig. 4. Amplifiers with low internal impedance provide a constant output voltage that is relatively independent of load.

In general, we are not interested in maximum power output into the speaker system. To try to achieve maximum power utilization from a public-address system where all the power is to be fed into just a small number of speakers would introduce far more distortion than would be tolerable. The distortion would not necessarily be the result of the amplifier, but more likely due to loudspeakers that are rated at how much power they can accept before damage, rather before discernible distortion, sets in.

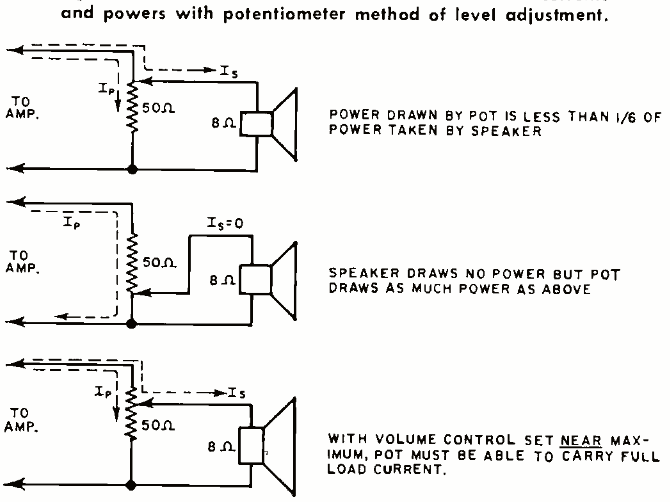
Small Distribution Systems & Level Adjustments

Consider a basic small system, such as in the suburban home, to which it is desired to add extensions to the swimming pool, the patio, or perhaps the den, or all three. Tying on one extension speaker is readily accomplished by simply putting it directly across one of the already installed speakers. With present transistor output circuitry there is no *noticeable* difference in output or frequency response whether the channel be loaded with 8 ohms or 4 ohms.

Having gone from an 8-ohm loading to a "mismatched" 4-ohm loading has not *significantly* affected the power drawn from the amplifier despite the mismatch. We would guess that, in this case of home use with a 50-watt-per-channel amplifier, we would not be drawing from the amplifier more than 2% of its normal full-power capacity. Even considering the more economical 25-watt-per-channel amplifier, the 4 to 5% of full power drawn from the amplifier would be more than enough for most uses.

But how can we control the power level to the added speaker while not upsetting the level to the original speaker. Or how can we cut down, or off, the level to the original speaker and simultaneously provide level adjustment for the

Fig. 5. Distribution of load and volume-control currents and powers with potentiometer method of level adjustment.



extension unit. Obviously, switches provide the easiest solution but these do not provide the convenience of individual adjustment rather than "off-on" operation. Some means of level or volume control must be provided.

If we are dealing with entirely transformerless operation, not only at the output of the amplifier, but at the speakers themselves, then the simplest means available for adjusting level is by use of a potentiometer. Since we are now dealing with power distribution—even if only three or four watts—these volume controls or potentiometers must be capable of handling and dissipating some power.

To prevent undue loading on the amplifier, the volume control for an 8-ohm speaker could be a 50-ohm wirewound pot, rated at say 5 watts, if that is as high as it is ever intended to drive the amplifier under practical circumstances. At maximum volume setting (Fig. 5), the 8-ohm speaker would be directly across the amplifier with the 50-ohm pot shunting the line. In this case, the volume control would draw from the amplifier only about one-sixth of the power drawn by the speaker—in a small distribution system, nothing too much to worry about. At minimum, or near minimum volume setting, the amplifier will see only the total 50-ohm resistance of the potentiometer, and again the pot will draw only a very small amount of power. However, in a complex system with many speakers, it is obvious that the power consumption of a number of such volume controls could add up to an appreciable amount of amplifier power, especially when the amplifier is operated close to its maximum capacity. If an individual speaker is adjusted at near maximum level, all the current being drawn by the speaker passes through the top few turns of the volume control, with possible burn out if the power rating of the pot is too low.

Moderate-Sized Systems

Let us next consider a moderate-sized school auditorium with two column speakers spanning the proscenium, aided by two supplemental speakers to fill in the acoustically shaded areas under the overhanging balcony, and another two speakers to help out in the rear of the balcony—a total of six speakers. For the purist on impedances, there will be an obvious problem of matching the impedance of six speakers rated at 8 ohms to an amplifier rated at 8 ohms. (Four 8-ohm speakers may be connected together in series-parallel in order to achieve an impedance of 8 ohms, but what do you do with six such speakers?)

Certainly we won't tie all the speakers in parallel; this would result in 1.33 ohms, far too low even for an amplifier that could be considered to have a 4-ohm output. Also, should one speaker become shorted out, then the short would be applied directly to the amplifier. Even were there to be no damage done to the amplifier, certainly the sound system would become entirely useless. The alternative of putting the speakers in series is equally undesirable; one open speaker would in this instance take out the whole system. And as far as matching is concerned, the series total impedance would be 48 ohms, which again is too far removed from even an amplifier rated at 16 ohms.

There are at least two better speaker configurations, as shown in Fig. 6, two parallel branches of three speakers in series with the resultant impedance of 12 ohms (Fig. 6A), or three parallel branches of two speakers in series, with a resultant impedance of 5⅓ ohms (Fig. 6B). Which should be used? The answer lies not with what impedance do we want the amplifier to see, but what sound coverage do we expect to get, and what restrictions or conveniences are there. Since the major seating area of the auditorium is to be served by the two proscenium-mounted columns, then most of the electrical output of the amplifier should go to these speakers, with a smaller portion to the pair of speakers under the balcony, and a different amount to the pair covering the upper section of the balcony. An arrangement as in Fig. 6B would make individual level control of each branch relatively easy.

Also important is that this sort of layout can be accomplished by running just one pair of lines from the amplifier to the three speaker branches, with the volume controls installed at each speaker-pair location.

Power Distribution in Impedance Networks

Four equal-impedance speakers may be connected in a series-parallel arrangement to present the same impedance as one speaker to the amplifier (Fig. 7A). In this case, the power delivered by the amplifier is divided equally among the four speakers. For purposes of reliability, a series connection of two speakers in parallel is to be preferred. Should one of the speakers open up, the other three would continue to operate but with changed power input. In contrast, in a parallel arrangement of two speakers in series, if one speaker opens up, its other series member becomes inoperative and the system has lost two speakers instead of one.

There may be some instances where speakers of unequal impedances are coordinated into an impedance-matched system because they may be the only kind available with the acoustic characteristics required. For public-address practice, such a combination might be an 8-ohm speaker and a 16-ohm speaker (Fig. 7B). Two such speakers in parallel result in an impedance of 5⅓ ohms. The voltage drop across the two speakers is the same for both and the power division would be two to one in favor of the 8-ohm unit. This unequal division of power would have to be taken into account in terms of the acoustic coverage expected.

The alternate arrangement of series connection of the unequal-impedance speakers would produce a branch impedance of 24 ohms with a power distribution that would be two to one in favor of the 16-ohm unit.

If the main 16-ohm speaker happens to be a conventional cone-type direct radiator, its maximum efficiency would be no more than about 5%. On the other hand, the auxiliary speaker with the 8-ohm impedance may be of the compression-driver, horn-loaded type with an efficiency of easily 25%. The ratio of power conversion efficiencies of the latter to the former would then be at least five to one. Combining this output efficiency ratio with the actual power taken by the two units gives us $5/1 \times 2 = 10$ for the parallel connection (Fig. 7C). Thus, despite the fact that the 8-ohm speaker is only taking twice as much electrical power as the 16-ohm unit, it is putting out 10 times as much acoustic power.

The situation is not quite so upsetting in the series connection. In this case, the 8-ohm unit is accepting only one-half the power that the 16-ohm unit will take, so that the power efficiency/power-input ratio now becomes $5/1 \times 1/2 = 2\frac{1}{2}$. Hence, despite the fact that the 8-ohm unit is taking only half the input power of the 16-ohm unit, it is producing 2½ times as much acoustic power.

Constant-Voltage Distribution System

The constant-voltage distribution system is a means of distributing audio power without the user having to match impedances or worry about the effect on one part of his distribution scheme by changes or additions. To the knowledgeable p.a. technicians the use of the constant-voltage system is as simple as the use of the utility power line throughout his shop. The 120 volts across the whole system is considered constant. The lamp he plugs across the line is *marked in power*. The higher the power rating, the more illumination; the technician doesn't have to stop to figure the impedance of the lamp. The manufacturer has already done it for him; and has marked the lamp with the corresponding power that it will draw from the 120-volt line (for its built-in impedance). The success of such a system lies in the fact that the system voltage is relatively insensitive to load.

Similarly, if we can depend upon the constancy of the line voltage from the p.a. amplifier, we should be able to realize a number of installation and operational benefits. The advantages are: (*a*) easy on-the-spot sound power adjustment of

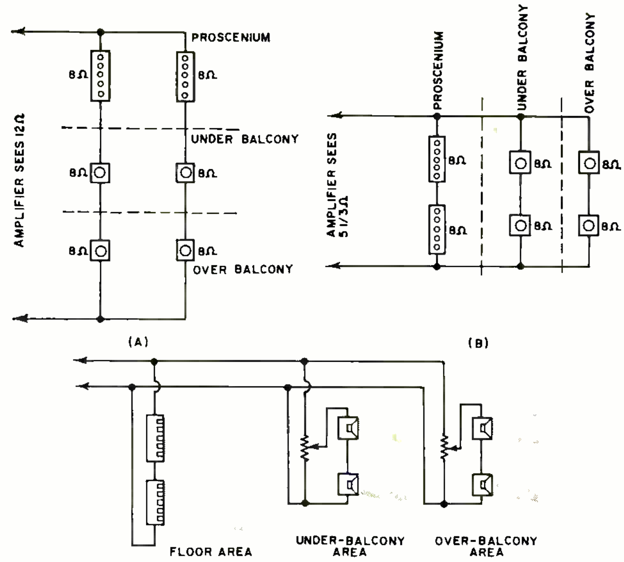


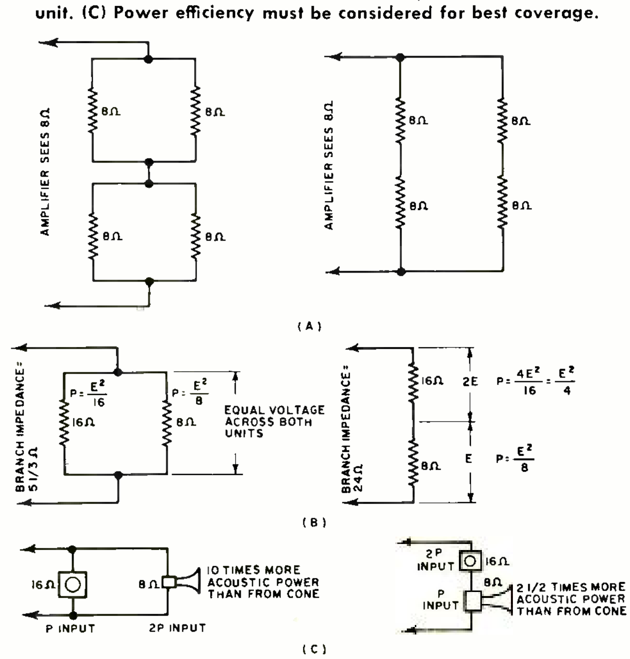
Fig. 6. Multiple speaker networks should be balanced for acoustic coverage as well as impedance-matching properties.

an individual speaker to suit the needs of the particular area served by that speaker without upsetting the level of any other speaker on the line; (*b*) overcomes the need of either installation or operational concern with the impedance concept; (*c*) conserves audio power; and (*d*) provides economy of original wire runs in that only one pair of lines is needed to cover the whole system.

There are some disadvantages to the system. While wire runs are more economical, each speaker or group of speakers requires its own line tie-in transformer and the main amplifier requires one master output transformer. Thus it would appear that transformer costs are high. However, in constant-voltage distribution systems, the individual speakers may often be operated at relatively low power so that fairly inexpensive transformers of 5, 7½, or 10 watts maximum are commonly used.

What is the maximum "constant voltage" that such p.a. amplifiers will deliver? There are three common systems in

Fig. 7. (A) Speakers in groups of four may be connected to produce same impedance as one speaker with equal power division among them. (B) In parallel arrangement, 8-ohm unit receives twice the power of 16-ohm unit; in series arrangement, 16-ohm unit will receive twice the power of the 8-ohm unit. (C) Power efficiency must be considered for best coverage.



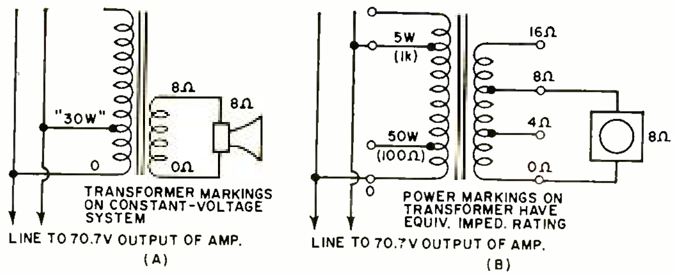


Fig. 8. Constant-voltage line transformers may have only input power markings or be marked in equivalent impedances.

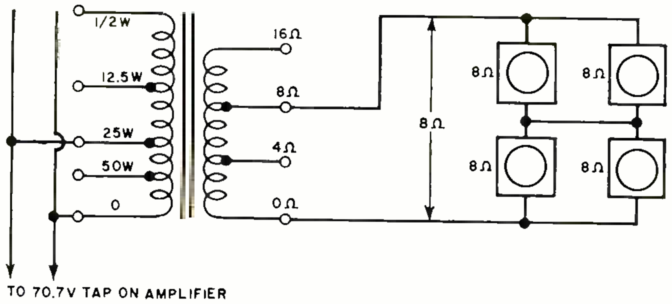


Fig. 9. Network mesh systems may be employed with the constant-voltage system where speaker group may be considered single load.

use; the 140-volt, the 70-volt, and the 25-volt. The 140-volt system is used in areas where there are very large and widespread distribution systems and where large amounts of power are to be transmitted; the high voltage cuts down on the power losses in the line by decreasing the current and the subsequent losses. The 25-volt system is generally used in schools, hospitals, and similar institutions, where the electrical code of the municipality may consider any voltage above 25 volts as dangerous and a fire hazard. The most popular of the three systems and the one most used is the 70, or more precisely, the 70.7-volt system. It meets most community electrical codes as far as hazardous operation is concerned without the need for enclosing the system wiring in armored cable, a matter of great economic importance to the architect and system designer. The reader is referred to Section 640.5 of the National Electrical Code for more complete details on proper installation.

In the matched-impedance system, it is the installer who must juggle the impedance around and calculate the necessary impedance branch values to determine what sort of speaker layout configuration will be required. In the constant-voltage system, this is taken care of by the manufacturer of the amplifier and transformers. When the user gets the line-matching transformer, taps on one of the windings are marked in power, power that will be taken from a 70.7-volt line when the other winding has connected to it a 4, 8, or 16-ohm speaker (Fig. 8A). There are no calculations to be made by the installer.

These relationships will hold for the transformer, provided that the input voltage to the transformer (line voltage) is maintained at 70.7 volts. The amplifier gain control should be set at that point where the loaded amplifier delivers 70.7 volts r.m.s. across the line at program peaks. Once this output voltage is set, then the transformer power ratings that are indicated will hold.

Power across an impedance is $P = E^2/Z$, thus in the 70.7-volt system the power delivered to any load across the system would be $P = (70.7)^2/Z$ which is equal to 5000/Z. The 5000 number makes the transformer impedance for a particular power-marked tap easy to determine for the manufacturer and for the user as well. Assume we have a transformer with an 8-ohm secondary to which is connected a speaker also rated at 8 ohms. It is desired to deliver 50 watts to this speaker. What should be the primary impedance to accept 50 watts from the 70.7-volt line? $Z = E^2/P = 5000/50 = 100$ ohms. Now suppose we want to draw only 5 watts from the line, the primary impedance of the amplifier would now have to be 5000/5 = 1000 ohms. We don't have to go through these calculations; the manufacturer has done it, and conveniently marked these primary taps in terms of *power* (Fig. 8B).

The individual constant-voltage transformer at each speaker makes it possible to quickly adjust the power into the speaker for a given sound coverage. There is another advantage where there is a mix of cone speakers and horn types. Compensation may be quickly made for the greater efficiency of the horn over the cone. If we wanted to get as much power out of the horn as the cone is delivering, and the cone is tied to the 5-watt tap of its transformer, then we would tie the horn to the 1-watt tap of its transformer. This would take into account the 5 to 1 efficiency ratio. If we wanted the horn system to be twice as loud as the cone, we would now step up its tapped position to the 2-W level.

As far as the amplifier is concerned things are spelled out quite simply at its terminal board. The line terminals are marked with "70" volts, or "140" volts, or "25" volts. Naturally, the individual line transformers should correspond to the particular voltage system used; don't use 70-volt transformers on 25-volt systems, for then the markings would be incorrect. However, there are some transformers that have both a 70-volt tap and a 25-volt tap for use at the speaker itself.

There is one limitation as to how far one can go in the process of just tying speakers across the line indiscriminately with transformers, and this limit holds for the transformerless matched system as well. When all the power drains on the line by all the speaker transformers and the speakers are added up, the sum should not exceed the total power capacity of the amplifier. It is easier to add up these powers by counting noses, as it were, in the transformer system. In the matched-impedance system, one would have to make actual voltage measurements across each individual speaker in use, convert the individually measured voltages to power, and then add them up.

What shall we do with a transformer that is marked in impedance with no mention of power, and we wish to use it on a constant-voltage line? Using the number 5000 which we derived above, we can easily convert primary impedance ratings of a transformer to power ratings. As an example, suppose the transformer had a primary marked 167 ohms and a secondary marked 8 ohms. What power would this transformer take from the 70.7-V constant-voltage line for its 8-ohm speaker load? As from above $P = 5000/Z = 5000/167 = 30$ watts. If there were a tap marked 335 ohms, this would solve out as 15 watts (or 3-dB down). Some manufacturers of constant-voltage transformers indicate along with the power the actual impedance that a tap represents when the transformer is loaded with the proper secondary impedance. This universal transformer can be easily used in a true constant-voltage system or in "mix and match" networks of speakers where the transformer is used simply as a level control rather than across the line.

To show that we are not completely "anti-user-impedance" minded, there is nothing to prevent the system designer from combining the two system philosophies if the situation warrants. He may use a line transformer to feed a combination of series-parallel circuits if he so desires (as in Fig. 9) with the advantage that he can have many such groups where each group is relatively independent of the others because they are coupled to the constant-voltage line through their own group transformer.

(*Concluded in December issue*)

EDITOR'S NOTE: *A subsequent and concluding article in this series on p.a. systems will go into the loudspeakers themselves. The various types will be discussed along with their comparative characteristics.*

The author directs the Engineering Technician activities at Hazeltine. His group performs the assembly of engineering prototype systems and the design, layout, fabrication, and assembly of PC boards. After serving five years in the U.S. Army Signal Corps, he joined the company in 1945. He assisted in setting up and currently directs the activities of the company's Printed Circuit Lab. He has given technical papers and holds two patents.

Printed-Circuit Technology

By SAL DiNUZZO / Head, Engineering Technician Div.
Engineering Dept., Hazeltine Corporation

An overview of the important characteristics and fabrication techniques of printed wiring. Practical information on making and using PC boards included.

SUCH engineering triumphs as the Apollo moon shots would have not been feasible if it had not been possible to reduce the weight and size of the interconnecting wiring of the electronic hardware. A giant stride forward in that direction was the development and refinement of the technology for the fabrication of printed wiring. If it had been necessary to use discrete hook-up wire and power bus-bars, the vehicles would have weighed almost too much to get off the ground. In addition, the countdown blast-off too would have been much longer because of the inordinate time required for checkout and testing of the discrete hook-up wiring.

The development of printed-circuit (PC) boards has kept pace with the fast-moving aerospace industry. Today we use PC boards in applications that were unheard of a decade ago: in motors, antennas, transformers, equivalent coaxial cables, and other applications. For more mundane applications, the PC board is the mainstay of the interconnection world.

Discrete versus Printed Wiring

Even the most ardent promoter of printed wiring will admit that there are many instances where discrete point-to-point wiring can do a better job. To help equipment designers decide between discrete and printed wiring, listings of advantages and drawbacks are presented in Tables 1 and 2. Table 2 is a cost-evaluation table developed by one major electronics company (*Hazeltine*) for the guidance of its engineers in deciding on the most economical choice between discrete wiring and the many different PC techniques. This chart shows the relative cost percentage increase for a given PC board design as related to the type of plating employed. Note the increase in cost as the design becomes more complex and sophisticated. Additional characteristics are noted relative to space, solderability, and corrosion resistance.

PC Board Sizes

Irrespective of the environment for which PC boards are designed, there are practical maximum and minimum dimensions. The size is usually selected as a compromise between conflicting requirements.

Large PC boards containing large amounts of circuitry and circuit interconnections require fewer external inputs and outputs and fewer connectors. This is particularly advantageous for high-speed logic or wide-band video circuits, because the high-frequency signals involved can often be confined to a single board, and thus need not enter the external board-to-board wiring. However, large boards require special provisions for mechanical support in order to satisfy both vibration and shock requirements. Twist of the base material makes automatic dip soldering or flow soldering troublesome. Also, large boards become costly to replace if damaged areas cannot be repaired, or if defective parts cannot be replaced.

Small PC boards in multiple quantities usually entail many interconnections, which results in a reduction of reliability. Connectors add weight and increase costs. However, small boards do not always dictate a higher cost per square inch because multiple fabrication techniques may be employed. For example, small PC boards can often be designed so that multiple boards may be laid out, fabricated, assembled, soldered, and finally cut apart before actual delivery.

Whenever possible, a standard size for modular construction should be considered. Standardization in size frequently allows the duplication of common design features among different boards and thus reduces costs by saving design man-hours.

The Printed-Circuit Industry

The Institute of Printed Circuits (IPC), 3525 Peterson Rd., Chicago, Illinois 60645, is conducting a two-phase survey designed to measure the size and scope of the printed-circuit market. The first phase is a study of the dollar value of printed-circuit boards produced and sold in 1968 by 80 independent producers. A detailed response of the participating companies has indicated sales of approximately $152,000,000 including single- and double-sided PC boards, multilayer PC boards, and flexible PC boards. The analysis

Advantages of Printed Wiring
1. Lower cost of interconnections for large-volume production.
2. No conductor-interconnection errors.
3. Reduction in test time.
4. Repeatable wiring for critical circuit layouts (shielding and isolation).
5. Lower assembly cost with automatic component insertion and soldering equipment.
6. Lower weight because of lack of insulation and associated hardware.
7. Improved reliability because of repeatability and better solder joints.
8. Parts easily identified.
9. Circuits more easily protected against environment.
10. Miniaturization simpler and less costly.
Disadvantages of Printed Wiring
1. Inflexible to change and repair.
2. Expensive for low or medium quantities.
3. Design usually restricted to one plane.
4. Higher skills required for layout, design, and assembly.
5. Thermal and vibration design difficult and often impossible.
6. Special equipment and tools required for assembly and repair.
7. Purchasing difficult because of complexity of product.

Table 1. Characteristics of printed wiring compared to discrete.

showed that the companies operated at about two-thirds of total capacity.

This phase of the survey also covers plans for expansion this year. The same 80 companies presently have a combined total of more than 8700 employees and plan to add approximately 2500 within the next 12 months, a manpower increase of almost 30 percent. Additional floor space, as well as new equipment, is also planned. This expansion should be sufficient to handle the increase in demand for printed-circuit boards and other printed-circuit products during 1969 and 1970.

Of particular interest was the IPC estimate of printed-circuit boards produced "in-plant" by various companies not included in the phase-one survey. It was estimated that approximately the same dollar value as shown by the 80 participating companies was "in-plant." This means an additional $152,000,000 or a total market value of $304,000,000 for 1968.

Making a Printed-Circuit Board

In the design and fabrication of printed-circuit boards, inputs are usually necessary from several engineering groups, such as electrical, mechanical, industrial, and chemical fields. These professions are supported by specialized skilled craftsmen.

Before layout can be started on printed-wiring artwork, the electrical engineer usually furnishes a schematic or logic diagram with reference designations (when applicable) and a component list. The mechanical engineer usually furnishes an outline drawing or engineering sketch of the circuit board.

A. ELECTRICAL SCHEMATIC

The schematic of the circuit is usually provided by the electrical engineer. The schematic should be complete and must contain the following important items of information:

1. All inputs, outputs, test points, and internal connections should be indicated. The interconnections between subassemblies should be designated (and cross-checked with an outline drawing, if available). Connector pins should be designated. An attempt should be made to standardize voltage and ground pins common to the particular equipment.

2. All circuitry and leads should be isolated. Shielding should be noted where it is required.

3. All tube pins, transistor leads, diode leads, transformers, test points, relays, and other terminal components should be numbered, and polarity indicated, where applicable. Direction of rotation of potentiometer shafts (as viewed from the shaft end) should be shown.

4. All voltage values and ground points should be designated. Peak voltages should also be noted. These reference voltages are needed to determine the spacing between conductors, whether or not the board is coated.

5. Any special configuration requirements, such as short lead lengths, orientation of components, minimum capacitance, voltage gradients, and ground planes should be noted.

6. A complete component list, including part numbers, should be provided. When a specific part number is not available, information as to physical configuration and method of mounting should be included. All component values should be indicated, as well as voltage and wattage ratings.

7. If the schematic covers more than one PC board, the boundaries of each board should be shown by enclosing its circuitry with a broken line.

B. OUTLINE DRAWING

The outline drawing is usually furnished by the mechanical engineer. The outline drawing should be complete and contain the following information:

1. The dimensional outline and stock thickness of the board.

2. The board mounting or locating holes and any mounting holes for special hardware or brackets.

3. When applicable, clearance between adjacent boards and between boards and surrounding chassis or other adjacent components.

4. Maximum projection of components (when available).

5. Board material, plating, and finishes (when available).

6. Datum lines ("X" and "Y") from which all holes and contacts are to be referenced. Holes located on these reference lines are usually manufacturing holes.

7. If the printed-wiring board is one of a family of similar boards, the outline drawing should contain all the common features (outline dimensions, contact fingers, mounting holes, material, finishes, reference dimensions, manufacturing holes, test points, keying dimensions, and reference drawing numbers).

C. PRELIMINARY ARTWORK

The preliminary artwork establishes the basic format for the board. All the trim lines, ground conductor, connector, and mounting-hole marks, and other fixed patterns are accurately placed on the preliminary artwork. This step is used when multiple similar boards are to be laid out. Only the common features which appear on all boards are shown on the preliminary artwork.

The finished size of the PC board is established by the outline drawing. The most practical scale for the artwork is four times the finished size, but the size of the board and the required line definition may dictate the choice of another scale. For example, if the board is longer than 10 inches, two times the finished size should be employed. For any artwork larger than four times the finished size, a check of camera limitations should be made. Where possible, the artwork pattern should not exceed 24" × 36" because of the increase in material and other costs.

The preliminary artwork for single-sided boards is made as if viewed from the *solder side* (conductors). It is important to remember that a 180° shift (mirror image) in views is common unless lettering or nomenclature is used on the conductor side. The process is the same as for a two-sided board except for the component-side view and registration marks.

The following procedure is typical for preparation of preliminary artwork for two-sided boards:

1. Secure a grid sheet to the sloping front of a light box. The next step is to overlay with a translucent Mylar film (Stabilene), with the matte side up. Allow sufficient blank border for the reference outline dimensions, trim lines, and registration marks. This will be the *component side* of the board.

2. Designate all corners of the board using printed-wiring tape. The trim lines should never be less than 1/32 inch from the artwork pattern on the finished board. Trim lines are only for use during the preliminary fabrication cycle.

3. Affix appliques or printed-circuit drafting aids on the finger or connector area, manufacturing holes, X-Y grid reference, and any other repetitive items such as ground strips, board extractor holes, and test points.

4. Lay down the registration marks.

5. Remove the component-side artwork and turn it face down on the grid. Center the manufacturing holes on the grid intersections. Overlay with another Mylar film of the same size, which will be the solder side of the board. Secure the second sheet, matte side up, to the first.

6. Lay down the registration marks within the designated tolerance (usually 0.002 inch) of those on the component-side layout.

7. Repeat the applicable parts of steps 2 and 3.

D. LAYOUT

To determine whether all parts and printed wiring will fit within the usable area of the board, a free-hand sketch showing the conductors is made (Fig. 1).

The following procedure is typical for a two-sided board.

1. After securing a grid sheet to a light box, overlay it with

Table 2. Various manufacturing techniques used for PC bg over and above the cost for the copper-etched board. cost percentages represent additional costs for the platinoards, along with characteristics and costs. Note that the

FINISH	DESCRIPTION	METAL THICKNESS	PLATING COST PERCENTAGE	ADVANTAGES	LIMITATIONS	APPLICATIONS
A	One-Sided, Copper Etched (No Plating)	Copper Clad — 1 oz , 0.00135 in ; 2 oz , 0.0027 in	-	Least costly; no space restriction; max. tolerance permissible	No corrosion & tarnish resistance; poor solderability	Commercial products, instruments, throw-away segments
B	One-Sided, Solder Plated	Solder (Sn60-Pb40), 0.0005 in min.	30	Solderability better than Finish A; eyelets can be used	Limited corrosion & tarnish resistance; number of circuits	Same as Finish A
C	One-Sided, Nickel Gold Plated	Nickel, 0.0005 in min. Gold, 0.00005 in min. (22.8 K min.)	50	Corrosion & tarnish resistance; no space restriction; good solderability; eyelets can be used; low noise voltage	Number of circuits	Switches, commutators, slip-rings
D	One-Sided, Nickel Rhodium Plated	Nickel, 0.0005 in min. Rhodium, 0.00002 in min. 0.00005 in max.	50	Corrosion & tarnish resistance; anti-galling; good sliding surface	Non-solderable; sources of supply	Switches, commutators, slip-rings
E	Two-Sided, Copper Etched (No Plating)	Copper Clad — 1 oz . 0.00135 in ; 2 oz . 0.0027 in	-	Less costly; eyelets & funnelets can be used	No corrosion & tarnish resistance; poor solderability	Low cost, commercial
F	Two-Sided, Plated-Thru Holes (Holes Sensitized, Surface Resisted, Solder Plated).	1 oz . Copper Clad — Copper Plate, 0.001 in ; Solder, 0.0005 in 2 oz . Copper Clad — Copper Plate, 0.002 in ; Solder, 0.0005 in	100	Space saving; circuits on both sides; fair solderability	Reproduction varies with plating technique; undercutting prevalent; limited corrosion & tarnish resistance	Miniaturization
G	Two-Sided, Plated-Thru Holes (Holes Sensitized, Copper Plated, Surface Resisted, Solder Plated).	1 oz . Copper Clad — Copper Plate, 0.001 in ; Solder, 0.0005 in 2 oz . Copper Clad — Copper Plate, 0.002 in ; Solder, 0.0005 in	140	Space saving; circuits on both sides; good reproduction; less undercutting than Finish F	Limited corrosion & tarnish resistance	Miniaturization, close tolerances, high quality
H	Two-Sided, Plated-Thru Holes (Holes Sensitized, Surface Resisted, Copper, Nickel, & Gold Plated)	1 oz . Copper Clad — Copper Plate, 0.001 Nickel, 0.0005 in ; Gold, 0.00005 in 2 oz . Copper Clad — Copper Plate, 0.002 in ; Nickel, 0.0005 in ; Gold, 0.00005 in	120	Space saving; circuits on both sides, long shelf life	Reproduction varies with plating technique; undercutting prevalent	Miniaturization
I	Two-Sided, Plated-Thru Holes (Holes Sensitized, Copper Plated, Surface Resisted, Nickel & Gold Plated).	1 oz . Copper Clad — Copper Plate, 0.001 in ; Nickel, 0.0005 in ; Gold, 0.00005 in 2 oz . Copper Clad — Copper Plate, 0.002 in ; Nickel, 0.0005 in ; Gold, 0.00005 in	160	Space saving; circuits on both sides; long shelf life; good reproduction; less undercutting than Finish H	Sources of supply	Miniaturization, close tolerances, high quality
J	Same as Finish F & H Plug-In Connections, Nickel & Rhodium Plated	Same as Finish F, Plug-In Connection: Nickel, 0.0005 in ; Rhodium, 0.00002 in min. 0.00005 in max.	180	Circuits on both sides; good plug-in connection wear	High cost; sources of supply	Miniaturization
K	Same as Finish G & I Plug-In Connections, Nickel & Rhodium Plated	Same as Finish G, Plug-In Connection: Nickel, 0.0005 in ; Rhodium, 0.00002 in min. 0.00005 in max.	220	Circuits on both sides; good plug-in connection wear	High cost; sources of supply	Miniaturization, close tolerances

the preliminary artwork (component side). Register the holes on the grid, and overlay the preliminary artwork with a piece of tracing paper.

2. Lay down all required pads, centering them on grid intersections. One pad is required for each component lead. The pads should be the same size for like components. Using a black lead pencil, sketch in the components or symbols between pads.

3. Indicate connections between component pads using different colored pencils or solid and dotted lines to represent the component side and solder side of the board, respectively. The same lines should never cross.

Note: Keep all components which are associated with inputs and outputs at the bottom portion (near the connector) of the board. In many cases this will not be possible. Therefore, an area on each side of the board should be left free for bringing the conductor leads down to the connector. Special consideration should also be given to test points that may be used.

Caution: Be sure that the proper spacing is maintained between pads and conductors and between conductors. Remember that the width and spacing of the pencil lines are not in proportion with the actual conductor pattern.

The procedure for the layout of a single-sided board is the same as for a two-sided board. Only one color or solid-black lines are used. The layout is viewed from the *component side.*

E. ARTWORK

The artwork (Fig. 2) is a tape-up representation from which the master pattern is generated. It contains all the features required on the finished board and must be accurately scaled.

The following procedure is typical for a two-sided board:

1. Secure the grid sheet to the sloping front of a light box and overlay it with the preliminary artwork (component side). Register the holes on the grid intersections.

2. Using the layout as a guide, duplicate the pad patterns on the artwork. The pads should be centered on the grid intersections within the tolerance allowed (usually 0.005 inch).

3. Interconnect the pads as indicated on the layout (color pencil lines or solid black lines) using the printed-wiring tapes. Do not cover the holes in the pads because this side is usually used for subsequent drilling operations. The doughnut-shaped pads are used as a drilling guide when the fabrication technique employs hand drilling.

4. The component side of the board is usually identified by placing the assembly part number within the field of the artwork. The lettering should have the same contrast as the artwork tape (the lettering should be opaque).

5. Remove the component-side artwork from the light box and reverse so that the taped-up artwork is face down. Register the holes on the grid intersections and overlay it with the preliminary artwork (solder side), registering both artworks within the allowed tolerance (usually 0.002 inch), using the registration marks.

6. Lay down the lines as indicated by the colored-pencil line or dotted line of the layout. Cover all the holes in the pads. Make sure the line tape is pressed tightly against the artwork in the vicinity of the pad to prevent reduction in the line width during the photographic generation of the master pattern.

7. Using the pads on the component side artwork as a guide, lay down the pads within the specified tolerance (usually 0.010 inch).

F. MASTER PATTERN

The master pattern, which is usually supplied on a stable photographic film, is a copy of the completed artwork. It is made shortly after the completion of the tape-up artwork because the tape-up is only a temporary representation of the pattern. The tape is subject to creepage and loosening. Sometimes features fall off the tape-up over a period of time. The mastern pattern is employed as a tool which, when reduced to the final scale, is used in the manufacture of the printed-circuit board.

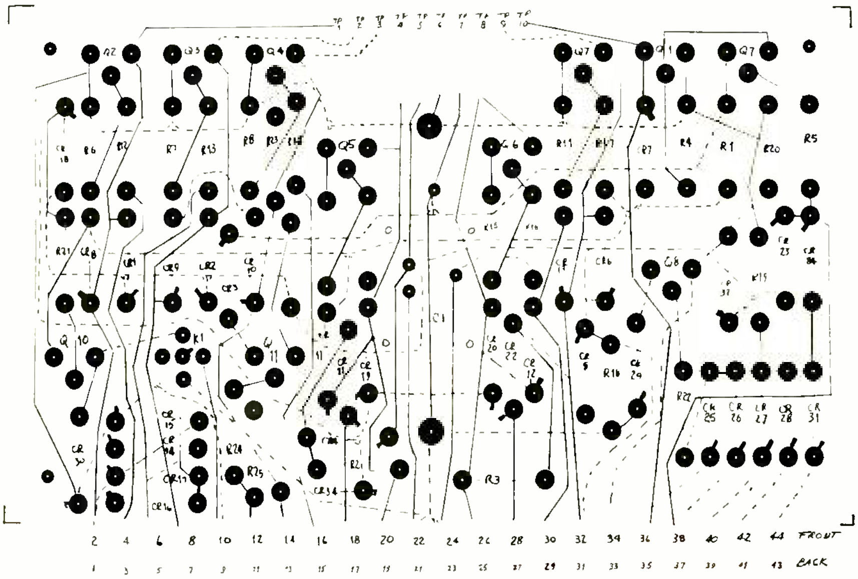
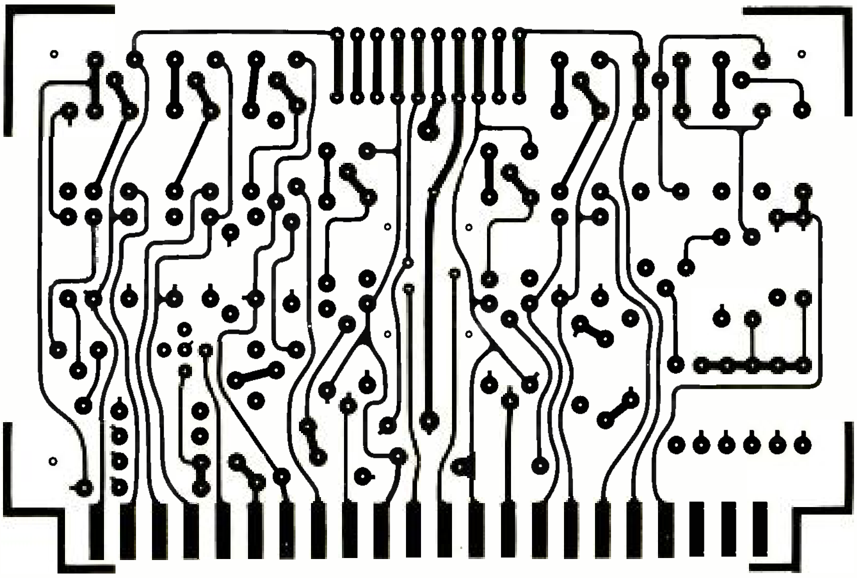


Fig. 1. Free-hand drawing showing typical layout of a PC board.

Fig. 2. Finished artwork from which master pattern is produced.



Basic Fabrication Process

The fabrication process for printed-circuit boards is similar to the photographic process used in lithography. There are many different methods which can be employed to create a circuit pattern. The two major methods are the *additive* and *subtractive* processes. The additive process deposits the desired conductor pattern on an unclad non-conductive base. This process is usually proprietary and is becoming more popular because of its potentially low cost. The subtractive process is most commonly used throughout the industry. This method etches away unwanted metal from a completely clad base, leaving the desired circuit pattern clad on the non-conductive base.

When large quantities and low cost are desired, silk screening is used to print the pattern. This method is easily repeated and requires standard skills and equipment. Hole-drilling equipment is programmed to the standards used during layout. If too many different hole sizes are used in the design, the board price increases due to repeated drilling set-up costs.

High-density board designs require close spacing, fine lines, and high definition, and are therefore more expensive to fabricate. Screen patterns cannot be used because screening inks (resist) have a tendency to flow after deposition and definition is generally poor due to inherent screening problems. The method for producing the pattern on high-density boards (spacing below 0.015 inch) requires the use of photographic resist. This is a liquid photosensitive emulsion which gives excellent results on fine-line definition. Special skills must be developed for its application, processing, and handling. Surface adhesion and resist breakdown during plating and/or etching are the most common causes for failure. Process repeatability requires careful in-process quality control and, preferably, an environmentally controlled working area.

The latest development in sensitized surfaces for printed-circuit boards is a photosensitive sheet film resist known as "Riston." This material was developed by *DuPont* and requires special laminating equipment for its application. The exposure and development processes are the same as with liquid photo-resist. In addition to the high-definition capabilities, the film has a tough surface which requires minimum touch-up, thereby reducing cost. This processing technique is gaining popularity, particularly with companies who have in-house PC board fabrication facilities.

PC Breadboard Technique

There are a number of simple ways to breadboard a printed-circuit board without generating artwork or going through the formal layout steps. One favorite is to use pre-punched insulated boards manufactured by a number of companies. Terminals are staked into position and interconnections are made by using wire jumpers between terminals; mounted connectors and other features are hand-wired into place. The only special tool needed is a set of dies to stake the terminals.

The use of these simulated PC boards enables the designer to closely approximate the final product. In fact, this technique is often employed for limited-quantity production and experimental units. The obvious limitation in this breadboard technique is that imposed by the fixed-hole pattern. The technique allows changes and addition to be easily made.

Another breadboarding method employs copper-clad laminates upon which drafting-aid tapes are affixed to form the interconnection pattern. The tapes perform the same function as the resist does during the etching cycle. The tape-up is similar to that used on the artwork but it is laid out at final scale. These etched-circuit kits are available in many variations under different tradenames.

Repair and Handling

When repairing PC boards, it is necessary to develop high-quality workmanship skills using special techniques and tools. Repair kits are available which not only contain unique tools but also such items as copper foil, epoxy cement, conductive epoxies, eyelets, solvents, swabs, and other special items. Some common faults which require repair are as follows:

1. Damaged conductors (cut lines).
2. Lifted conductors (lines, pads).
3. Blistered or delaminated base materials.
4. Poor conductivity of connector contacts.
5. Component replacement.
6. Warped boards.
7. Addition of components.
8. Damaged plated-through holes.

Don't scratch conductors.

Don't stack boards without protecting surfaces.

Don't dip-solder while the board is ladened with moisture.

Don't use flux-ladened solvents for cleaning.

Don't use excessive heat and pressure.

Don't electrically overload conductors and components.

Do handle board along edges (like a color slide).

Do prevent moisture absorption.

Do keep clean.

Do use proper heat sinks, crimpers, and bending tools.

Do package in containers to avoid abuse.

Do remove contaminants from under components (flat packs, transformers, and pots) resting on board surfaces.

Table 3. Listing of handling do's and don't's for PC boards.

The techniques for making repairs dictate the special tools and skills required. For example, a cut line is repaired by first tinning the broken conductor and pre-tinning the bottom of a strip of copper foil which is cut to the proper width. The foil is then reflow-soldered in place, using a fine-tipped pencil soldering iron. It is customary to cover the repair with epoxy cement after it has been properly cleaned.

It is essential to note that contamination of any type during board repair is certain to produce subsequent failures. Unlike discrete insulated wires, conductors on boards rely on base-laminate resistivity for their successful use. A common error in board repair is the failure to remove *all* flux and residue to prevent organics (flux and dirt) from reducing the surface resistivity and eventually forming unwanted conductive paths both inside and on the surface of the dielectric base material.

Never handle a PC board in a rough manner. The useful life of a PC board is dependent upon its history of treatment during the fabrication and assembly phases. Even if a board is designed for a rugged environment, rough handling should not be tolerated. Special skills in handling must be developed to insure optimum success during the total life cycle. A listing of important handling do's and don't's are shown in Table 3.

PC manufacturers commonly package their finished products in a plastic zipper-top bag. This lends itself to re-use of the bags during storage, assembly, and testing phases by the board user. Dirt and scratched conductors, prime causes of circuit failure, are avoided by using these bags.

An equally important failure factor is moisture absorption. Blistering and delamination occur more frequently during humid periods. Conductors lift more easily when gases and moisture are driven from the base material due to high heat. It is recommended, during high-humidity conditions, that the moisture content of the PC board be reduced before dip soldering (use a slow baking cycle or pack in desiccant over a period of time). ▲

The author joined the company in 1960 with a sales engineering background in commercial refrigeration. He studied at NYU and Hartford Institute of Accounting.

High-Density PC Boards

By HAL R. ROFFMANN, Jr./Executive Vice-President
The Sibley Company

Smaller components and more complex equipment have led to higher density and multilayer boards. Here is how the user can help to alleviate some of the manufacturing problems and reduce his costs.

HIGH-DENSITY electronic packaging has caused severe problems for the printed-circuit manufacturing industry. Smaller conductor lines, tighter spacing, stringent hole locations, relationship of hole size to pad size, and plating requirements specified to satisfy a variety of soldering techniques all add up to process and production difficulties in determining manufacturing yields and in predetermining costs.

What is meant by a high-density printed circuit? Actually the amount of circuitry on a printed circuit has little to do with the number of processes involved. A circuit with two holes and one conductor line will travel the same route in process as its more complicated brother. A circuit with many terminal areas and conductor lines will only require more time in hole drilling, retouching, and inspection. All of the other processes remain the same.

Although the number of processes is the same, the most significant difference between the simple and the dense printed circuit is the size of the multiple-image panel which can be used. A variety of factors dictate the feasible size of a panel for manufacturing purposes. Obviously, it would be prohibitively expensive to manufacture a circuit of reasonable size one at a time. The usual technique, therefore, is to step-and-repeat the image photographically and to apply as many processes as possible to the panel or "flat" containing a number of circuits which are separated later in the fabrication process.

Fig. 1 shows a plated-through hole circuit which can be manufactured in a panel containing eight circuits. The following characteristics had to be analyzed in order to determine if an "8-up panel" would be feasible.

1. Physical size of the panel: It must be compatible with all plant equipment, such as tanks, drilling equipment, and screens.

2. Relationship of holes to circuitry pattern: The holes in this circuit, as related to their surrounding terminal area, will yield a nominal 0.020" of metal remaining between the edge of the hole and the edge of the terminal area. The specification for minimum annular ring tells us we must have 0.010" minimum metal remaining after all processing. This results in an over-all tolerance of 0.010" which will permit the pattern to be applied by the screening process over the total distance of the 8-up panel. The tolerance used up in screening can be as much as 0.005", which leaves us an additional 0.005" for other processes.

3. Plating specifications: Plating thicknesses must be in the normal range: Copper, 0.001" to 0.002"; nickel, 0.0002" to 0.00005"; gold, 0.00005" to 0.0001"; or solder, 0.0003" to 0.001". If plating thicknesses are specified beyond these ranges, too large a panel may develop high-current density areas which can result in unequal amounts of electroplate being deposited over the entire area.

4. Hole sizes and tolerance: If a wide range of hole sizes is specified, too large a panel will cause difficulty in plating down to the desired diameters. The circuit in Fig. 1 requires only 3 sizes, the smallest being 0.030". It must be remembered that the final diameter of a plated-through hole is created by electroplating. Therefore, the drilled size has to be substantially larger than the specified finished hole diameter.

5. Order requirements: Two factors which are often overlooked by both the customer and the manufacturer are *time* and *money* as related to manufacturing feasibility. Tighter-than-normal tolerances can easily be met (*a*) when the requirement involves only a small number of circuits (1 to 25 pieces), (*b*) when the economics of the procurement permit high cost per unit ($25 to $50 each for a circuit which, in large quantity would cost $8-$10), and (*c*) when sufficient time is available for careful tooling and processing by the manufacturer.

In view of the many assessments necessary to successful compliance with high-density specifications, it becomes mandatory for close communication with potential suppliers. This line of communication must be opened very early in order to avoid designing into a potential trap. Design criteria and specification writing should be done in consultation with the printed-circuit supplier or suppliers. Time-consuming or not, this policy can preclude the possibility of expensive or even impossible criteria creeping into specifications and on to blueprints.

High-density printed circuits can best be defined by listing their characteristics. Any *one* of these items prevalent in either the design or its related specification will place the circuit in the high-density category.

Design:

1. Conductor widths (at 1:1) of less than 0.010".
2. Spacing between conductors or terminal areas (at 1:1) of less than 0.010".

3. Dimensional hole locations, expressed either in true position or a linear dimension equivalent to ±0.003″.

4. Integrated-circuit hole patterns, with or without conductor lines passing between the holes.

5. Plated-through hole diameter tolerances less than ±0.005″.

Specifications:

1. Front-to-back registration of less than ±0.005″.

2. Annular ring requirement allowing less than ±0.010″ from the nominal. Example: Pad (terminal area) diameter at 1:1 is 0.062″. Finished-hole diameter is nominally 0.040″. Annular ring (amount of metal remaining between edge of hole and edge of pad) specified is 0.005″. Nominal annular ring is 0.011″, leaving permissible mis-registration of hole and surrounding pattern of only ±0.006″.

3. Spacing or conductor dimension tolerances less than ±0.002″.

The most significant factor in all of the criteria related to distinguishing between a high-density printed circuit and a "normal" printed circuit is the relationship of the plated-through hole to its surrounding terminal area. This becomes the focal point for a multitude of accumulated tolerances. The designer's first consideration should be "functional acceptance." In consultation with his quality-assurance engineers, it must be decided exactly what will constitute a reliable solder connection at the terminal area for the desired end result. For example, it is obviously not the prerogative of the printed-circuit manufacturer to determine whether a minimum annular ring of 0.003″ will yield a solder connection substantial enough for the environmental conditions of the end equipment. In some applications, the plated-through hole can drift all the way to the very edge of the terminal area without causing any detrimental effects to the integrity of the device, while in other equipment it may be mandatory to leave no less than 0.010″ of metal remaining at any point in the 360 degrees of the terminal area. Although a determination of solder-joint reliability is difficult, it is of extreme importance in order to avoid over-specifying, or imposing impossible tolerance restrictions on the manufacturer.

The following factors are involved in the accumulation of annular ring tolerances:

1. Artwork Preparation: The tolerances start to disappear even at 4:1. Commercially available tapes and terminal areas (pads) have a tolerance. A pad which, at 1:1, should be nominally 0.062″, at 4:1 can be as much as 0.002″ out of dimension. Before it is even laid down on the Mylar, a potential 1:1 dimension of 0.0005″ can be missing. The method by which the pads are applied to the Mylar master is of extreme importance. Laying pads down by hand on a grid can use up as much as 0.10″ at 4:1, with a resulting 0.0025″ disappearing at 1:1.

2. Hole Drilling: Many different types of equipment are used in the industry for drilling printed circuits. The most accurate drilling can be achieved with numerically controlled tape equipment. Although some of the equipment manufacturers advertise repeatable tolerances of 0.0005″ to 0.001″, in actuality the printed-circuit manufacturer is achieving 0.0015″ to 0.002″ and, in some cases where equipment is not properly maintained, even greater variances. Production quantities also involve stacking of panels during the drilling operation. If this is not done judiciously, drill wandering will further compound hole drift.

3. Pattern Delineation: The least expensive method of applying a printed-circuit pattern is by screening. Further cost benefits are realized due to the fact that screening inks will withstand plating cycles more reliably than other direct photo-printing methods. There is less breakdown of the plating resist and, therefore, less subsequent operations for removal of unwanted plating. With a carefully controlled screening operation, many high-density patterns are "screenable." Depending upon the size of the multiple-

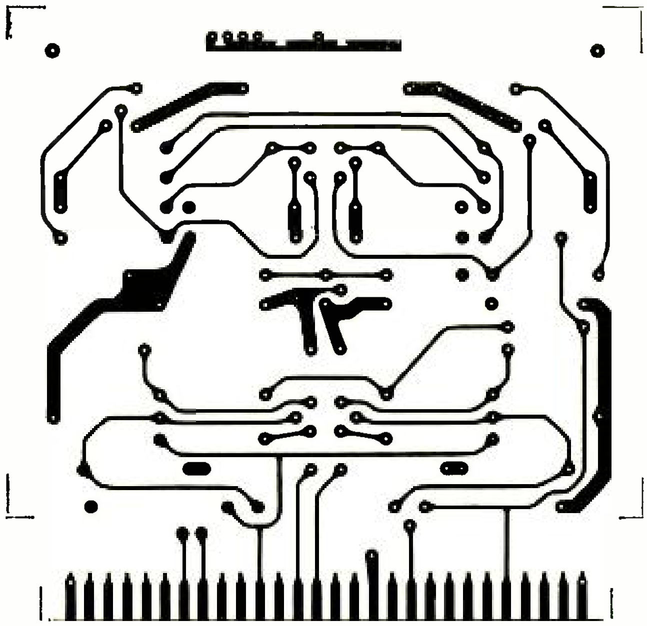


Fig. 1. Example of circuit requiring only three hole sizes.

image panel, however, there is enough movement of the screen during the operation to cause pattern shift up to 0.005″. Here, again, the terminal area is moving in its relationship to the pre-drilled hole.

4. Plating: Plating build-ups can change the terminal area dimension significantly. Therefore, allowances must be incorporated in the master artwork commensurate with the plating specifications. Where tight spacing and tight conductor width tolerances are specified, the master artwork may have to be drawn on the low side, on the nominal, or on the high side of the tolerances depending upon the metals to be plated, their respective thicknesses, and their sequence.

5. Etching: The thickness of the copper foil on the base material will have its effect on the end dimensions. The least effect on the artwork dimensions is achieved by using 0.0014″ (one-ounce) copper foil and then pattern plating the rest of the required copper. This leaves a minimum amount of unwanted copper under the plating resist, and etching can be achieved with less undercut and a minimum effect on the pattern dimensions.

A tolerance study of the foregoing steps in creating a printed circuit reveals some disturbing facts. When the manufacturer receives the master artwork he stands a good chance of having lost 0.0025″ of tolerance before the photographic reduction. Assuming that the reduction is extremely accurate, he then proceeds to manufacture faced with the certainty that he will lose another accumulation of at least 0.007″ just between hole drilling and screening. If the plating and etching processes cancel each other out dimensionally, he will reach the end of the road having used up a total of 0.0095″. Thus, if a terminal area is laid out at 0.062″ and is to contain a 0.040″ hole with an annular ring specification of 0.005″, the only additional remaining tolerance for the manufacturer is 0.0015″. Although this is a "worst-condition" analysis, it points up the critical aspects of high-density circuit design as related to the allocation of necessary tolerances for manufacturing feasibility.

When high-density packaging imposes designs and specifications which approach optimum manufacturing capabilities, consideration must be given to expanding the design to multilayer boards. Relief in conductor-line proximities and hole size to pad size relationships can be accomplished by using the multilayer technique. It is often more economically feasible to design a more expensive multilayer printed circuit than to attempt to achieve the same functions on a two-sided, extremely dense printed circuit. ▲

The author holds B.S., M.S., and Ch. E. degrees in Chemical Engineering from the State University of Iowa and a Ph.D. in Chemistry from Cornell University. He was a Fellow at the University of Iowa and at one time taught chemistry at Cornell. His entire career has been focused on plastics—fifteen years as a research engineer for Bakelite Corp. and, since 1945, as Synthane Director of Research until his appointment as a vice-president in 1969. He is a member of Sigma Xi and active in the ACS, SPE, A.I.Ch.E, ASTM, NEMA, and IPC. He is active in the American delegation of ISO (International Standards Organization), and has made many trips abroad in the interests of this group. He holds several patents. Articles he has authored have appeared in twenty-six publications.

Printed-Circuit Laminates

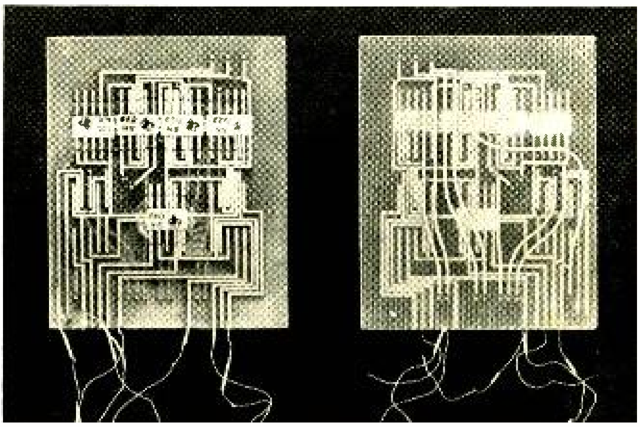
By NORMAN A. SKOW / Vice-Pres. & Tech. Director
Research & Development, Synthane-Taylor Corp.

The laminate, the base material on which PC board components are mounted, must have the proper electrical and mechanical characteristics. Here is what is available, along with guidance in making the proper selection.

FOR the processor seeking high production yields of assembled printed-circuit boards, for the circuit designer requiring good electrical and mechanical qualities, and for the ultimate user looking for high reliability and good performance, the quality of the metal-clad laminate used for the printed-circuit board is an important item. To get high yield, it is important to use copper-clad laminates that are free from pits and dents and which are readily sheared, punched, or sawed. If the laminate is free from defects like these, it will help to eliminate open circuits and high resistance points, two faults which decrease printed-circuit board reliability.

Production of high-quality circuits can be achieved by photoengraving, silk screening, or offset printing if the boards are flat and the copper clean. In addition, the board must be adequately bonded not only between the layers of laminate but also between the laminate and the metal.

Top and bottom of a printed circuit on a nickel-clad glass-epoxy laminate shows fine-line circuitry that can be etched.



This bonding is important if deterioration of the board or separation of the board from its circuitry is to be avoided. The laminate must be able to offer sufficient resistance to acid, alkali, and solvent attack during the fabrication and processing.

The need for sufficient bonding of metal to laminate board is even more critical where fine-wire circuitry or wiring must be produced. In addition, the board must have heat resistance to stand up to the temperature of the solder bath without deterioration. This must be true for boards that have been stored for long periods of time, as well as for those which are new.

To meet these requirements, the correct resin binder must be used, it must properly impregnate the right reinforcement material, and from that point on the laminate must be given "white-glove" handling in atmosphere-controlled clean rooms. Final inspection and shipment must be under equally controlled conditions.

Metals Used for Cladding

Of the cladding metals available, the only ones used to any great extent are copper, aluminum, and nickel, and of these copper accounts for more than 99% of boards manufactured. Aluminum is readily available in film form and adheres well to laminates, but is handicapped by relatively poor soldering efficiency.

Electrolytically deposited nickel is also available and has several advantages, such as scratch resistance, tarnish resis-

	RIGID				ULTRA-THIN	FLEXIBLE
	Phenolic	Polyester	Epoxy	Poly-tetra-fluoroethylene*	Epoxy	Polyimide Film
Cellulose Paper	X		X			Generally used without reinforcement
Glass Mat		X		X		
Woven Glass Fiber			X	X	X	

*Such as DuPont's Teflon

Table 1. Materials commonly used to manufacture PC laminates. Various resins (shown horizontal) are used to impregnate a number of different reinforcement materials (shown at the left of table).

tance, and weldability. But higher costs of nickel over copper and aluminum represent a major disadvantage.

Copper of printed-circuit quality is used in large quantities because of ready availability and because the metal can be made to have uniform thickness and density, and is free from pits, pinholes, and scratches.

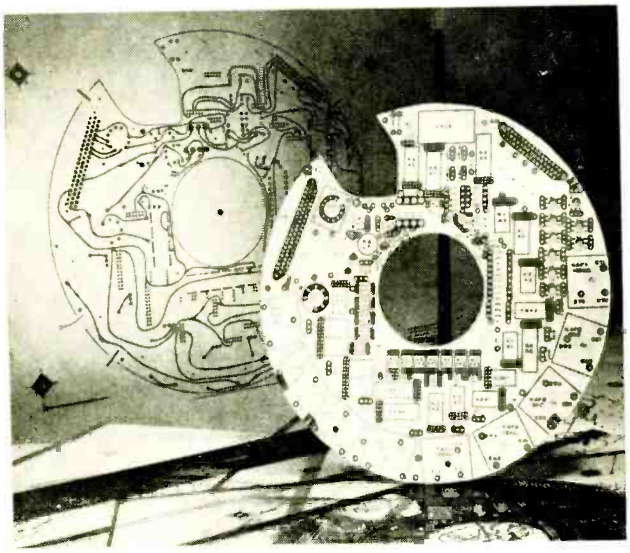
Copper for printed-circuit boards can be manufactured with one surface that is readily solderable and the other treated to produce consistently good bonds to the laminate.

Selecting the Proper Laminate

In order to select the proper laminate, the end user needs to know the properties of the grades that are available. Of the 80 grades of laminates, less than a dozen are used in printed-circuit board applications.

Laminates are made in three different classifications: rigid board, ultra thin panels for multilayer board, and flexible films for flat cables and flexible printed circuitry. The materials that are commonly used to manufacture these types are shown in Table 1.

Printed-circuit rigid boards of paper-phenolic construction have various tradenames and are designated by the National Electrical Manufacturers Association (NEMA) and the American Society of Testing Materials (ASTM) as grades XP, XXXP, XXXPC, and FR-2. These grades are relatively inexpensive and can be used in such commercial applications

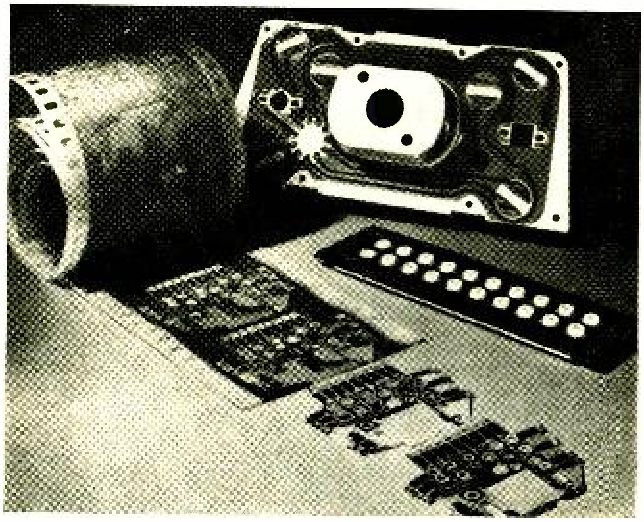


Multilayer board measuring 0.07-in thick consists of five layers of ultra-thin glass-epoxy copper-clad laminate. Four of the layers have copper on both sides, the fifth has copper on one side. The registration of each layer is held to within 0.003 in of the first layer. Over 800 plated-through holes are used, ranging from 0.028 to 0.144 in in diameter.

Table 2. NEMA and military grade designations of laminates, along with some of their typical applications.

Reinforcement-Resin	NEMA Designation	Military* Designation	Typical Uses
Paper-Phenolic	XP		Radio Circuits
Paper-Phenolic	XXXP		Radio & TV Circuits
Paper-Phenolic	XXXPC		Radio & TV Circuits
Paper-Phenolic, flame resistant	FR-2	PH	Radio & TV Circuits
Paper-Epoxy, flame resistant	FR-3	PX	Computer & Military Circuits
Glass Fabric-Epoxy	G-10	GE	Airborne Computer Circuits
Glass Fabric-Epoxy, temp. resistant	G-11	GB	Airborne Computer Circuits
Glass Fabric-Epoxy, flame resistant	FR-4	GF	Airborne Computer Circuits
Glass Fabric-Epoxy, flame resistant, temperature resistant	FR-5	GH	Airborne Computer Circuits

*MIL-P-13949E



Flexible printed-circuit film offers advantages of lower cost, less space, and smaller volume. High flexibility of pliable film permits creasing without breaking circuit.

as radio and television receivers where a flat, strong board is needed. These grades are relatively warp-free and have good impact strength, high adhesion, and excellent insulation resistance, in addition to good dimensional stability. Glass mat polyester type board also finds limited use in commercial markets.

The glass-epoxy and glass-polytetrafluoroethylene laminates maintain excellent electronic properties even under severe humidity environments. They are therefore designated for more sophisticated applications in computers, military electronic devices, and communications equipment or any electronic device requiring the highest reliability even under extreme temperatures and humidities.

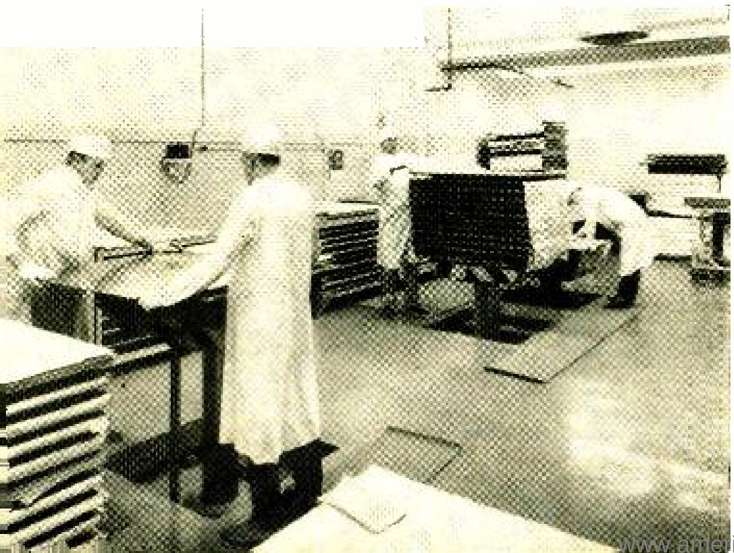
While rigid boards are made from these few materials, they are manufactured in various grades. These grades are shown in Table 2, which indicates both NEMA and military grade designations. The thickness of rigid board is from 1/32" to 1/8".

In order to increase the circuit concentration in a small space, designers have gone to smaller and multilayer boards necessitating the manufacture of ultra-thin laminates. These thin laminates may vary in thickness from 0.002" to 0.031" (1/32").

The two laminates generally used in making multilayer boards are NEMA grades G-10 and FR-4, which are designated GE and GF by the military.

Flexible printed-circuit laminates are flat, pliable, copper-clad films manufactured from high-temperature thermoset adhesive and a flexible plastic film substrate. Among the films used in this type of laminate are polyamide, fluorinated ethylene propylene (FEP), polyvinylidene fluoride (PVF), polyethylene terephthalene, polyimide, polyvinyl chloride, flexible epoxy glass, and tetrafluoroethylene.

Atmospherically controlled white-room conditions help keep PC laminates free from defects. Here pre-pregnated materials and copper for cladding are stored and weighed out.



The basic difference between rigid and flexible wiring is in the base material to which the copper foil conductors are bonded. In rigid board it is stiff laminated plastic, in flexible wiring it is a pliable plastic film.

Flexible printed circuitry offers advantages of lower cost, lighter weight, and smaller space and volume without loss of reliability. One added advantage of flexible printed wiring is the fact that its manufacture poses no particularly difficult production problems.

The films possess excellent dimensional stability and resistance to soldering temperatures. The basic properties of a flexible laminate film coupled with the thermoset adhesive permit circuit fabrication with extreme ease due to the high chemical and heat resistivity of the copper-clad film. It is also possible to use high pressures in multilayer circuit production without circuit rupture. The extreme flexibility of this laminate, available with copper cladding on one or both sides, permits 180° creases in any direction without cracking, rupturing, or separating the foil from the dielectric film.

(Editor's Note: For further information on this type of material, refer to the article "Flexible Printed Wiring" in this Special Section.)

Sizes and Dimensions Available

Printed-circuit laminates are available in standard sizes and thicknesses. Rigid circuit board comes in 36" by 36", 36" by 72", and 24" by 96" sizes. Some grades are available in 36" by 42" and 36" by 48" sizes. Some grades may be supplied in 24" widths and in lengths longer than 96". Standard rigid board thickness ranges from 1/32" to 1/8". Copper foil varies in thickness from 0.0014" to 0.007" and is bonded to one or both sides of the board.

Ultra-thin laminates for use in multilayer boards come in thicknesses ranging from 0.002" to 0.031". The same copper thicknesses are used here as on rigid board, and the copper can be bonded to either one or two sides. Ultra-thin laminates are produced in standard sheet sizes of 36" by 36" and 36" by 48". Some PC-laminate manufacturers will cut panels to size.

Flexible copper-clad film laminates are manufactured in maximum roll widths of 59" and maximum roll diameters of 14" (2000 feet). Flexible film measures from 1.5 to 9.9 mils thick with copper on one side, and from 2.5 through 14.8 mils with copper on two sides. In addition to copper, other metals can be used in metal-clad laminate construction, among these are steel, Nichrome, Kovar, and nickel.

PC Laminate Costs

The cost of printed-circuit laminates depends on the type laminate selected. Further variation in costs results from the different materials from which the laminate is manufactured. In general, the more sophisticated and critical the application, the higher the cost of the laminate.

Printed-circuit laminates were developed and used successfully for the first time about 15 years ago. The first efforts were to develop the proper mechanical and electrical properties and adequate peel strength of the copper during soldering.

These problems were solved in the early years. But more recently attention was directed to improving copper-clad material in the face of today's trend toward miniaturized electronic circuitry.

Meeting these more exacting requirements has created a demand for laminates with greater dimensional stability and stronger resistance to processing techniques. Great strides have been made in these directions so far and more will be made in the future. ▲

The author was graduated from VPI in 1946 and has attended advanced courses at the University of Pennsylvania and UCLA. He holds two patents in the electronics field and has published papers on digital calendar clocks and computer-controlled telemetry systems.

Computer-Designed PC Boards

By J. A. BAUER / Advanced Digital Design Manager
Missile and Surface Radar Division, RCA

How and when computers should be used to produce artwork for PC boards. Computer hardware and programming are described.

MILITARY and commercial electronic systems are becoming more complex as performance requirements increase. Through use of low-cost digital integrated circuits these requirements can be met economically. Electrical components can be reliably packaged and interconnected on multilayer printed-circuit boards. Interconnections between component leads and conducting-board layers are made by plated-through "*via*" holes.

Critical to the production of printed-circuit boards is the artwork required for each layer of conductors. The artwork must contain all interconnecting information in precise and accurate form on film or glass transparencies to expose the copper layers for subsequent etching to form individual conductors.

Printed circuits can range from a simple, single-sided board with a few components and connections to complicated boards with hundreds of components and thousands of interconnecting copper paths. Manufacturing artwork for the simple board is easily laid out and checked by hand, but the multilayer board poses problems in component placement, lead routing, and multilayer circuit tracing. Since multilayer boards are extremely complicated, they are better handled by the high-speed digital computer which is capable of large-scale processing without error.

Two avenues of approach have proved practical and are being concentrated on within the printed-circuit industry. One is *computer-aided design* where the computer is used as a bookkeeping and drafting tool. Entered data is displayed by way of a cathode-ray tube where it can be controlled by the designer. The other is *design automation*, which makes use of sophisticated computer software programs to make decisions, such as where to place components, how to route wire paths, and how to test the finished board. Both systems have one thing in common—the requirement for a complete description of the printed-circuit board. Within the computer memory the size, shape, and detail geography of the board must be laid out. The memory must also include a pattern of allowable interconnection points for the components and connectors and a grid system for the possible paths of interconnecting wires. At this point it becomes obvious that a set of printed-circuit boards for any one job should have common physical dimensions and placement grid, not only to reduce the task of the packaging and layout designer, but also to reduce the effort in entering this data to the computer. Since this is the practice whether a computer is used or not, the computer presents no limiting factor.

Although both computer-aided design and design automation are tools in printed-circuit design, this article will concentrate on design automation because of its rapid decision-making capability in addition to bookkeeping and, therefore, its faster operation in preparing large-scale artwork for PC boards.

The computer can't cheat, lie, or steal because it is constrained to operate within its program. It is not capable of inventing new methods of solution to a problem as the program progresses. Therefore, it is desirable that the computer program take into account as many subtle factors as possible in order to achieve competitive operation with the human designer's layout. For this reason, computer programs are difficult and time consuming to write and are considered to be a major effort.

Design Automation

A typical printed-circuit artwork program consists of a memory bookkeeping section, an interconnection checking section, a component placement section, a wire path routing section, and a magnetic tape output to a numerically controlled artwork generator. In addition to the artwork program, drill point location and test programs may also be prepared to drive numerically controlled drills and test machines.

Inputs to the system are the board configuration and the interconnection list of the components. A flow diagram of a typical design automation system is shown in Fig. 1.

After the board configuration and the interconnection list have been entered either by means of keypunched cards or other mechanisms, the computer is programmed to check the interconnection list for completeness. If an error has been

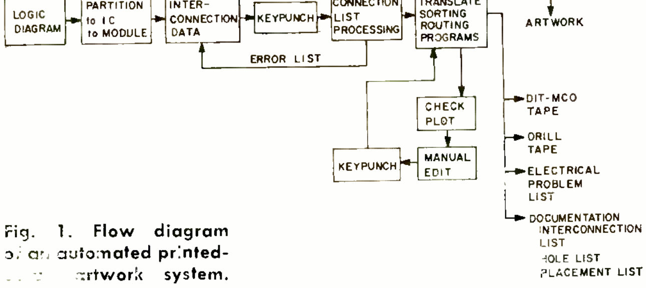


Fig. 1. Flow diagram of an automated printed-circuit artwork system.

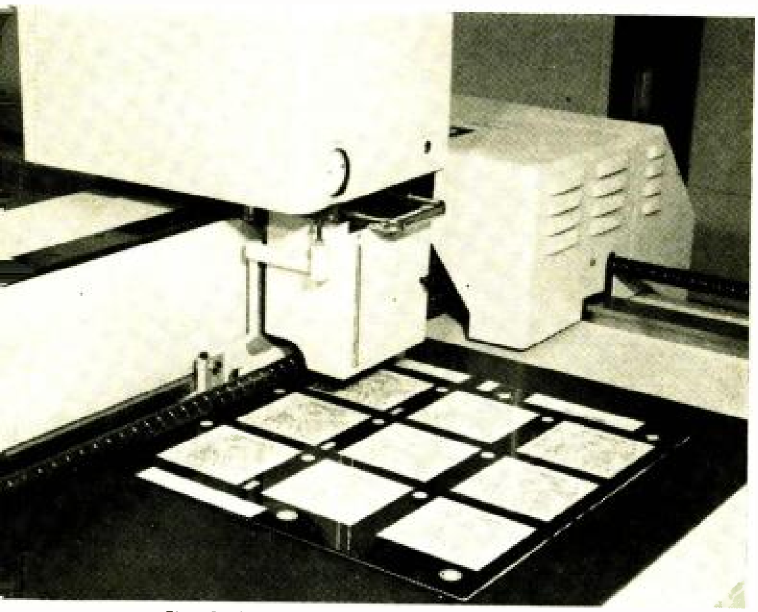


Fig. 2. Numerically controlled artwork generator producing the artwork for a group of nine identical PC boards.

made in transcribing from the logic diagram or in making the logic diagram, the computer produces an error list which is typed out and fed back to the designer. A typical check run by the computer includes completeness of wiring path; a wiring path must terminate at connections.

After check of the manually generated data, the computer is programmed to place components so they will be interconnected as simply as possible. The usual placement criterion is to reduce to a minimum the length of connections while taking into account the available channels for interconnections in each direction. For instance, if the board geometry dictates that only two wiring channels are available between components in the X direction and four wiring channels are available in the Y direction, this factor should be considered in preparing the computer program so that component placement is made with more wires available in the Y direction. Component placement is done by the placement algorithm.

The computer rapidly assembles the total wiring length, then re-arranges components and checks wiring lengths again to achieve a minimum total wire length. An additional constraint can be made to eliminate excessively long interconnection paths, particularly for critical signals. Because the computer can make multiple placements and wiring length calculations very quickly, several thousand alternate placements can be made before the optimum placement is selected.

Routing Program

Once an optimum placement is selected, a *routing program* is initiated. In this phase, the computer attempts to interconnect components in accordance with the interconnection list given to it by the logic designer. At this point, it is programmed to operate like a mouse running through a maze from start to end of the interconnect—it must avoid components, wiring pads, and previously laid out wiring paths. This is called the *routing* or *maze-runner* program. However, unlike the mouse in a maze, there are usually many alternate paths available to make an interconnection. The interconnection may stay on one layer of the printed-circuit board or it may be allowed to go from layer to layer. It may be preferable for it to follow one direction over another in order to avoid blocking interconnections which will be made later. Also its possible path may be so long around other components and wires that it would be preferable to reserve the path for a different layer on the board where the path would be shorter. All of these various constraints should be taken into account when setting up the routing program.

It has been our experience that as the computer program is made more sophisticated in this area, better performance is achieved, thereby increasing the number of interconnects per layer of artwork. Most of the industry's efforts are concentrated on improving computer programs because the more factors that can be taken into account in the program, the more efficient the artwork can be made.

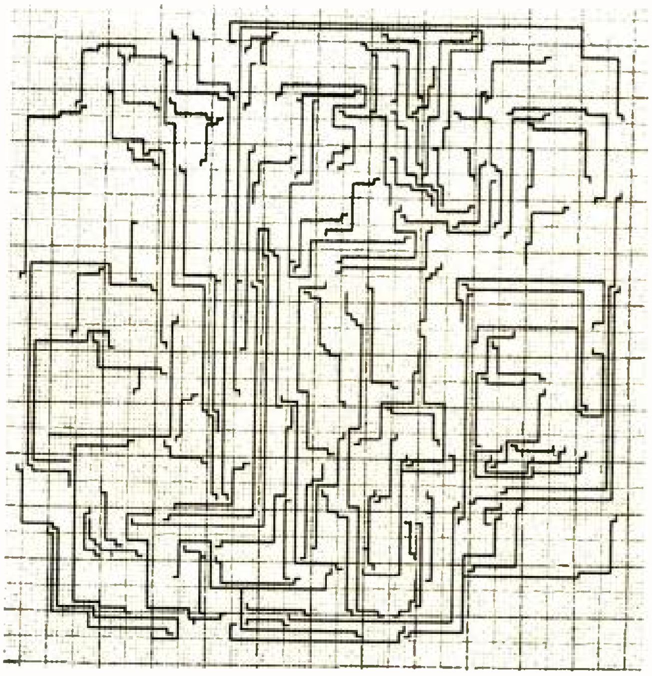
The current state of the art indicates that human intervention is still desirable in order to reduce the number of layers in densely packaged printed-circuit boards. However, it is also highly desirable to have all of the information included within the computer so that directions to the numerically controlled artwork generator, drill, and tester can include all data.

A typical example of computer routing for a densely packaged board mounting one-hundred integrated circuits may take two hours of computer time and produce eight layers of signal wiring. With manual intervention, the number of layers may be reduced to six. A prototype multilayer board may be made with the computer program, then changes to the interconnection and additional edited reduction of printed-circuit signal layers may be made for the production boards along with any additional changes determined by prototype test. As many as 22 layers have been successfully interconnected with printed-circuit techniques, indicating the current success of this method.

The programming complexity required by computer layout of multilayer printed-circuit boards indicates that this service requires a large investment. Therefore, it is usually more economical to utilize available programs from one of the large printed-circuit producers, who will accept circuit or logic diagrams or interconnection lists rather than requiring each engineer to start from scratch to generate computer programs effective enough to prepare artwork.

The engineer and packaging designer should then consider very carefully whether it would be more efficient to manually lay out his densely packed printed-circuit boards or utilize one of the available services of the printed-circuit manufacturer. One of the items to be taken into account is the number of errors produced by the many steps of manual placement and layout of thousands of interconnects, and the resultant recycling of artwork to correct mistakes compared to the relatively error-free operations of design automation.

Fig. 3. Example of computer-generated artwork in which most of the lines are in the Y, or vertical-axis, direction.



The designer should also consider the time savings of design automation caused by rapid computer operations.

Making the Artwork

Once the placement and interconnection routing have been accomplished, a magnetic tape is prepared by the computer to drive a numerically controlled artwork generator. Fig. 2 shows an artwork generator in operation. It is possible to prepare artwork to within 0.0001-inch accuracy with this machine made by the *Gerber Scientific Co.* Notice that multiple artwork is being prepared on one master so that a group of nine identical printed circuits can be etched at one time. The machines, currently used by *RCA*, drive a light head which exposes the film master on the table. Two machines are available to produce automated artwork for printed-circuit boards, integrated circuits, and for shadow masks for color-TV picture tubes.

An example of computer-generated artwork is shown in Fig. 3, which is a sketch of one of two layers of a multilayer board prepared for checkout before final artwork is made. The typical layouts for a pair of adjacent layers results in artwork in which most of the lines in one layer run at right angles to most of the lines in the next layer. This is an important programmed portion of the computer-generated artwork because a single X (horizontal-axis) connection allowed to cross a layer with most of the connections in the vertical-axis (Y) direction could block paths of many wires in that layer, thereby limiting the wiring density of the layer pair.

Other, more subtle, effects can occur when attempting to program multiple-layer printed-circuit cards. For instance, it is desirable to vary the interconnection path selection depending on which edge of the board is being wired in order to make maximum use of the board edge. It is also desirable to anticipate the result of using *via* holes by the computer program since it may be more efficient to reserve them for manual additions.

Considering the above information, the circuit-card designer may feel that designing an efficient automated artwork program is specialized and expensive. This is true. At least several man-years of professional programmer's time are required to prepare the computer software which is competitive with manual layout methods. There is no simple mathematical proof for any of the placement and routing algorithms used. They must be invented and tested by practice with actual printed-circuit boards to gain sufficient experience in predicting performance.

Since the exact number of layers to be produced by the automated program is difficult to predict for densely packed boards, it is desirable to have a manual editing program to take advantage of human inventiveness and visualization which the computer program cannot have built in. As an example of performance currently obtainable, a circuit board with 800 interconnecting wires may be produced automatically in eight layers and, with additional manual editing, could be reduced to six.

The Equipment Involved

The equipment involved in automated artwork should also be considered. The limiting factor of the computer used to design large multilayer printed-circuits is the memory capacity. Each grid point capable of accepting a wiring path must be entered in memory. A printed-circuit board with dimensions of 6 × 6 inches and a grid of 50 thousandths of an inch requires at least 30,000 bytes of memory. A board with 25 thousandths of an inch grid requires 120,000 bytes of memory. Alternatively, a 12 × 12 inch board with 50 thousandths of an inch grid requires 120,000 bytes of memory. This memory capacity is supplied by a medium- to large-scale computer.

The computer, when properly programmed, is capable of preparing tapes driving numerically controlled artwork generators. These may be of the high-speed, medium-accuracy cathode-ray-tube type or the slower speed but highly accurate electro-mechanical plot board. These are the two major hardware components required for automated artwork preparation. Although it is possible to rent service on these devices, most of the producers making printed-circuit boards have them available in-house. *RCA*, Moorestown, has available on its Spectra 70/55 computer, a memory capacity of 262,000 bytes. Two highly accurate *Gerber* photoplotters are also available. Each completed circuit board must be tested to assure quality. At our printed-circuit facility, automated continuity and short-circuit tests are run by the *DIT-MCO* tester shown in Fig. 4.

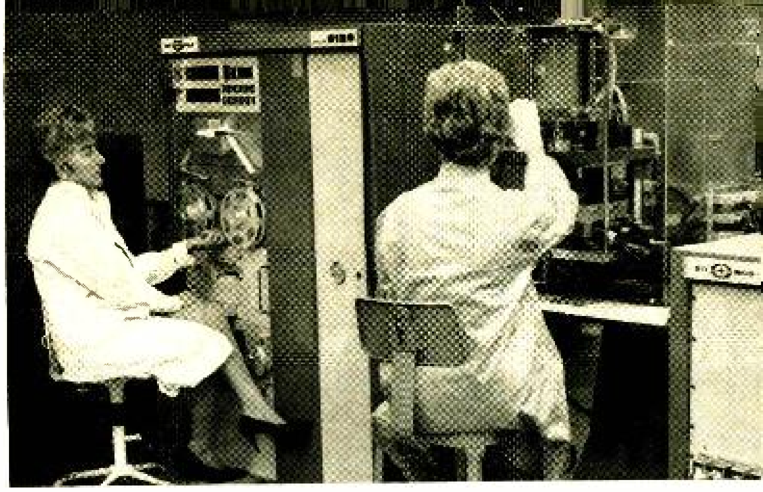


Fig. 4. Using automatic equipment to run continuity and short-circuit tests on completed printed-circuit boards.

Because of the large investment in time and equipment, design automation for multilayer printed-circuit boards will be most effectively used as a service from the printed-circuit manufacturers rather than as separate programs generated by each of the designers. This currently available service reduces artwork production time and cost and should be considered in choosing PC manufacturers.

Automated artwork can be most advantageously applied to more complicated, densely packed integrated-circuit boards requiring multiple layers of interconnection. Single-layer boards are currently laid out more efficiently by manual means. One of the reasons is that as complexity increases so does the chance for making errors in manual artwork. These errors are difficult to catch and only one error in an 800 interconnect board requires modifications of the board.

Future Developments

Automated artwork is one of the items required not only for efficient production of multilayer printed circuits but also for large-scale integrated circuits. An advance in one of these technologies will also benefit the other. The state of the art is rapidly improving because of the newness of the field and the current availability of all the tools, such as computers and plotters.

The limiting factor advancing the state of the art is the inventiveness of programmers preparing software. Certainly in the future computers will produce more calculations per dollar and plotters will become faster and more accurate, still the capability of automatic artwork will depend on the capabilities put in by the programmer.

In addition to solving the placement and routing problems, the programmer will be adding wiring rule calculations for solving reflection and cross-talk caused by interconnections of high-speed circuits. Moreover, minimum test specifications and a program to define and locate logic errors will also be added in the future.

Programs are available to check the logic by simulation and to prepare waveform and timing checks. When these are integrated into the over-all printed-circuit artwork preparation, the engineer will be assured of the proper logic operation in accordance with his design as well as efficient artwork production and test. ▲

The author received his engineering degree from the University of London in 1939. Shortly after his service in the U.S. Army in World War II, he co-founded Columbia Technical Corp. of which he is a Director and the Vice President. He was General Manager of its electronic-components division until 1966 and now manages its HumiSeal Div., which manufactures conformal coatings for the electronics industry. He is a member of the IEEE and a Lt. Col. in the Reserves.

Conformal Coatings for Printed Circuits

By VICTOR LEIBMANN
HumiSeal Div., Columbia Technical Corp.

Providing a barrier against humidity, abrasion, solvents, and fungus is the job of the coating. Used on just about all military PC boards, these coatings are gaining acceptance in both industrial and consumer products.

THE greatest deterrents to the proper functioning of a PC board assembly are the environmental stresses under which it is to operate. Humidity is generally recognized as the principal culprit, as the military learned from bitter experience on jungle battlefields stretching from the Pacific Islands to Vietnam.

While other environmental stresses, such as dust, shock, vibration, and temperature extremes, may affect the performance of a PC board, humidity, especially when under high temperatures, will invariably degrade its electrical performance and eventually lead to ultimate failure. Humidity will, for instance, drastically lower the insulation resistance between printed conductors, cause arcing, corrode conductors, and stimulate fungus growth.

A barrier against environmental stresses was therefore needed, hence, the emergence of conformal coatings. These have become a must on all military electronic PC boards and are steadily gaining acceptance in industrial and consumer electronic systems.

A coating must, first of all, constitute a barrier to protect the board and its components against harmful environmental effects. In addition, it must also satisfy many other frequently conflicting prerequisites. It must be hard enough to withstand abrasion and marring, but flexible enough to withstand temperature shock or flexing without tearing. It must be viscous enough to build up an adequate film thickness, but thin enough to flow under and around closely mounted components. It must be easy to handle and apply, be economical, have a long pot life, be non-toxic, have a wide operating temperature range, a low water-vapor permeability, and have many other desirable characteristics.

Needless to say, such an ideal coating does not exist nor is likely to ever be formulated. Therefore, we must trade off one characteristic for another and concentrate on those which are really essential to assure reliability of performance under those particular environmental conditions specified for the equipment.

Selecting a Coating

This may be a difficult task indeed. The number of coatings of every description now available is overwhelming; however, only a relative few are suited for electronic applications. It would be unwise for the packaging engineer to consult a resin manufacturer directly, rather he should turn for assistance to coating manufacturers who specialize in materials suitable for electrical and electronic applications. Such manufacturers usually have a selected line of coatings which have been carefully formulated to offer those mechanical, electrical, and chemical characteristics that are most desirable. Their printed data is generally directed to the electronic engineer and contains extensive information from which he can determine if a particular coating meets his specific requirements.

Generally speaking, most conformal coatings used for coating PC boards are formulations based primarily on epoxy, polyurethane, or acrylic resins and, to a lesser extent, on polystyrene, diallyl phthalate, silicone, and polyimide resins. Many variations within each chemical group are made possible through the addition of various chemicals which enhance some particular characteristic of the coating, sometimes at the expense of another. Table 1 gives a comparison of the average group characteristics of PC board coatings most frequently employed.

Preparation of the Board

Before a board is coated, it must first be thoroughly dried and cleansed of all extraneous materials, such as solder flux, mold release, oil, dust, fingerprints, and moisture. A clean and dry board is one prerequisite which will govern the effectiveness of the coating; its importance cannot be overemphasized. A good work flow plan will usually specify several successive washing and drying operations before a board is submitted to actual coating.

Many of the customary cleansing methods may be used: vapor degreasing, ultrasonic cleaning, or washing in trichloroethane, Freon, or other similar solvents. Cleansing is followed by a period of forced drying to remove all traces of solvent or moisture. The board should then be protected from further contamination until it receives its first application of protective coating.

Sharp edges, corners, and ridges are the most difficult to coat, as coatings have a tendency to flow away from them.

These should be rounded off, if possible eliminated entirely. Leads sticking out prominently beyond the board are particularly unreceptive to coating; they should either be bent or clipped short.

Areas of the board which should be free of coating are usually masked off. Flat areas, such as contact fingers or slides, and tunable components are covered with masking tape; cavities, such as test jacks, are plugged with a toothpick or a tapered pin of suitable size.

The Coating Process

Coatings may be applied by brushing, dipping, spraying, screening, or flowing. Of these, dipping and spraying are most frequently used in production: both methods are quite readily adaptable to either manual or automatic methods of operation.

Dip coating is the most reliable method since it assures that a board is totally covered with coating material. The angle and speed of immersion and withdrawal are important and must be optimized to avoid air bubbles and allow coating to flow freely and uniformly. Speeds of withdrawal are usually on the order of 2 to 4 feet per minute.

The viscosity of the coating must be monitored and closely maintained by gradual addition of solvents, otherwise the coating thickness and penetration under and around components will be greatly affected.

Spraying can be accomplished with conventional low-pressure spraying equipment. In a manual operation, a certain degree of skill is required of the operator to assure thorough coverage and uniformity. Here again, both in a manual or an automatic operation, viscosity has to be maintained at a constant level.

The Drying Operation

Following the dipping or spraying operation, the boards are allowed to dry in a dust-free area, either at room temperature or in ovens, depending on the materials that are used.

Most coatings will be dry to handle in under one hour at room temperature; this could be expedited by exposure to moderate heat. A dry film, however, does not necessarily mean that it is fully cured and has reached its optimum properties. Full cure for most coatings requires heat, but some others will cure by exposure to oxygen, or to ambient moisture.

It is a good practice to apply two or three successive layers of coating to a board as this will minimize the possibility of pinholes which would provide a path for the ingress of moisture. A total build of 1 to 3 mils is usually an adequate film thickness for most purposes. The thickness of the film can be controlled by thinning down the liquid coating with an adequate solvent.

Military Specifications

MIL-I-46058B specifies the requirements for electrical insulating compounds for coating printed-circuit assemblies. This specification classifies coatings in four groups: epoxies, polyurethanes, silicones, and polystyrenes. Acrylic coatings, although widely used, are not included at the present time.

Testing under this specification is primarily electrical at steady state as well as under environmental conditions, such as humidity, temperature extremes, and immersion in water. Other tests evaluate the coating for flexibility, resistance to fungus, and thermal shock.

Electrical tests are performed on specimen PC boards consisting of two parallel conductors 1-inch long by 0.030-inch wide, laid 0.030-inch apart. The coating applied must have a thickness of 2 ± 0.5 mils.

The U.S. Army Electronics Command maintains a Qualified Product List (QPL) of products which have been qualified under the requirements of this particular military specification.

Whether a coating is qualified under this specification or not, it is still desirable, if not mandatory, that it be evaluated in the system in which it is intended to be used. It must be remembered that qualification of a product under this specification is performed under ideal laboratory conditions and with specimen boards that are flat and devoid of components. Results obtained in testing production boards may be, and usually are, substantially lower than the minimum requirements established in this specification. Hence, the necessity to ascertain that the minimum requirements of the system are also met. ▲

Table 1. Comparative characteristics of commonly used coating materials used for printed-circuit boards.

COATING MATERIAL	EPOXY	URETHANE	ACRYLIC	SILICONE	POLYIMIDE	DIALLYL PHTHALATE
Electrical Properties	Ex	Ex	Ex	Ex	Ex	Ex
Resistance to Humidity	G	Ex	G	Ex	Ex	G
Resistance to Solvents	G	Ex	F	G	Ex	G
Resistance to Fungus	Ex	G	Ex	Ex	Ex	Ex
Resistance to Abrasion	Ex	G	G	Ex	Ex	Ex
Maximum Operating Temperature	180°C	130°C	130°C	220°C	220°C	180°C
Flexibility	G	Ex	G	G	G	P
Adhesion	Ex	Ex	Ex	G	G	G
Repairability	P	G	Ex	none	none	none
Curing Conditions	Room temp. or oven	Room temp. or oven	Room temp. or oven	Oven	Oven	Oven
Shelf Life	6-12 mos	3-6 mos	12-24 mos	6-12 mos	6-12 mos	3-6 mos

Ex: Excellent; G: Good; F: Fair; P: Poor

Mr. Hecker is responsible for the marketing of all standard Amphenol Industrial Div. PC connectors as well as development of new products. He has had twenty years of marketing experience combined with a close association with engineering and production. Previously associated with Cessna Aircraft and E.C.I., he joined Amphenol in 1961.

Mr. Novak is responsible for marketing special PC connectors that are developed for specific application programs. With 14 years experience in electronics, he has worked directly with production, industrial, and design engineering departments. He was formerly associated with Hotpoint, joined Amphenol in 1960.

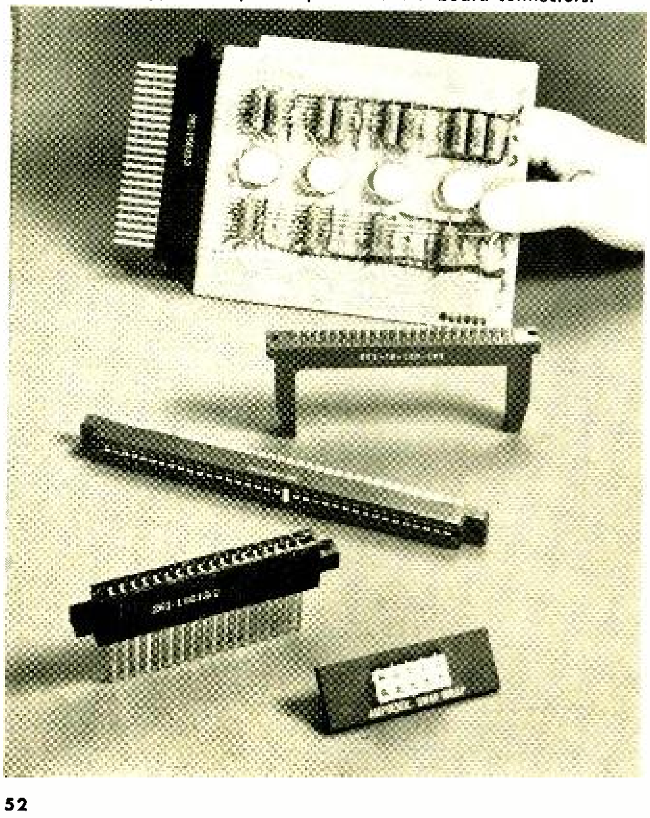
Connectors for PC Boards

By PHILIP C. HECKER and CHARLES T. NOVAK / Product Managers
Standard and Special PC Connectors, Amphenol Industrial Div., The Bunker-Ramo Corp.

The great variety of connectors makes selection difficult, but it does away with the need for expensive, custom designs. Here is guidance in making the proper connector selection.

THE constant demand for printed-circuit board connectors to meet specific circuit requirements has resulted in a most awesome collection of configurations, sizes, contact designs, and spacings. Although the variety can make connector selection difficult, it does allow use of existing or "standard" connectors in a large number of applications that might otherwise call for custom designs requiring expensive tooling.

Group of typical Amphenol printed-circuit board connectors.



Evaluation of several circuit parameters helps to reduce the number of connectors that can be used in a given application. Each connector can offer the right qualities for a wide range of uses. To realize maximum benefit from a given PC connector, however, it must be employed within its best range.

One of the most important factors to consider—and one that is often overlooked—is the probable number of insertion and withdrawal cycles.

Types of Contacts

Contact design and plating determine the number of cycles that a connector can undergo. For applications with 500 cycles or less, several contact designs are used. One type resembles a tuning fork in which the extra-long spring base of the contact and the contact material resilience provide a wide flexing range with elastic reserve. A base plating of copper or nickel is followed by gold plating. These contacts have been tested for 500 cycles of insertion and withdrawal plus a 48-hour salt-spray exposure with only negligible change in contact resistance.

Tuning-fork-type contacts can effectively accommodate printed-circuit boards from 0.054- to 0.71-in thickness. Micro-finished contact surfaces afford excellent insertion characteristics and controlled lateral float of the contacts permits accommodation of warped boards with positive continuity of all circuits.

For applications requiring more than 500 insertions and withdrawals, bellows-type contacts are recommended. These contacts, formed from phosphor bronze or beryllium copper strip, have a convex contour that concentrates bearing pressure on the mating surface, displaces semiconductive film that may exist, and reduces voltage losses to a minimum. Plating is usually gold over copper or gold over nickel. The bellows action of the contacts absorbs the actual deflection force so that mating surface can withstand in excess of 1000 insertions and withdrawals.

Many bellows-type contacts have bifurcated mating surfaces which provide two points of electrical contact per circuit even on irregular surfaces. The bifurcated design also helps to keep the contact on the board during any vibration that might occur.

Also, for applications requiring more than 500 insertion and withdrawal cycles, a recently developed connector with precious metal contacts (usually a gold/silver alloy), is applied to a spring member at the point of contact. Thickness and shape of the tip can be varied to suit the application. The entire contact itself, except for the tip, can be solder- or tin-plated, eliminating costly over-all gold plate. These contacts have been tested to more than 1000 insertions with no increase in resistivity. The gold is literally where the action is, at the point of contact.

Although for most applications the printed-circuit board is inserted directly into the connector receptacle, a plug connector or male contact pins can be fastened, most often by dip soldering, to the board. This is done when the cost of a board with components is particularly expensive or perhaps non-repairable, as in the case of welded or encapsulated components.

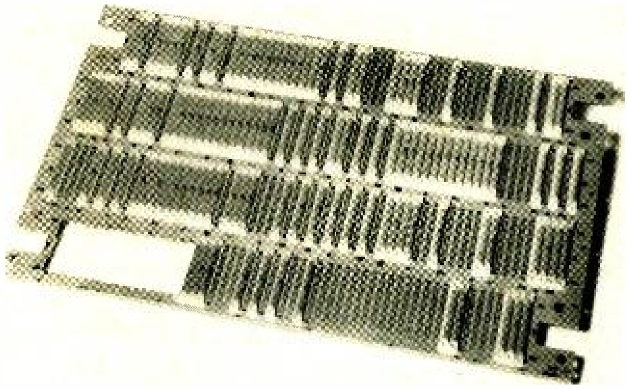
Connector Materials

Specifiers of PC connectors should have a general knowledge of materials available and how they affect not only connector performance but also connector cost.

A number of different dielectric materials are used. Phenolic, the most common and least expensive, is intended for applications requiring good electrical qualities with mechanical qualities better than the acceptable minimum. It will withstand a maximum operating temperature of 300° F. See Table 1.

Mica-filled phenolic, a low-loss and low-water-absorbing material, is used for applications requiring superior dielectric properties. It has a thousand times the insulation resistance of general-purpose phenolic, but costs only 50 percent more.

Cellulose-filled melamine has excellent electrical and mechanical properties and should be considered when resistance to surface creepage is needed. Costs are approximately the same as mica-filled phenolic. Ceramic steatite withstands high temperatures—1400° F *vs* 325° F for melamine—is non-hygroscopic and has a low loss factor, but it costs about three times as much as phenolic.



This board with its large number of PC connectors has been designed for Navy's multiple-warhead Poseiden.

Mineral-filled diallyl phthalate is used where dimensional stability of the connector and close tolerances are important. Insulation resistance is excellent—4 x 10^7 megohms—and it withstands extremes of humidity and temperature, but it is almost four times more costly than phenolic. Glass-filled diallyl phthalate has generally the same electric properties as its mineral-filled counterpart, but has higher flexural strength. For this reason, it is specified by the military for rugged environments. The cost is approximately six times that of phenolic.

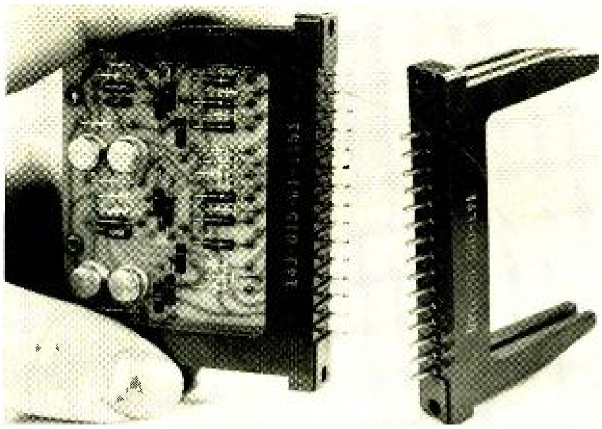
The thermoplastic resins, which include polysulfone, nylon, polycarbonate, and ABS, are often used where resiliency is required. Additionally, glass reinforcement can be applied for increased strength and heat resistance. Thermoplastic resins exhibit considerably more flexural strength than the thermosets. From a procurement standpoint, reduced costs can often be realized through shorter cycling times that are inherent in the thermoplastic molding process.

Contact Materials & Plating

Three basic contact materials are used in PC connectors: brass, phosphor bronze, and beryllium copper. The right choice for a given connector application is a compromise between electrical and mechanical properties. Brass, although it has the best conductivity and is relatively low in cost, will not stand up under excessive insertion and with-

Table 1. Characteristics of popular dielectrics that are used for printed-circuit connectors.

Molding Compound	General-Purpose Phenolic	Mica-Filled Phenolic	Melamine	Ceramic	Mineral-Filled Diallyl	Glass-Filled Diallyl	Nylon	Glass-Filled Nylon
MIL-Spec Type	MIL-M-14F CFG	MIL-M-14F MFE	MIL-M-14F CMG	JAN-1-10 Grade L4	MIL-M-14 MDG	MIL-M-14 SDGF	---	---
Max. Oper. Temperature (Continuous)	300°F	300°F	325°F	1400°F	300°F	300°F	225°F	300°F
Insulation Resistance (M/cm³)	10^3	10^6	7.4 X 10^6	10^8	4 X 10^7	3 X 10^{10}	10^{13}	1.5 X 10^{15}
Water Absorption (ASTM 24 hrs)	1.31%	0.61%	1.00%	0.00%	0.4%	0.3%	2.00%	1.00%
Tensile Strength (psi)	6100	5400	6500	8500	5500	10,000	11,000	20,000
Dielectric Strength (Volts/mil)	346	475	252	400	360	400	420	400



Popular "card-guide" printed-circuit board connector.

drawal cycles. Spring qualities of brass, good at the outset, become less effective as the material age-hardens or crystallizes under stress.

Phosphor bronze, twice the cost of brass, has good spring qualities over connector life, but conductivity is relatively low.

Heat-treated beryllium copper contacts of the proper design will withstand more insertion and withdrawal cycles than most other non-ferrous spring materials. Conductivity is almost as good as brass but contact cost is about five times that of brass due to both material and tool maintenance.

In addition to these three basic materials, a number of other alloys can be used to fit the specific requirements of an application.

So many variables, not only the different types of plating materials and combinations, but also plating thickness and contact shape, make meaningful cost comparisons more involved.

Gold, probably the most common plating used, is applied in many thicknesses: commercial applications require 20 to 30 millionths of an inch; military specifications call for 50 millionths; and some special applications call for 100 millionths or more. Gold over copper or nickel is generally used in dry-circuit applications requiring low contact resistance and good corrosion resistance. Silver over copper or nickel is used in higher power applications, but corrosion resistance is not as high as gold. Naturally, heavier plating and the number of plating operations increase connector cost.

Contact Spacing vs Cost

The two main material costs in a PC connector are, of course, contacts and dielectric. Increasing the contact density in a given size and dielectric block results in some saving in dielectric cost but it is relatively minor. The limiting factors in increasing density are dimensional stability of the dielectric material, contact true position requirements, unusual connector shapes, and termination methods used.

Cost of a given size connector will rise as contact density increases, but on a per-contact basis cost actually decreases. For example, assume a certain size connector dielectric block costs 25 cents. This block with 15 contacts at 5 cents apiece would cost $1.00; the same block with 30 contacts would cost $1.75. Cost of the connector on a precontact basis with 15 contacts is about 6.7 cents, with 30 contacts it is about 5.8 cents. (The saving in dielectric cost in the 30-contact connector is small enough to be considered negligible.)

Crosstalk in a PC connector is usually insignificant. Tests have shown that connectors, because of their fixed contact spacing, present fewer crosstalk problems than wiring and cabling.

Important MIL-Specs

A military specification covering many printed-circuit connectors is MIL-C-21097B which outlines electrical and environmental tests as well as connector dimensions to insure interchangeability. For example, PC connectors meeting the spec must withstand thermal shock, vibration, and 50 G's physical shock tests in accordance with MIL-STD-202. An insulation resistance of 5000 megohms at a high-potential test (no breakdown at sea level with 1800 V a. c. and at 70,000-ft altitude with 450 V a. c. applied) are also specified.

Although the electrical and environmental requirements of MIL-C-21097B necessarily limit the contact and dielectric materials that can be used, certain materials are specified by type. For example, dielectrics are specified under MIL-M-14F and MIL-M-19833; plating requirements under MIL-C-45204.

Contact resistance specified is for a voltage drop of 30 millivolts at a current of 5 amperes. What is most important, however, is that contact resistance, whatever the particular value, remain reasonably constant over the specific connector's rated number of insertion and withdrawal cycles.

Some PC connectors are available for commercial applications that meet the performance and environmental requirements of military specifications although they do not necessarily have the exact dielectric or plating thickness specified. These connectors, since they are not restricted to the spec, can provide greater flexibility for design.

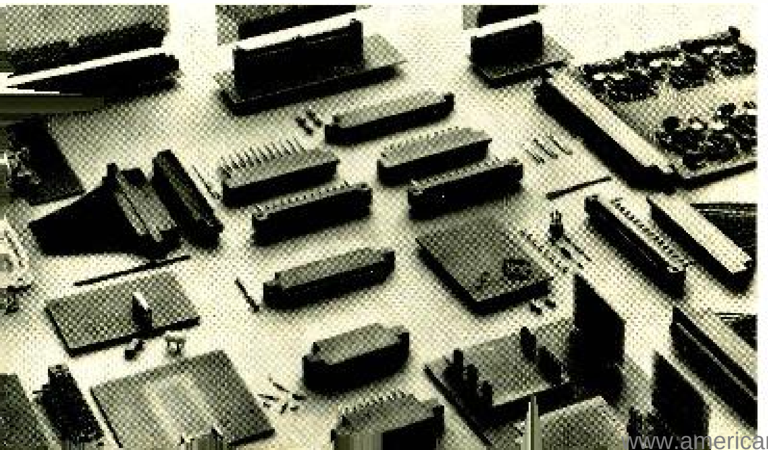
Choosing the Right Terminating Method

Military specifications cover standard solder and crimp pin terminations. Commercial PC connectors can also employ taper-pin type (similar to standard crimp type except that a separate pin is required), percussive welded terminations, and mechanical terminations. The terminating method chosen does not greatly affect the initial cost of the connector, however termination cost variations can be significant.

Connectors with solder terminations are designed for direct wiring or for installation on printed-circuit boards, panels, or chassis for dip-solder applications. Taper-pin terminations provide flexibility of assembly procedure and easy modification and repair. Crimp terminations, available with the flexibility of removable contacts, are very economical in applications where programming changes for PC connectors are anticipated. In general, mechanical termination methods—such as solderless wrap and automatic crimp—offer the user significant assembly time savings where large quantities of connectors are involved. For short-run PC board production or applications with a very small number of connectors, soldered terminations are usually the most economical.

Individual insert blocks with from one to well over 500 contacts are available with contact centers ranging from

Collection of AMP connectors, showing variety available.



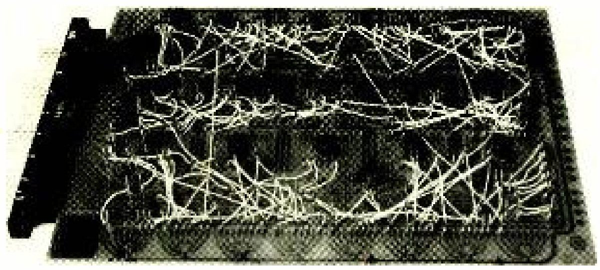
0.025 to 0.250 in. PC connectors are usually referred to as miniature, subminiature, microminiature, and ultraminiature but at present there are few standards that cover these types.

In addition to the standard lines of PC connectors on the market, a number of special types have been developed that are available as stock items. For example, card-guide units provide alignment in blind-spot installations and prevent PC board "rocking." Connectors with coaxial contacts, with alternating contact tails that provide more space for terminating, and double-sided connectors are only a few of the special-purpose units available to the designer.

Two outstanding examples of special-purpose connectors are direct-entry and indirect-entry plate assemblies. Both types utilize an aluminum plate punched to accept thermoplastic modules containing one or more contacts. Direct-entry plate assemblies utilize three- and four-position modules in addition to two-position "L"-shaped card guides; enabling the connector manufacturer to use standard components to produce special configurations. The plate assembly makes framing unnecessary, providing both rigidity and true positioning of contact tails for automatic termination.

Indirect-entry plate assemblies are made up of individual single-contact insulators pressed into the plates, creating complete versatility in terms of wrap-tail number, limited only by a designer's imagination. This provides maximum use of contact density, reduction in size of the end product, and economical contact termination. Several manufacturers have been soldering ground and voltage planes on the contact tails and wrapping the balance of the tails. Provisions for grounding contacts are made in both versions.

Other special-purpose connectors include PC headers, crimp headers, and male wrap-tail headers allowing for use of any of a wide range of economical termination equipment currently available. Selection of such a special also precludes additional expense of a mold charge. Additionally, these techniques permit repair or replacement of the male and female solderless wrap contact subassembly by simple removal and insertion of an individual contact subassembly with hand tools.



This one-piece, economy-type 40-terminal, card-edge connector is employed in a new automatic writing machine.

If a designer keeps the connector in mind at the time he first begins laying out the printed-circuit board, he will most likely to be able to adapt his PC board leads to conform to the contact spacing and over-all width of a standard PC connector. If the connector is not considered until the board is completely designed, there may be no choice but to specify a special connector that not only will require longer delivery time but also involve expensive tooling costs.

Designers should provide the PC connector manufacturer with as much information as possible about the unit required: not only the obvious factors of size, number of contacts, current/voltage capacity, but also environmental aspects of the application, contact finishes, dielectric materials, and terminating method preferred.

In addition, knowledge of the mounting requirements into the specific end product may enable the connector manufacturer to provide services the user may not have been aware of. Several connector manufacturers are tooled to provide plate assemblies with connectors mounted and to completely wrap, crimp, or solder-terminate the assembly. ▲

DRY PROCESS FOR MAKING PC BOARDS

PROTOTYPE PC boards, in sizes up to 8½ x 11 inches, are manufactured in less than 8 minutes using dry-process equipment available from *Xerox*. Recommended for prototype quantities, up to 200 boards may be made from a single drawing. The basic system, including a camera, processor, and vapor fuser, may be purchased for some $6000. A rental plan recommended by *Xerox* enables the user to rent the equipment for $45 per month plus 10 cents for each manufactured board. In addition, approximately $200 has to be invested in accessories and $50 in expendable items. After 90 days the system may be purchased for $1250. No special room temperature or light conditions are required for the installation of equipment. It is claimed that the simplicity of the equipment permits untrained personnel to master the process in one hour.

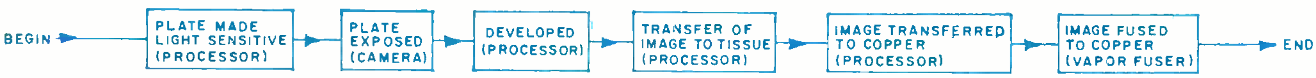
A flow chart illustrating the sequence of steps in manufacturing a PC board is shown below. Initially, the operator slides a selenium-coated plate into the processor where it is made light-sensitive with a positive charge of electricity. The plate is reusable, enjoying long life if handled carefully. Protected by a light shield, it is then placed in the camera. The shield is withdrawn and the plate exposed to the artwork. Your original layout may be used for obtaining the image of the printed-circuit pattern.

After exposure, the plate is returned to the processor and developed. Negatively charged black powder is cascaded over the plate, the powder adhering to the areas unexposed to light. The resulting image is transferred electrostatically to an intermediate tissue which has been positioned on the plate and inserted into the processor. The copper-clad laminate is then placed on a special transfer plate in the processor where the image on the intermediate tissue is transferred electrostatically to the copper surface. Following the transfer, the tissue is peeled away.

In the final step before conventional etching, the black-powder image is fused to the copper surface of the laminate. This is accomplished in the vapor fuser which is an air-tight compartment containing a rack for inserting the laminate. Vapor emanating from a solution (Flo-Set) supplied by *Xerox* forms a permanent toned image of the layout on the copper.

The preceding steps, from beginning to end, should take under 8 minutes for an experienced operator. It is possible to repeat the process and form another layout on the other side of the board, producing a two-sided PC board. Transferring the image on the first side does not, in any manner, affect the second side. A possible difficulty is registration. With proper care, satisfactory two-sided boards are realizable.

The system is flexible. For example, the circuit and component sides of a board may be shown in one simplified view on an assembly drawing. The artwork is photographed with a white-dot pattern Craftint screen overlay (25 to an inch). The result is a full-sized screened copy of the artwork copied on the reverse side of a drawing form. Viewed from the front, the layout appears to be reverse reading. The draftsman can visually locate the placement of components from the terminal pads located on the reverse side of the drawing. Prints made from the drawing show details of each mounted component superimposed on the screened "ghost" circuit image. ▲



The author has been associated with various satellite programs utilizing the Agena vehicle since joining Lockheed Missiles and Space Company in 1963. Areas of responsibility have included guidance and control, communications and command, and electrical power systems. He was previously employed by Montronics Inc., now a subsidiary of John Fluke Mfg. Co., while attending Montana State University (BSEE). He has written for various electronics magazines.

Printed-Circuit Kits for Short Runs

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

Here is a rundown on some of the PC kits that are readily available for use by small laboratories or in the workshop.

PROFESSIONAL-quality etched-circuit boards may be produced in the small laboratory or in the workshop. The process is neither difficult nor particularly hazardous, and special equipment is not required. The purchase of one or more of the several inexpensive printed-circuit kits that are available affords an excellent means of becoming acquainted with the various materials and techniques. The kits contain all of the constituents (including instructions) necessary to produce a limited quantity of quality boards. The kit materials may be replenished, and the per-board cost will be reduced significantly if larger quantities of the individual items are purchased.

Selecting & Using a Kit

Selecting the most appropriate kit for an intended application requires some initial familiarity with the commonly used materials and processes. Board materials, resists, and etchants may then be chosen to best suit the technical requirements or interests of the user.

Copper-clad PC board material is readily available in either NEMA grade XXXP phenolic paper or grade G-10 general-purpose epoxy-glass laminates, 1/16" thick, covered uniformly on one or both sides with copper foil, 1 or 2 ounces per square foot of board material, and with or without a photosensitive resist coating. Grade XXXP is less expensive than G-10, is easier to machine, and is entirely adequate for most applications. Grade G-10 should be used, however, for high-frequency r.f. applications. The foil thickness required is a function of available conductor width and required current-carrying capacity. A 0.100" wide conductor of 1-ounce (0.00135") foil will safely carry 3 amperes, and the same width of 2-ounce foil (0.00270" thick) will carry 5 amperes. Both figures are for a 20°C maximum temperature rise.

The resist is applied mechanically to an unsensitized board, or created photographically on a sensitized board. Mechanical resists are available in tape (stick-on), dry transfer (rub-on), or liquid form; the most suitable mechanical resists have an asphalt or vinyl base. The more expensive photographic process requires the preparation of a mechanical or photographic negative of the PC board layout. It is ideal when several identical boards are required, when the artwork is to be prepared on a larger format than that of the finished board, or when the ultimate in finished appearance is required. Both the dry-transfer resists and the photoresists have a limited storage life (approximately one year).

Ferric chloride or ammonium persulfate are the two most commonly used etchants. A typical ferric-chloride etchant is 34% (by weight) $FeCl_3$ in water, although the concentration may range from approximately 28% to 42%. The mixed solution will contain a small amount of hydrochloric acid; proprietary etchants may be modified to contain up to 5% HCl. Ferric-chloride etchant has an indefinite shelf life, may be reused, and has a useful capacity of around 12 to 15 ounces of copper per gallon of solution. The etching time decreases with increasing temperature; the solution may be used from room temperature up to about 160°F. Ferric chloride attacks solder, steel, cast iron, and many other metals.

Typical ammonium-persulfate etchants contain about two pounds of ammonium persulfate per gallon of water. A mercuric-chloride (1 ml of 27 g/l solution per gallon) or sulphuric acid (60 ml of 96% H_2SO_4 per gallon) catalyst is usually added. The mercuric chloride is poisonous, but the etchant should not be stored in a tightly stoppered bottle because of gas release. The ammonium-persulfate etchant has a useful capacity of about 7 ounces of copper per gallon of etchant and should be used warm (115°F typical).

When the concentration of copper reaches 5 ounces per gallon, the etch temperature should be kept above 130°F. It is unstable above 150°F and should be used within a few days after mixing. Spontaneous decomposition may occur if it comes in contact with ferric chloride. Its chief advantage lies in its compatibility with most of the plated-metal resists.

All traces of the etchant must be removed from the finished board. Ferric chloride, especially, has a tendency to contaminate the laminate substrate with insoluble forms of ferric oxide. The etchant can normally be removed from the board by thorough rinsing and scrubbing immediately after etching. Tape resists are simply peeled off; liquid resists, dry-transfer resists, and photoresists can be removed by scrubbing the board with an abrasive household cleanser or washing with a suitable solvent.

Typical Available Kits

Printed-circuit kits are available from several sources and range in price from $3.49 to $42.95. Seven kits, representing five major vendors and priced under $10.00, were examined and tried by the author. They represent a comprehensive selection of board materials, foil configurations, resists and etchants. In addition to the seven PC board kits, two special kits designed for the production of photographic artwork and contact negatives are included in the brief summary that follows.

Editor's Note: *There are many other PC kits available for use for short runs or in the workshop. However, we are including the following as representative examples of those kits that are most readily available from the larger electronics parts dealers.*

Amidon Associates (12033 Otsego Street, North Hollywood, Calif. 91607).

E-Z Etch Printed-Circuit Kit No. 246-D ($5.95) contains dry-transfer resist, 48 square inches (2 pieces) of 1/16" epoxy fiber glass board clad on one side with 2-ounce copper foil, and dry ammonium-persulfate etchant crystals.

A single-board kit is available at a corresponding reduction in price. The small pads and narrow conductor strips included in this kit will be of particular interest to IC users.

The complete line of *Amidon* products may be obtained from *Amidon* or from *World Radio Laboratories*. Many of the local *Lafayette Radio Electronics* stores stock the printed-circuit kits.

Injectorall Electronics Corp. (4 North Rd., Great Neck, N. Y. 11024).

Printed-Circuit Kit No. 500 ($5.95) consists of 2 3" x 1½" 1/16" XXXP phenolic boards clad on one side, a resist-ink pen, resist-ink solvent, a 6-oz bottle of ferric-chloride etchant, a 1/16" drill bit, and a 5" x 7" x 2" plastic case in which the boards are etched and the kit is packaged. Kit is available from *Lafayette Radio Electronics* and other parts dealers.

Kepro Circuit Systems, Inc. (3630 Scarlet Oak Blvd., St. Louis, Missouri 63122).

Standard Kit No. S-101A ($3.95) contains both liquid and tape resists, 54 square inches (3 pieces) of plain and perforated 1/16" XXXP phenolic board clad on one side with 1-ounce copper foil, and liquid ferric-chloride etchant.

Professional Kit No. P-101A ($5.85) utilizes the photographic process. It contains 45 square inches (3 pieces) of 1/16" XXXP phenolic board clad on one side with 1-ounce presensitized copper foil, mechanical negative material, photoresist developer, and liquid ferric-chloride etchant.

Both kits are available with G-10 glass epoxy boards instead of phenolic boards at a corresponding increase in price.

Photo Layout Kit No. PL-2A ($3.95) is designed for making photographic artwork layouts for contact or photographically reduced negatives. It contains mechanical negative material, clear acetate film, and pressure-sensitive tapes, pads, and letters.

Photo-Reversing Kit No. FK-701 ($7.20) is a unique kit for producing high-contrast line negatives from inked or taped artwork. The artwork is contact-exposed on the film provided (480 square inches total) and developed with the developer supplied.

Kepro products may be obtained from *Allied Electronics*, *Newark Electronics Corporation*, and *Burstein-Applebee*.

Techniques, Inc. (235 Jackson Street, Englewood, New Jersey 07631).

Experimenters Printed Circuit Kit No. 5002 ($4.75) contains tape resist, 72 square inches (6 pieces) of 1/16" XXXP phenolic board clad on one and both sides with 1-ounce copper foil, and the liquid ferric-chloride etchant.

Typical example of printed-circuit kit showing all the components. The kit shown, the Techniques No. 5003, at around $10, has ample supplies for several projects.

Technicians Printed Circuit Kit No. 5003 ($9.75) is an enlarged version of the 5002 kit, containing both tape and liquid resists, 128 square inches (10 pieces) of board material, and proportionately larger amounts of the other supplies.

Techniques products may be obtained from *Lafayette Radio Electronics*. Do not order small quantities of material directly from *Techniques* in Englewood.

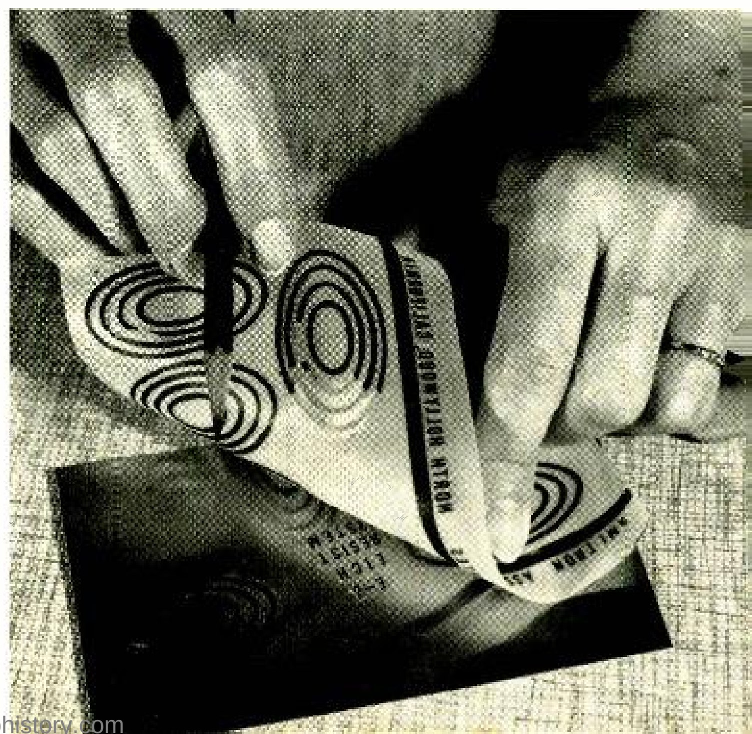
Vector Electronic Company, Inc. (12460 Gladstone Ave., Sylmar, Calif. 91342).

Etched Circuit Kit No. 27XA ($6.50) contains dry-transfer resist, approximately 80 square inches (4 pieces) of plain and prepunched XXXP phenolic board clad on one side with 2-ounce copper foil, and dry ammonium-persulfate etchant crystals.

Vector products may be obtained from *Allied Electronics*, *Newark Electronics Corporation*, or *Lafayette Radio Electronics*.

The prospective PC board user would do well to obtain catalogues from the listed vendors and examine the other products they have to offer. ▲

The dry-transfer resists are applied easily and rapidly. The ones shown being used here are from Amidon Assoc.



The author is a graduate of Columbia University (Chemical Engineering). He holds several patents in metal processing and chemical engineering. He has been a consultant to industry and federal government in process engineering problems.

Flexible Printed Wiring

By GAETANO T. VIGLIONE / Manager, Product R & D
Flexiprint Division, Sanders Associates, Inc.

This wiring can be preformed, folded and rolled, twisted and turned to fit any conceivable irregular configuration. It is particularly useful in very dense electronic packages.

FLEXIBLE printed circuitry consists of flat etched copper conductors bonded between layers of pliable insulation. While this sounds simple enough, flexible printed circuitry has had placed upon it many demands, some of which are due to the numerous design features which appear to be attainable. The use of flexible circuitry as an interconnection medium has begun to inspire the design engineer because of its many advantages.

For example, the significant difference of less weight per unit of area coupled with the reduction of volume over conventional cabling techniques, results in reductions in mass of 2:1 and, in some cases, 8:1. The feature of flexibility allows circuits to be preformed, folded and rolled, or twisted and turned to fit any conceivable irregular configuration in the more dense electronic packages, especially those typical of aerospace applications. Further, flexible printed circuitry is readily shielded and inherently more reliable due to its design and the adaptation and use of materials having exceptional physical properties.

The real dollar savings come at the time of assembly of the electronic package because of a reduction in man-hours required for assembly. Another benefit is the reduced possibility of error when connecting by flexible printed circuitry as compared to the greater possibility of error when using point-to-point wiring.

Listing of Advantages

The benefits resulting from the use of flexible printed wiring and cabling include the following:

1. Each circuit is a finished unit, ready for component assembly.
2. Handling of individual wires is eliminated because there is no need to measure, cut, strip, tin, route, solder, and lace.
3. Circuits are custom-designed for each job; therefore, wiring errors are eliminated.
4. Each circuit of a particular design is mechanically and electrically identical and completely repeatable.
5. Solder pads are in one place, rendering them ideal for automatic processing.
6. Wiring requirements no longer limit package geometry. Circuits can be run flat, bent around sharp corners, folded, and twisted.
7. Conductor breakage is nil. High-reliability hinge, spring return, and extensible interconnections can be readily designed.
8. Flexible printed circuitry can be bonded to rigid circuit boards to create a complete, one-piece interconnection assembly, eliminating unnecessary solder joints.
9. Single and multilayer circuits are closely spaced and held to close tolerances; therefore, high wiring and internal package densities are possible.
10. Flexible printed circuitry has a high volumetric efficiency. Close-tolerance conductor location is possible because each circuit is a precision etched unit.
11. Material normally needed in the form of a relief loop for the bend radius using standard wire cable can be eliminated, resulting in shorter wiring runs.
12. Thin, flat, two-dimensional geometry permits cable routing through narrow slots and along smooth surfaces, eliminating the excessive bulk of round wire.
13. Depending on the specific application, flexible printed circuitry can save approximately 75% of volume and weight over conventional round-wire cable.
14. Foreign material, such as moisture, flux, and gases which could "wick" inside the insulation of wire, cannot degrade flexible printed-circuit performance because all conductors are completely encapsulated.
15. Tension loads are carried by the entire cable, not by individual wires; therefore, each circuit part is a solid mechanical structure.
16. High reliability in demanding environments is inher-

CHARACTERISTICS	UNITS	VINYL	MYLAR	ACLAR (FLUOROCARBON)	FEP TEFLON	KAPTON (H-FILM)
Max. Continuous Temp.	°C	65	149	149	204	204
Absolute Max. Temp.	°C	93	149	200	274	400
Low Temp. Embrittlement	°C	2	-50	-85	-85	-250
Thermal Expansion	mils/°C/in	0.07-0.25	0.027	0.045-0.07	0.083-0.105	.020
Thermal Conductivity	10^{-4} cal/sec-cm³-°C	3-4	3.63	6	6	3.72
Burning Rate	ASTM-D635	Slow	Slow	None	None	None
Tensile Strength	psi	3300	4000	5700	2700-3100	6500-10,000
Elongation	%	200-450	100	100-200	250-330	70
Specific Volume	in³/lb	22.8	30.4	13.2	12.8-13	15
Modulus of Elasticity	10^5 psi		5	2-3	0.5	4
Water Absorption	% (24 hr immersion)	0.4-0.6	0.01	0.00	0.01	3.0
Weathering Resistance	MIL-STD-2026	Fair	Fair	Excellent	Excellent	Excellent
Fungus Resistance*	MIL-E-5272	Nutrient	Non-Nutrient	Non-Nutrient	Non-Nutrient	Non-Nutrient
Chemical Resistance		Good	Excellent	Excellent	Excellent	Excellent
Abrasion Resistance	Taber Abraser	Good	Excellent	Excellent	Excellent	Excellent
Flexibility		Excellent	Good	Good	Excellent	Fair
Dielectric Constant	ASTM-D150					
60 Hz		6-8	3.15	2.6-2.8	2.1	3.5
1 kHz		5-6	3.1	2.5-2.6	2.1	3.4
1 MHz		3.5-4.5	3.0	2.4-2.5	2.1	3.3
Relative Dielectric Constant Ratio	ASTM-D150	2.3	1.2	1.0	0.8	1.4
Dissipation Fact.	ASTM-D150					
60 Hz		0.10	0.002	0.015	0.0003	0.0014
1 kHz		0.10	0.005	0.025	0.0003	0.0016
1 MHz		0.08	0.016	0.010	0.0003	0.0071
Dielectric Strength	V/mil in 5-mil thickness**	1700	3300	1300	5000	3000
Volume Resistance	ohm-cm	10^{11}-10^{14}	10^{18}	10^{18}	10^{17}	10^{17}
Minimum Available Thickness	in	0.006	0.0025	0.002	0.002	0.0005
Standard Thickness	in	0.012	0.0025	0.005	0.005	0.005

*Per MIL-E-5272 Procedure 1. **Conservative design rating is 1000 volts at 5-mil thickness for all insulations.

Table 1. Characteristics of the most commonly used insulation material for flexible printed wiring.

ent because the entire circuit flexes as a unit under stress of vibration and shock.

17. Distributed capacitance and cross coupling do not vary from unit to unit of a single design, resulting in constant electrical characteristics.

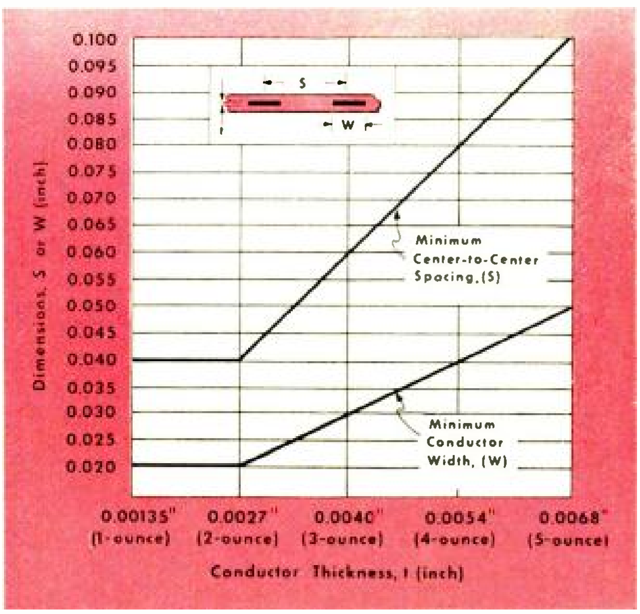
18. Circuits are easier to solder and inspect than a tangle of conventional wires; therefore, quality-control operations are more accurate.

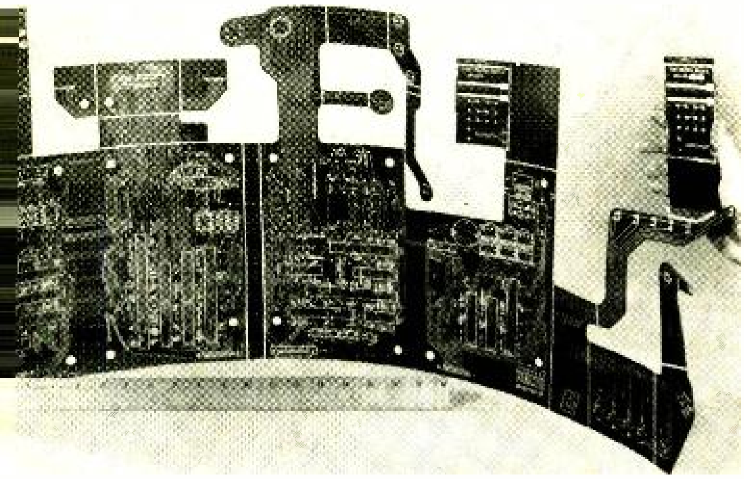
Design Criteria & Costs

When considering the use of flexible circuitry for interconnecting either printed-circuit boards or black boxes, certain basic design criteria should be remembered. General guidelines to keep the number of layers in flexible circuitry to a minimum are: set-up pin address to reduce or eliminate crossovers; use the freedom of pin address as a method of reducing layers; consider the use of narrower conductors and spacing; and use fold-outs to increase density at the terminal area.

There are many factors that affect the cost of a flexible circuit. Major cost advantages result if standard flexible-circuit materials and sizes are used and if non-critical tolerances are loose enough to allow economical, automated production. The following items will also serve to keep costs to a minimum:

Fig. 1. Conductor widths and spacings for various thicknesses.





This complex flexible printed circuit, which is shown here along with an 18-in rule for size comparison, demonstrates how a complicated interconnection problem has been handled.

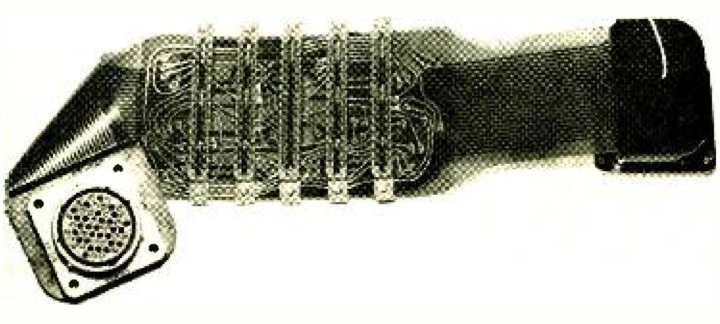
1. Specify 0.0027" thick (2-ounce) copper conductors if possible. These are the most economical because raw materials are purchased, handled, and stocked in large quantities. Other sizes, such as 0.00135" (1 ounce) and 0.0040" (3 ounces) are available should the need arise.
2. Specify enlarged punched-out areas in the covercoat at solder-pad areas rather than tight-fitting, pad-sized individually punched areas. This eases registration in manufacturing and thereby reduces cost.
3. Try to keep punched-out bare copper areas on the same side of the circuit. If it is necessary to present bare copper on the reverse side of a circuit, try to eliminate the extra cost involved in punching the base insulation by folding the circuit.
4. Keep large punched-out areas in simple shapes to lower the cost of intricate dies and/or to avoid excessive hand-cutting and punching.
5. Design terminal pads somewhat oversized to allow for slight drift.
6. Specify insulation as shown in Table 1. These are usually stocked in quantity.
7. It is recommended that conductor widths be specified *larger* than the minimum shown in Fig. 1.
8. It is recommended that conductor spacing be specified *larger* than the minimum shown in Fig. 1.
9. Hold over-all flexible-circuit length and width to a minimum.
10. Use the fewest number of layers possible.

Terminating Methods

Another important design consideration is the selection of the termination method. Recently, connectors for flat cable that accommodate circuits of 50-mil centers have become available. The type and size of terminating pins and connectors and the method of attaching the circuits to them is important in keeping down the size and weight and permitting greater accessibility. The method of terminating using a pad with a hole or a "lap" soldering technique utilizing pins from a connector are two of the most commonly used fabricating techniques.

For reasons of greater economy and increased reliability, a new generation of terminations welded to flexible circuitry has evolved. Materials such as tinned copper, nickel, and gold-plated Kovar are being satisfactorily welded to flexible circuits and potted as a substitute for specifically designed connectors. All of these terminal lead materials are easily solderable and, in some cases, they are also welded to weldable printed-circuit boards. The advantages here are: lower attrition due to the fact that leads do not become unsoldered upon secondary soldering; faster processing, reducing the possibility of process effects such as delamination due to less time at high temperatures as when a solder joint is made.

A multilayer flexible circuit with layer-to-layer interconnections along with connectors attached is illustrated.



Materials Used

The materials used in the fabrication of flexible printed circuitry depend upon the application and environment in which the equipment will be expected to operate. Normally, Kapton-F film, to which copper has been laminated, is used because of its desirable high-temperature properties. (Kapton-F is the trademark of the *duPont Company* for its plastic film consisting of a layer of Teflon FEP resin bonded to one or both sides of a polyimide film.)

Covercoat materials can be varied depending on the humidity characteristics and high-temperature properties expected in the system operation. To some extent, the choice of materials is dictated by the amount of flexing anticipated prior to and during assembly of the units. Generally, the polyimide materials are most popular since the physical influences, mentioned above, are most easily overcome. However, copper, due to its inherent nature when subjected to excessive flexing and vibration, can eventually result in fatigue and electrical failure unless proper support of the connector areas and the crucial bend radii are carefully observed and practiced.

Testing Flexible Printed Circuitry

While much information is available on the applications aspects of flexible circuits, very little data has been presented about the environmental characteristics of the finished product. *Sanders*, as well as other manufacturers of flexible printed wiring, has set up test programs to run environmental checks on its products to make sure they meet customer specifications. The following government and industry standards have been used for such tests: MIL-T-5422E, MIL-STD-354, MIL-STD-202, MIL-P-55110A, MIL-STD-810, MIL-E-5272, MIL-P-13949, IPC-CF-150 copper foil specification, ASTM-D-635, and ASTM-D-150.

The parameters evaluated include: operating temperature; moisture absorption; flexing and tensile strength; resistance to chemicals, abrasion, and fungus; aging and weathering effects; distributed capacitance and required shielding; flammability; dielectric constant and strength; conductor and insulation resistance; and current-carrying capability.

The results of the test data will be supplied to customers and potential customers by the manufacturers of flexible printed wiring. Such test data, while considered to be evidence of the present and potential quality of flexible circuitry, is really only a start. Much testing of new materials and advanced processes is continuing, insuring that advanced technology is made available to the user of flexible printed circuitry as new materials are developed and placed on the market. ▲

FREE!

Mail This Card Today

LAFAYETTE 1970 Catalog 700 Our 49th Year

BETTER THAN EVER

Your Complete Buying Guide to Everything in Electronics

496 Pages

Featuring Everything in Electronics For
- HOME
- INDUSTRY
- LABORATORY

Use LAFAYETTE'S Easy-Pay Budget Plan
No Money Down . .
Up to 24 Months to Pay
Satisfaction Guaranteed or Money Refunded

Do A Friend A Favor
Give Him This Card To Send For His

FREE LAFAYETTE CATALOG

STORE LOCATIONS

NEW YORK	NEW JERSEY	MASSACHUSETTS	CONNECTICUT	PENNSYLVANIA
Brooklyn, Jamaica, Lynbrook, Lake Grove, Manhattan, Rochester, Scarsdale, Syosset, New Rochelle	Newark, Paramus, Plainfield	Boston, Natick, Saugus	Hamden, W. Hartford	King of Prussia, Monroeville, Philadelphia, Pittsburgh

WASHINGTON, D.C. (Area) — Falls Church, Va., Mt. Rainier, Md.

Mail The Coupon Today for your FREE 1970 LAFAYETTE CATALOG 700

LAFAYETTE Radio ELECTRONICS
Dept. C2109 P.O. Box 10
Syosset, L.I., N.Y. 11791

Please Send the FREE 1970 LAFAYETTE CATALOG 700

Name ____________________

Address ____________________

City __________ State __________ Zip __________

MAIL THIS CARD TODAY FOR YOUR

FREE!

1970 LAFAYETTE CATALOG 700

Dept. 01109

Name ____________________

Address ____________________

City ____________________

State ____________________

Zip ____________________

(Please Give Your Zip Code No.)

MAIL THIS CARD TODAY FOR YOUR

FREE!

1970 LAFAYETTE CATALOG 700

Dept. 01109

Name ____________________

Address ____________________

City ____________________

State __________ Zip __________

JOHN FRYE

Servicing medical electronic equipment can be a rewarding job for responsible, knowledgeable, well-equipped technicians.

MEDICAL ELECTRONICS SERVICING

IT was a jewel of an October morning—sparkling with dew, flooded with sunshine, and tinged with just a trace of that too-good-to-last gentle melancholy that always is a part of true beauty. Barney reluctantly stepped out of the glorious autumn morning into the service shop, but his eyes widened as he saw Mac, his employer, seated cross-legged on the service bench reading a loose-leaf brown manual.

"Hey," the youth exclaimed. "I didn't know your rheumatic old legs would fold up like that. How come you're sitting on the bench?"

"Because Matilda beat me down here this morning and painted both the bench stools," Mac growled, nodding to where the bright green stools rested on top of the "intermittent-cooker" bench. "They didn't really need it. I painted them myself only ten or twelve years ago."

"When you encounter a determined woman with a paintbrush, you may as well give in gracefully," Barney advised. "Even I, a bachelor, know that much. What are you reading?"

"A service manual on a piece of medical diagnostic equipment called an 'UltraSonoscope.' Last week I had a phone call from the manufacturer on the East Coast who said one of these units was being sold to the local hospital. A couple of doctors in the lab here had suggested we be contacted to see if we would undertake service of the instrument in case of failure.

"You see it's hardly practical for a manufacturer of medical electronic equipment to maintain service stations manned by factory-trained personnel in all parts of the country. Not enough units are sold to warrant that. Neither is it feasible to send a serviceman out from the factory every time trouble is reported with one of the units, especially when most of these difficulties are simply 'cockpit troubles' caused by improper adjustment or operation. A more satisfactory arrangement, according to the man who called me, is to locate a well-equipped service technician in the area who is willing to undertake maintenance of the unit."

"Yeah, but can a radio and TV service technician successfully undertake a job like that?" Barney questioned. "It seems to me he should have both a medical and electronic background for that kind of work."

"A medical background certainly wouldn't hurt," Mac admitted, "but in this case, at least, it's not really essential to understanding the operation of the instrument. Let me tell you what an UltraSonoscope does:

"Essentially it's a precision short-range sonar system using sharply beamed pulses of ultrasonic sound to probe tissue by observing on a CR tube echoes returned from interfaces in the tissue. The transducer used to send the pulses into the tissue also is used to pick up the returning echoes and feed them into an amplifier for display on the scope tube.

"Since sound waves travel through tissue at a velocity of about 150,000 cm/s, the horizontal sweep of the scope can be calibrated in terms of the depth of tissue through which the echo is returned. A precision marker generator and dividers in the instrument produce a calibrated base-line display marked off in centimeters and fractions of tissue penetration. If the instrument is adjusted so that the 'main bang' pip indicating the surface of the body is on a centimeter mark at the left of the screen, the indicated distance to the right of this mark that an echo pip appears is a measure of the depth of tissue through which the echo is returning.

"This is with the instrument operating in the 'A-Scan' mode in which the horizontal axis represents time translated into tissue penetration and the vertical axis represents intensity of the echo. In the 'B-Scan' mode, the display is effectively turned through 90 degrees so that the former vertical pips come out towards the observer. In other words, the beam is intensity modulated by the echo signals feeding the receiver. Now if the location of the initial pulse on the face of the tube can be directly correlated with the movement of the transducer over the body and if a photograph of the resulting scanned display be made, the result is a 'tomogram,' a kind of cross-sectional view of the tissue beneath the scanning transducer.

"In another application, called 'echocardiography,' the transducer is applied over a beating heart and the dimmed horizontal trace, intensity modulated by echoes returning from moving tissues of the heart, is swept slowly upwards from the bottom of the CR tube while a camera photographs the resulting scanned display. Movement of tissue surfaces toward and away from the transducer—say the surfaces of the leaves of the mitral valve—cause the echoes returned from this tissue to move respectively left and right on the base line. When the base line is scanned upwards at a uniform velocity, this lateral shift in the echo signal traces out a continuous sawtooth-like display. If an EKG trace is simultaneously displayed on the left side of the screen, the position of the parts of the mitral valve—or any other moving parts of the heart, for that matter—can be correlated with any particular portion of the heartbeat cycle."

"Hold on," Barney interrupted. "Let's see if I'm with you so far, doctor. Apparently this UltraSonoscope consists essentially of a precision laboratory-type scope, a marker generator that's probably crystal-controlled, an ultrasonic pulser, and a specialized vertical amplifier for displaying the echoes. That much would take care of the A-Scan display. The slow-sweep vertical scan used in B-Scan echocardiography would require a vertical sweep circuit. And to produce that tomogram you were talking about there would have to be some device that would cause the movement of the transducer to produce spot-positioning voltages for the CR tube. How am I doing?"

"Not bad, but of course things are not quite that simple. For example, the UltraSonoscope has an adjustable Sensitivity Depth Compensation circuit to compensate automatically for the attenuation of pulse signal echoes as they are returned from deeper and deeper tissues. This is actually a time-variable gain control keyed to the horizontal sweep so that the gain of the vertical amplifier increases as the trace moves to the right, insuring that the strength of the echo

←CIRCLE NO. 124 ON READER SERVICE CARD

returned will be a function of the interface itself and will not be greatly influenced by how far this interface lies beneath the surface of the body. There are other tricky circuits involved in both the basic instrument and the many accessory modules available for it. Still and all, the circuitry consists of sophisticated applications of fundamental electronic concepts that should be understood by any good TV service technician."

"You did, then, agree to take on the maintenance job?"

"Yes, after a little arm twisting. The manufacturer agreed to furnish complete service data on the instrument plus consultation privileges. In other words, if something goes wrong with the instrument that cannot be easily and quickly located from directions contained in this service manual, I can pick up the telephone and call the company and talk with their engineer. His experience and familiarity with the instrument plus my observation of symptoms and carrying out of suggested tests will, hopefully, get the thing going again in jig time."

"I'm still surprised you let him talk you into it. Surely the comparatively small amount of loot involved in servicing one instrument wasn't a factor."

"No, but there are other things to consider. In the first place this is an opportunity for us to expand our knowledge of electronic applications. Secondly, it may open the door to a great deal more of this kind of specialized service that could become quite lucrative. We both know medical electronics is just starting to take off, and this could be an opportunity for us to get in on the ground floor. Finally, *someone* must service medical electronic equipment if it is to take the place it should in the prevention and curing of disease. If we, who can do it, won't, the widespread application of such equipment will lag far behind its true potential; and people will suffer and die needlessly as a result."

"You sound as though you're getting ready to plunge into medical electronics servicing with both feet."

"Far from it! I'm just dipping a cautious toe into the water. Candidly, this kind of service work is not for every TV technician, and anyone considering it should do a lot of soul searching before he tries it.

"This kind of servicing requires a truly responsible person. When you are working on equipment that may mean life or death to an individual, there is no room for guessing, carelessness, or slipshod techniques. You must be willing to devote extra time and effort to the job. Not only must you be willing to study the operation and service manuals thoroughly in advance of any service needed, but you must be prepared to drop everything and take care of the equipment when it does fail—even though that means working extra long hours.

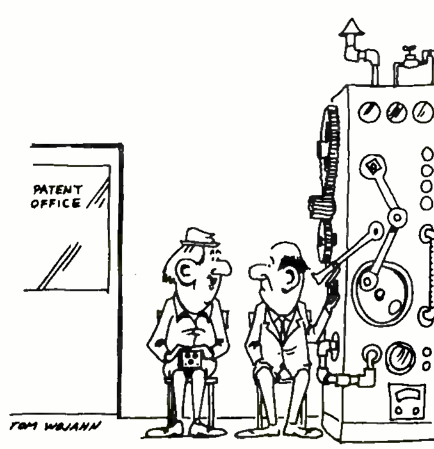
"You must be constantly safety-minded in working on this equipment. This service manual has several paragraphs on just that subject as applied to the UltraSonoscope and its use. Every effort has been made to prevent leakage and to insure good grounding of the instrument and all its attachments, but the maintenance technician must take every care to see to it that these precautions continue in effect."

"But in spite of all these drawbacks, you are still going to venture into this kind of service."

"Yes, for the reasons I mentioned and because doing this kind of service may sharpen our TV service techniques. Working as we do on the same basic kind of equipment day after day, there is an increasing tendency for us to depend more and more on well-learned experience and habit and to divorce the higher thought processes from what we are doing. As lots of guys boast, 'I can service these things in my sleep.' Servicing unfamiliar equipment will force us to think hard about every symptom we perceive and every test we make. If the doctors are going to be able to depend on the UltraSonoscope to diagnose faulty hearts, locate brain tumors or objects in the eye, determine the size and shape of gall stones, or measure the size of an unborn infant's head, we are going to have to be on our toes every minute we are servicing the instrument.

"Hey," Mac broke off, "why are you staring at your shop coat so hard? Something on it?"

"No, but I was just wondering if maybe we shouldn't trade these green jobs in for some smart-looking white laboratory smocks more in keeping with our new career," Barney said with a grin. "But come on, Grandpa; unkink your legs and crawl down off that bench while you still can. It makes me hurt just to look at you!" ▲



"Well, how about that! Mine does the same thing as yours!"

BREADBOARD CIRCUITS from PC BOARDS

By J. M. FIRTH

Pure Physics Div.
National Research Council of Canada

THE technique of using printed-circuit (PC) boards for breadboard circuits has been employed for several months and has proven very useful in construction of special laboratory instruments.

The heart of the idea is a special 3/8" diameter cutter used in a low-speed 1/4" drill. A 1/16" drill is used to cut a center hole and acts as a mandrel for the radial cutting edges which then effectively mills an "island" on the board (Fig. 1).

The components are then soldered directly to the islands. By using a double-sided board, excellent shielding can be obtained at the expense of an island-to-ground capacitance of 1.3 pF ("Q" factor >300 at 50 MHz on glass-laminate epoxy board). The top surface ground plane makes it very convenient for mounting decoupling components that may be required.

This technique can be further extended by adding sides and top to the breadboard circuit, on which connectors and controls can be mounted. Thus, a working breadboard can be converted to a useful and moderately rugged laboratory instrument.

Fig. 2 shows an r.f. amplifier with a 20-dB gain at 120 MHz using this technique. ▲

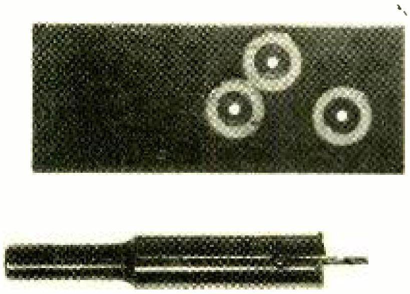
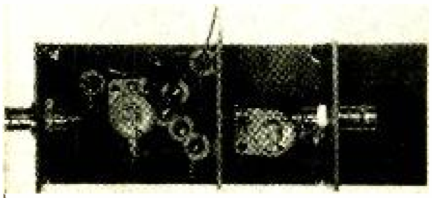


Fig. 1. The special 3/8" diameter cutter used to form "islands" on printed-circuit board.

Fig. 2. Breadboard design of r.f. amplifier built by author from printed-circuit board.



HI-FI SHOW SEMINARS PROGRAM

October 1-5, 1969
Ambassador Hotel
Los Angeles, California

WE hope that all of our readers and friends in the Los Angeles area are looking forward to the forthcoming Hi-Fi Show as much as we are. Expectations are that a much larger crowd than ever before will attend. In addition to the latest equipment in the field of home entertainment displayed by over 51 exhibitors, the added attraction of live entertainment, contests, and prizes are expected to create a festive atmosphere during the five-day run of the show. Additional activities will include a series of semi-technical seminars, of particular interest to us, since this is the 6th consecutive year the Institute of High Fidelity has asked us to originate and plan them. We're quite excited about this year's program. Two old-timers, Abe Cohen and Jim Kogen, who have participated every year, will be with us again. Joe Lesly, Jim Lantz, Russ Molloy, Ed Miller, and George Augspurger all did such outstanding jobs in both New York and L.A. last year that they will be back again this year too. And we have two newcomers: Howard Souther, vice-president, engineering, *Koss Electronics* is rather an old-timer in the industry whom we have known for many years, going back to his days with *Electro-Voice*; and Bob Beavers, chief engineer, acoustics, *Altec-Lansing*, who is a stranger to us but we've heard so many good things about him that we certainly look forward to meeting him in L.A.

We're sorry to report that the New York Hi-Fi Show will not be held this year. This is rather unfortunate in that many readers in the New York area looked upon the New York show as an annual event. We, too, will miss it this year and do hope that 1970 will see a return of this important event.

THURSDAY, OCT. 2, 1969

8:15—9:15 p.m.
"CHANGERS, TURNTABLES & CARTRIDGES"

Moderator: **BILL STOCKLIN,** Electronics World
Panelists: **JIM KOGEN,** Shure Brothers, Inc.
JOE LESLY, United Audio (Dual)

FRIDAY, OCT. 3, 1969

8:15—9:15 p.m.
"TAPE RECORDERS—REEL-TO-REEL & CARTRIDGE MACHINES"

Moderator: **BILL STOCKLIN,** Electronics World
Panelists: **JIM LANTZ,** Ampex Corp.
RUSS MOLLOY, Telex Communications Div.

SATURDAY, OCT. 4, 1969

3:00—4:00 p.m.
"THE STEREO SENSATION"

Moderator: **BILL STOCKLIN,** Electronics World
Panelists: **HOWARD SOUTHER,** Koss Electronics
ABE COHEN, ISC/Telephonics

8:15—9:15 p.m.
"ROOM ACOUSTICS & THE LOUDSPEAKER"

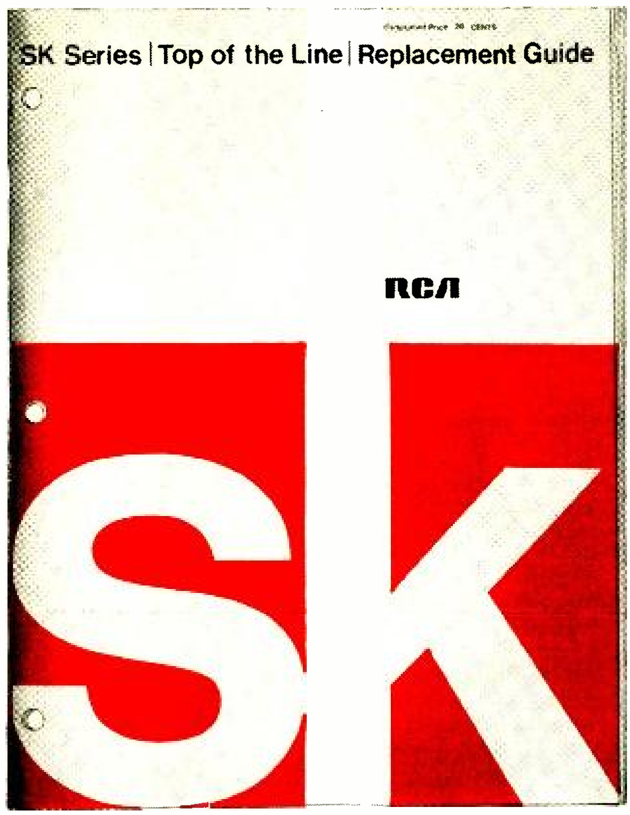
Moderator: **BILL STOCKLIN,** Electronics World
Panelists: **ABE COHEN,** ISC/Telephonics
BOB BEAVERS, Altec-Lansing

SUNDAY, OCT. 5, 1969

3:15—4:15 p.m.
"SPEAKERS & AMPLIFIERS"

Moderator: **BILL STOCKLIN,** Electronics World
Panelists: **ED MILLER,** Sherwood Electronics
GEORGE AUGSPURGER, James B. Lansing Sound

LATEST BEST SELLER
(for you)



Here it is, strictly non-fiction—in fact, all fact—the indispensable RCA solid-state replacement guide.
It works for you by charting the replacements of some 12,200 semiconductors—domestic and foreign.
The 39 SK "Top-of-the Line" transistors, integrated circuits, and rectifiers are designed and manufactured specifically for your kind of servicing problems.
All top quality, too—no cast-offs, no factory seconds, no unbranded culls. All with electrical characteristics comparable or superior to originally designed-in devices.
As for range—from small-signal operations to the newest 100-watt audio outputs!
The comprehensive RCA SK Series—and the thousands of types they can replace—are *clearly* cross-referenced in the RCA SK Series Top-of-the-Line Replacement Guide.
Pick up your copy from your local RCA Distributor today.
RCA/Electronic Components/Harrison, N. J. 07029.

RCA

CIRCLE NO. 115 ON READER SERVICE CARD

SALES OF PRE-RECORDED TAPES SOAR

AMPEX has estimated that in 1968 the U.S. recorded music industry grew about 20 percent, from roughly $1.15 billion to a value of $1.35 billion in retail sales.

Of this $200-million growth, disc records accounted for about $50 million or 25% while pre-recorded stereo tapes accounted for about $150 million or 75%. 1968 was the first year in which the growth in tape sales exceeded that of records in dollars. Stereo tapes represented about 20% of 1968 recorded music sales, up from 3-4% of the total in 1966.

The company is predicting that tape sales may reach the $350-million level this year and that over the next three years may rise to as much as 35% to 40% of the total recorded music business.

There are four major segments of the stereo tape business (open reel, four-track cartridge, eight-track cartridge, cassette), and, to a degree, they are competitive.

The four-track open-reel stereo tapes were introduced in 1959. Sales were sluggish at first but accelerated well into 1963-1966 as recorder sales rose and a broader range of music was put on tapes. In the past two years, sales in popular-music open-reel tapes have leveled off because of the availability of tapes in other forms. However, the open-reel tape remains the favorite for hi-fi reproduction and for classical recordings.

Four-track cartridge tapes were introduced in the late 1950's but didn't make much headway until the mid-'60's. They were used primarily in auto stereo systems and had no pretentions of being "hi-fi." Eight-track cartridge tapes are still holding their own as the most popular and largest part of the tape market. 90% of the sales are for auto use with the balance for home or portable playback.

The cassette stereo tape was developed by *Philips* of Eindhoven. *Norelco* and *Ampex* started the cassette stereo push in 1966-67 followed by dozens of other firms in 1968. By the end of that year, sales of cassette tapes began to develop a strong growth although still trailing the 8-track. *Ampex* is predicting that 1969 cassette tape sales will overtake 4-track and open reel and begin a real run at 8-track. The company also believes that within a time period of about three years cassettes will take over the lead. ▲

Johnson Messenger 125 $99.95

Only the famous Johnson "talk-power" is big as ever on Johnson's radically new Messenger 125! Virtually every vehicle on the road, including the 1969 and 1970 models, can easily accommodate this versatile new radio. Its far-ahead features make operation extremely simple and enjoyable. Best of all, we sliced the most out of the price!

Features

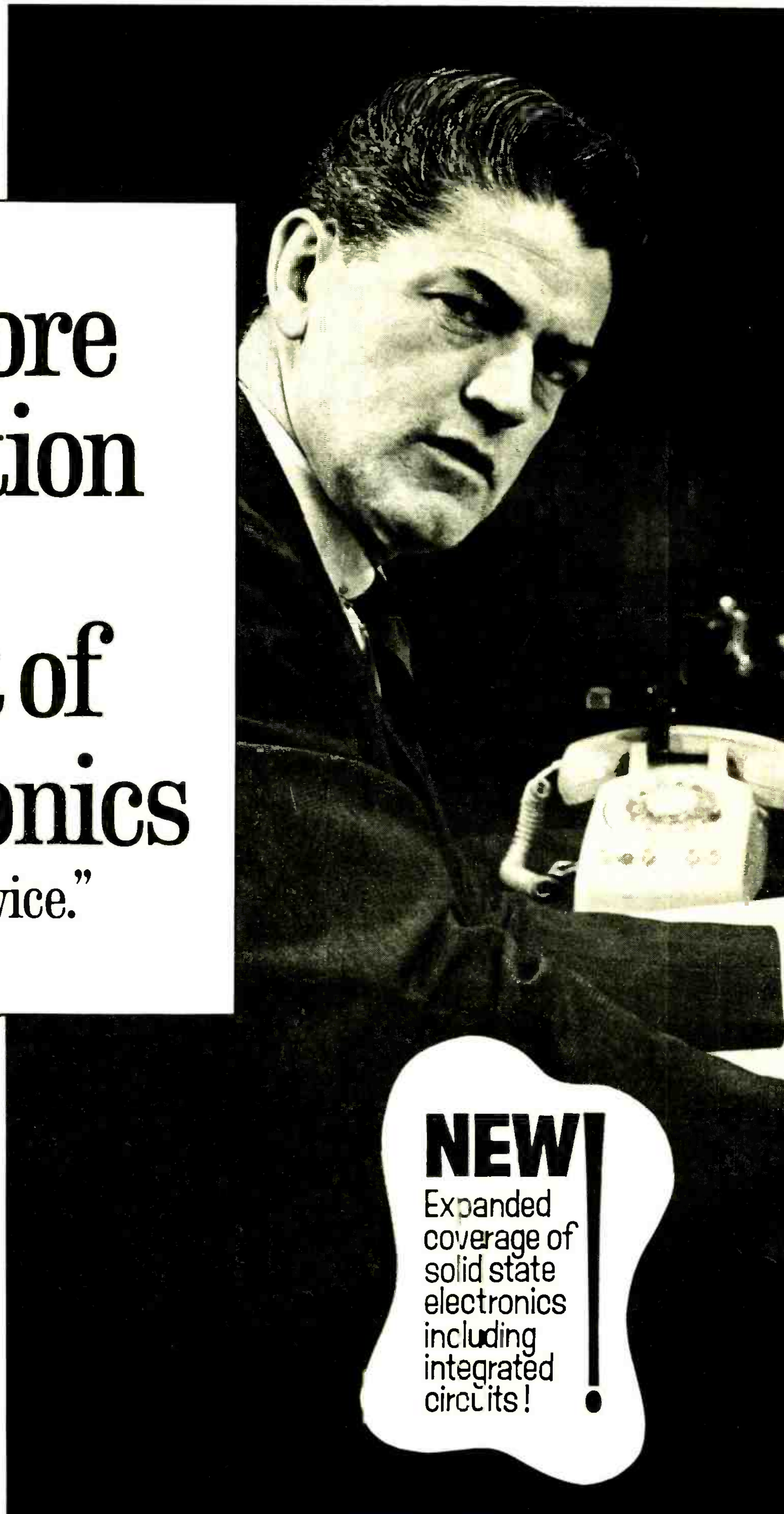
■ 5 push button channels—no knobs ■ slide-lever vol. and squelch
■ World's smallest panel configuration—1$\frac{9}{16}$" by 4$\frac{19}{32}$", just 7" deep
■ 4 watts output at 13.8 VDC ■ Accessories for portable use

E. F. JOHNSON CO.
WASECA, MINNESOTA 56093

CIRCLE NO. 127 ON READER SERVICE CARD

"Get more education or get out of electronics

...that's my advice."



SCS Crystal-Controlled Oscillator

By FRANK H. TOOKER

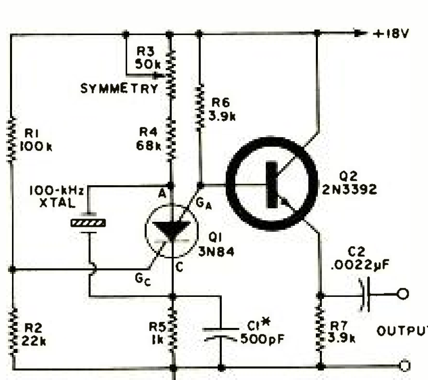
IT is usual for the silicon controlled switch to be thought of as controlled at the cathode gate, or occasionally, at the anode gate. But an SCS can be controlled quite sensitively at the anode as well. The circuit in the diagram below is an excellent example of this. Here, the alternating potential developed across an oscillating quartz crystal (connected between anode and cathode of *Q1*) controls the anode-gate current at a repetition rate of 100 kHz, the resonant frequency of the crystal.

The output waveform of this circuit is approximately rectangular. The limit of the negative-going excursion of the wave is quite horizontal, but the limit of the positive-going excursion needs to be modified by cathode capacitor *C1*. This is because the turn-on of the SCS is quite sharply defined, but the turn-off is not nearly as rapid or as clean. The condition is aggravated by the repetition rate of 100 kHz, which is quite high for the SCS.

The value of 500 pF proved to be about right for *C1* in the prototype, but in another assembly of the instrument some modification of the value of this capacitor might improve the squareness of the output waveform. If *C1* is made too small, considerable rounding will occur in the leading edge of the wave's positive-going excursion, while too large a value will produce overshoot. If the value of *C1* is much too high, it will cause the crystal to lose control of the frequency.

The setting of potentiometer *R3* determines the symmetry of the output waveform, *i.e.*, this control should be adjusted to equalize the duration of the wave's positive- and negative-going excursions.

Output from the SCS is taken at the anode-gate and fed directly to the base of bipolar transistor *Q2*, which is connected to operate as a common-collector amplifier (emitter-follower). Output from *Q2*, taken at the emitter, is fed to the output terminal *via* capacitor *C2*. Current consumption of the circuit is about 5 mA at 18 V d.c. ▲



Don't sell a color picture tube unless its been on a test ride.

Down at the bottom of the page, you have a major advance in space-age homeliness.

And a major advance in color tube testing as well.

That machine squatting down there is our beloved Iron Horse, the fully-automated, revolving carousel we use to test our color bright 85® tubes for emission, gas leakage, shorts, arcing and screen uniformity prior to shipment.

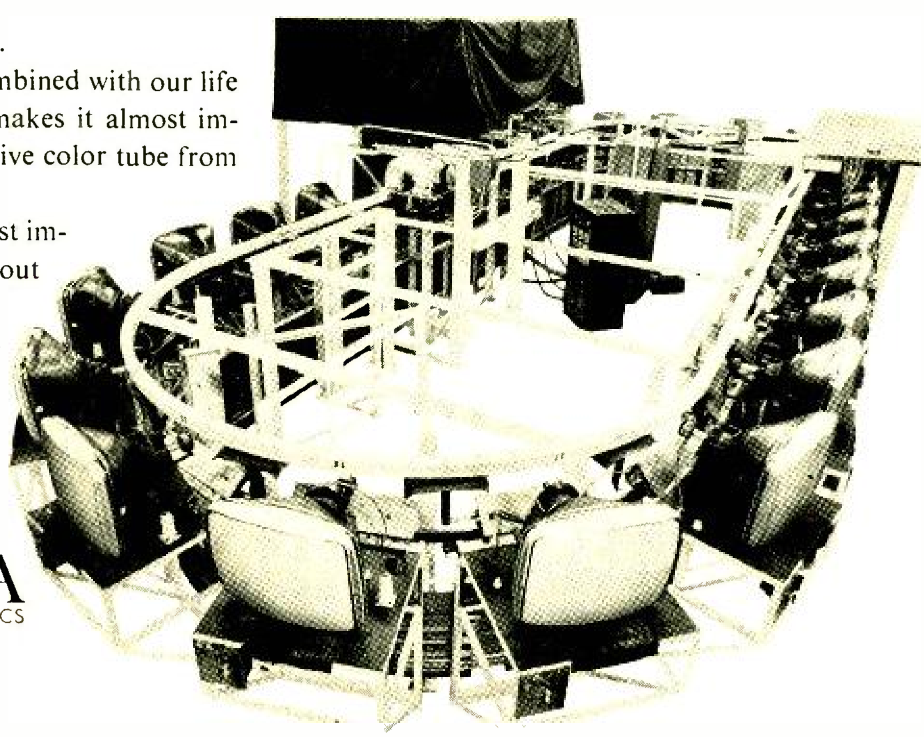
Now we don't intend to go into a song and dance on how total automation reduces testing error.

But we will tell you one thing.

Our Iron Horse test ride, combined with our life testing and 100% set testing, makes it almost impossible for you to get a defective color tube from us.

Which in turn makes it almost impossible for you to get chewed out by a customer.

Next time you need a color replacement tube, remember the great thing about the color bright 85. We don't send it to you till it's been around.



SYLVANIA
GENERAL TELEPHONE & ELECTRONICS

CIRCLE NO 100 ON READER SERVICE CARD

VARIABLE-RATE WINDSHIELD WIPER

By SANDOR MENTLER

OFTEN the amount of rain or mist on a windshield does not require continuous operation of the windshield wipers. In such instances it suffices to have the windshield wiped off with a single stroke of the blades once every few seconds.

Time-delayed relay circuits can be used to obtain such operation, but a better solution, without relays and using a minimum number of parts, is the adapter circuit shown in Fig. 1.

The UJT (*G-E* X10) operates as a relaxation oscillator with the period given by $T = RC\ ln\ (1 / [1 - \eta])$ where η is the UJT's intrinsic stand-off ratio, $R = R1 + R4$ (Fig. 1) and the units are in seconds, megohms, and microfarads. If $\eta = 0.63$, a typical value, then $T = RC$. For the values given in Fig. 1, T varies between 3 and 30 seconds, depending on the setting of $R1$.

The pulses appearing at base 1 of the UJT fire the SCR (*G-E* X3) which is actually in series with the windshield wiper motor. Once the wiper blades are set in motion, a cam-operated switch, S1, which is an integral part of the mechanism, is driven to its closed position. This action effectively places a short circuit across the SCR, turning it off. Due to the very low duty cycle that results, no heat sinks are required.

Other UJT's, such as the 2N1671 or 2N2160 may be used in place of the G-E X10. The SCR must be capable of handling about 8 amperes and $D1$ can be any good-quality silicon rectifier.

The adapter is connected directly across the existing windshield wiper switch with the polarities as indicated in Fig. 2. For cars with positive ground, the connections shown in Fig. 2 must be reversed. On multiple-speed windshield wiper switches, however, the adapter should be connected across the terminals corresponding to high-speed operation.

It should be emphasized here that the adapter will not work on automobiles having self-reversing motors used to park the wiper blades in a recessed position. ▲

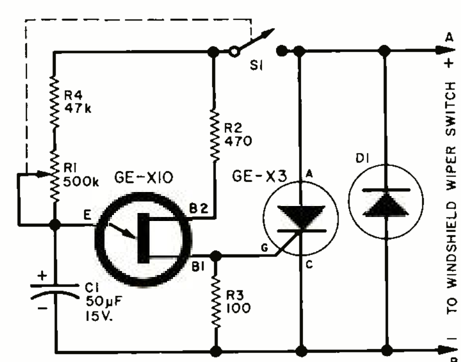


Fig. 1. Schematic of adapter for controlling windshield wiper operation.

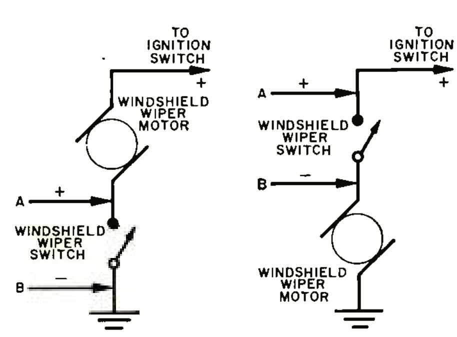


Fig. 2. Two methods for connecting the adapter to the windshield wiper switch.

smooth

RCA WP-700A, 702A, 703A and 704A constant voltage dc power supplies are all solid-state. A negative feedback circuit maintains constant output voltage with low ripple – regardless of varying line. In fact, at rated load, these supplies are so smooth that "they hardly cause a ripple."

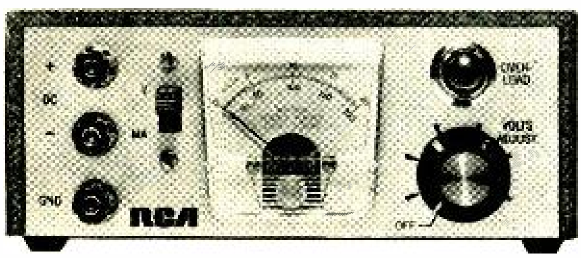
They are versatile bench-type units – ideally suited for use in circuit design, servicing, industrial, and educational applications.

Output voltage of the WP-700A and WP-702A is continuously adjustable from 0 to 20 volts at current levels up to 200 mA.

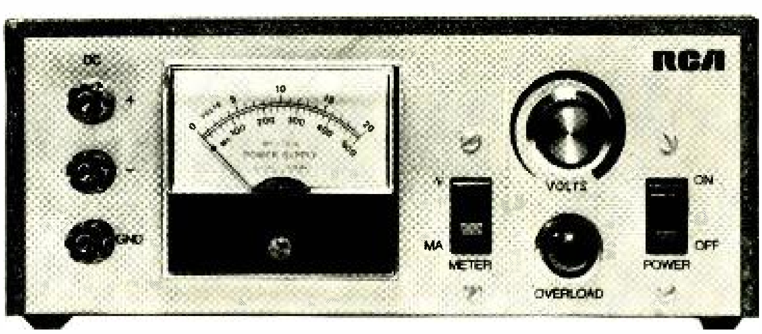
Output voltage of the WP-703A is continuously adjustable from 0 to 20 volts at current levels up to 500 mA.

Output voltage of the WP-704A is continuously adjustable from 0 to 40 volts at current levels up to 250 mA.

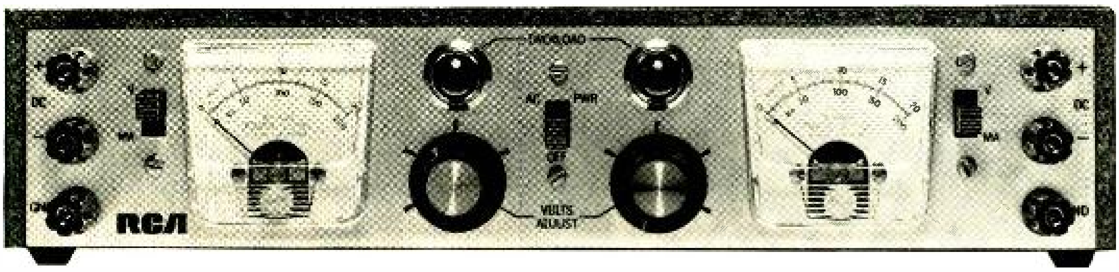
All four power supplies have built-in electronic short-circuit protection – and a front panel overload-indicator that signals approach to maximum rated current level.



WP-700A: $40.00* (five or more) $48.00* (less than five)



WP-703A: $49.00* (five or more) $58.00* (less than five)
WP-704A: $49.00* (five or more) $58.00* (less than five)



*Optional Distributor Resale Price.

WP-702A: Siamese Twins of WP-700A, but electrically isolated $73.00* (five or more) $87.00* (less than five)

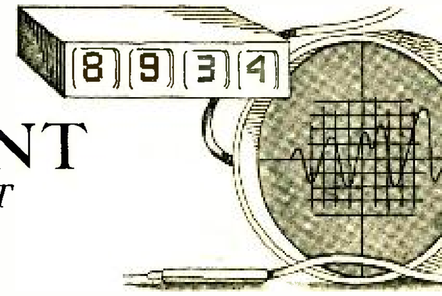
For further information write: RCA Electronic Components, Commercial Engineering, Department J-41W, Harrison, N. J. 07029.

Look to RCA for instruments to test/measure/view/monitor/generate

RCA

CIRCLE NO. 96 ON READER SERVICE CARD

TEST EQUIPMENT
PRODUCT REPORT



B&K Model 415 Sweep/Marker Generator

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

FROM our discussions with test-equipment manufacturers lately, it seems that service technicians are doing more and more alignment of color sets these days. At least there is quite a demand for combination sweep and marker generators. These instruments are solid-state devices, with a number of crystal-controlled marker frequencies, using post injection for the markers; they include a couple of built-in bias supplies for the color set, and a number of special features that make it simple to do a fast alignment job. We recall the "Knight-Kit" (*Allied Radio*) Model KG-687, the *Heathkit* IG-57, the *Sencore* SM-152 (covered in this column two months back), and now the *B&K* Model 415.

B&K has been demonstrating this unit in the field to groups of TV technicians. Their field engineers claim that they will completely misalign a color set and then realign it, using the Model 415, in less than ten minutes. We have been told that the average time to date is eight minutes. This demonstrates a very easy-to-use piece of test equipment, but also extreme familiarity with the instrument as well as the television set.

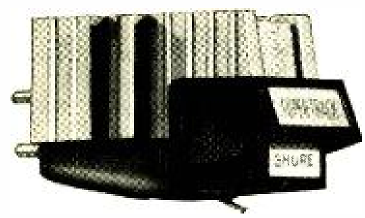
The new *B&K* 415 is an all-solid-state unit with dual-gate MOSFET's. It provides all the signals and voltages needed for alignment except for a scope and meter. Sweep frequencies, marker frequencies, and three separate bias supplies are included.

A unique feature is the reproduction of the alignment curves and marker indicators on the front panel. The user can select any or all markers, which are crystal-controlled for accuracy. A number of markers can be used simultaneously to completely mark an i.f. or chroma response curve; by using post injection of the markers there is no curve distortion by the markers and all can be seen clearly. Marker lights on the front-panel curves show which markers are being used and where they should be on the curve. Another unusual feature is that the markers can be tilted for easy identification. This is fine when the markers appear on the sides or slopes of the response curves.

In addition to the ten crystal-controlled i.f. markers, two of the r.f. channel outputs (channels 4 and 10) are also crystal-controlled. A 15-kHz filter is incorporated in the instrument to eliminate the need to disable high voltage during alignment. Besides the TV i.f. and chroma sweeps, there are also a 10.7-MHz sweep for FM-receiver alignment and a 4.5-MHz sweep for the TV audio section.

The 100-page, 8½ by 11-inch instruction manual furnished with the generator is a veritable textbook on sweep alignment. Written in the style of some of the military tech manuals we have

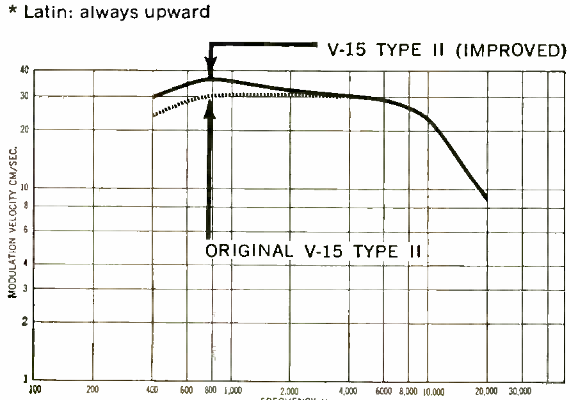
Excelsior!*



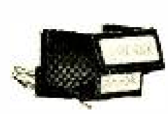
We couldn't leave well enough alone

We have improved the trackability of the V-15 Type II in the bass and mid-range registers — without affecting its redoubtable treble. Result: where, in the past, you may have been required to increase tracking forces to track heavily modulated bass drum, tympani, organ pedal, bassoon, tuba, or piano passages . . . you can now play these passages *without* increasing tracking force, without bass flutter or IM distortion . . . and significantly increase record and stylus tip life. Only $67.50 for the world's highest trackability cartridge.

* Latin: always upward



TRACKABILITY CHART (1 GRAM STYLUS FORCE)



YOU CAN MODIFY YOUR PRESENT V-15 TYPE II . . .

You may attain this higher bass and mid-range trackability by installing the IMPROVED VN15E stylus at $27.00. Look for the *word* "Shure" in red letters on the stylus grip.

NEW

SHURE

V-15 TYPE II (IMPROVED)

SUPER TRACKABILITY PHONO CARTRIDGE

CIRCLE NO. 104 ON READER SERVICE CARD

seen, the book not only covers the generator thoroughly, but also gives many practical examples of its use in a number of typical color-TV receivers.

Price of the *B&K* Model 415 sweep/marker generator is $349.95. ▲

Leader Model LTC-901 Transistor Tester

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

THERE are quite a few transistor testers on the market, but this Model LTC-901 from *Leader Electronics Corp.* is unusual. Not only does it function as a fairly conventional in-circuit and out-of-circuit transistor checker, but it can also be used as a signal injector and signal tracer for audio and r.f. circuits. What is more, the meter can be used to measure the amounts of voltage and current found in most transistor circuits. This makes it a useful and versatile piece of test equipment for the technician working on solid-state circuits.

As a transistor tester, the unit measures *beta* on two ranges (0-100 and 0-200) and collector-to-emitter leakage current up to 1 mA. Diodes can also be checked with the instrument.

For signal tracing in transistor radios or audio equipment, there is built into the unit an audio amplifier circuit, complete with push-pull output and built-in loudspeaker. The input to this circuit is from a signal tracing probe with a built-in diode detector. For tracing through r.f. or i.f. signals in a receiver, the probe is simply moved along through the circuits from antenna to detector. Output will be heard on the built-in speaker up to the point in the circuit where a defect exists. For signal tracing in audio circuits, the detector diode in the probe is simply switched out of the circuit.

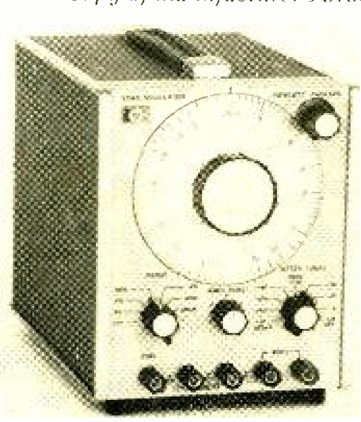
A built-in single-transistor oscillator is incorporated for producing a signal for signal-injection purposes. The output is 1000 Hz so that audio circuits can be checked. Harmonics of this oscillator can be used to inject a test signal into r.f. circuits as well.

When you are not using the meter as a readout for the transistor tests, you can employ it as a voltmeter or a milliammeter. A single d.c. voltage range of 20 volts and a single d.c. current range of 50 mA are provided. Hence, you can check the battery or power-supply voltage as well as current drain in transistor radios and other low-power solid-state equipment.

Price of the Model LTC-901 is $69. ▲

Hewlett-Packard Model 204D Audio Oscillator

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



THIS is the latest in *Hewlett-Packard's* line of high-quality, low-distortion audio oscillators. The new oscillator is similar in design and performance to the Model 204C covered in this column in our May, 1968 issue, but it has a much wider output amplitude range. Its amplitude goes up to 2.5 volts into 600 ohms (5 V on open circuit) and down to less than 250 microvolts. Frequency coverage is well beyond the audio range; the instrument covers from 5 Hz up to 1.2 MHz.

The compact, lightweight oscillator will be especially useful in the testing and design of sensitive circuits requiring low-level test signals, like those in audio, medical, geophysical, communications, and ultrasonic equipment.

Its 80-dB attenuator range is covered in fixed 10-dB steps with a vernier amplitude adjustment that provides a good overlap on any range. Extremely pure sine-wave signals are produced with less than 0.1-percent distortion between 30 Hz and 100 kHz. Output amplitude is extremely flat; within only ±0.05 dB between 100 Hz and 300 MHz, and within ±0.1 dB over the rest of the range.

A sync output supplies a separate in-phase sine wave that can be used to sync scopes and other related equipment without affecting the main output signal. A sync input terminal is also provided for synchronizing the output with another source. The oscillator can function as a high-quality tunable filter to clean up distorted signals applied to this input.

The oscillator is normally powered by 115- or 230-volt a.c. line power at frequencies from 50 to 400 Hz. It may also be equipped with mercury batteries or rechargeable batteries for portable operation. Price of the a.c.-operated Model 204D oscillator is $325. ▲

LASER SAFETY PLAN

A plan aimed at promoting the safe use of lasers has been approved by the EIA's Laser Subdivision. The plan consists of guides for identifying categories of laser equipment and the degree of hazard connected with each so that necessary safety measures can be applied.

Laser usage is classified in terms of the effective use of radiation confinement and control and the amount of hazardous radiation produced within the equipment.

Laser system radiation comes from primary laser beams, secondary beams, and laser pump sources. The plan requires definition of the magnitudes of laser systems radiation to be considered acceptable for exposure to the human eye or the skin. ▲

"George! What's Mother's picture doing over the p.a. speaker?"

Electrolytic-Capacitor Tester

By D.F. FLESHREN

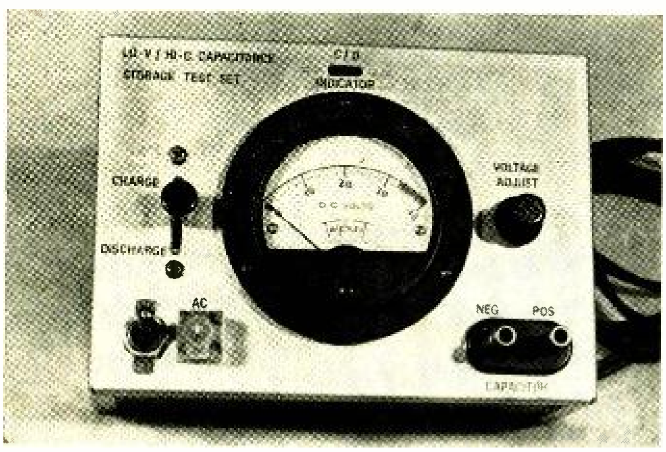
Provides a unique method of testing miniature high-capacitance, low-voltage electrolytics now widely used in solid-state circuits.

THE inherent nature of a capacitor does not readily permit a simple and reliable ohmmeter check as is frequently used in testing other components. This is true because of the time required to charge and discharge a capacitor, and the fact that no direct-current path exists through the device. Then, too, the applied working voltage must be considered in making such a test.

The test set and method described here does not measure actual capacitance, but rather provides a qualitative test, using the required working voltage. Its useful range is 0.001 µF to approximately 1000 µF, with a variable 0-35 volts d.c. applied. The unit makes a non-destructive test of the capacitor regardless of its condition.

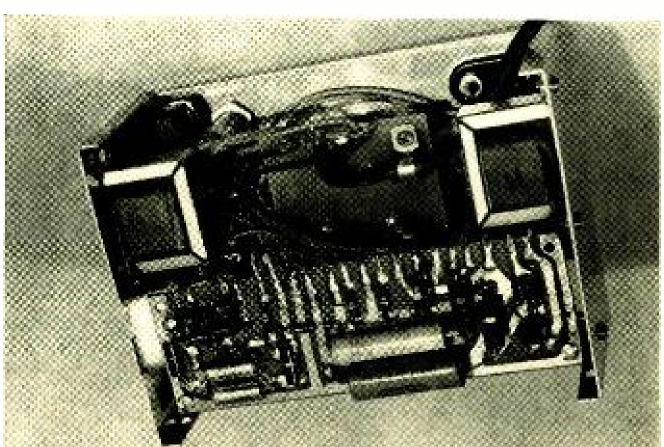
Test Method Employed

The basic principle used in this test method consists of applying the normal working voltage to the capacitor, while observing the charging current in terms of the voltage developed across a series resistor. The capacitor is then switched to discharge across a similar resistor, and again the resulting discharge current monitored in terms of the voltage across the resistor.



Front-panel of tester. The indicator tube is mounted behind ⅛ by ½ in opening directly above the d.c. voltmeter.

Inside view shows hand-drawn printed-circuit board used.



The *RC* time constant (*T*) determines the length of time required to charge or discharge the capacitor. Accordingly, using the formula $T = RC$, with *T* (time) in seconds, *R* (resistance) in ohms, and *C* (capacitance) in farads, a capacitor is considered to be fully charged (or discharged) in 5 (*T*) seconds. When the resistance is held constant, the charge/discharge time will be determined entirely by the capacitor. Therefore, the test set readout device must indicate the charge and discharge in direct relation to the value of the capacitance.

The initial problem was that of monitoring the small voltage which resulted from the charging and discharging current through the respective load resistors. The monitoring device had to be sensitive to a very small voltage change and exhibit a high input impedance so as to insure minimum circuit loading. It also required a high-speed device capable of following the instantaneous voltage changes. A mechanical readout, such as a meter, could obviously not be used. Several lamp circuits were tried, as well as a number of transistor sensing circuits with various types of indicators, but results proved unsatisfactory, and did not warrant the additional cost and complexity.

In search of a miniature electric-eye indicator tube, a relatively unknown little tube was tried, and found to meet and/or exceed the requirements. It provided a high input impedance, near instantaneous response, the required sensitivity, and performed as an excellent visual readout display. The device, a Type 6977 triode indicator tube, manufactured by *Sylvania*, *Amperex*, and *Tung-Sol*, sells for approximately $2.50 apiece.

As indicated in Table 1, this tube has a phosphorescent coating on its anode which glows pale blue when the tube is made to conduct. This condition exists with zero volts on the grid. The visual glow can be observed along the side of the tube for an area of ½ x ⅛ inch. The tube can be cut off with a negative grid input of 3 to 4 volts.

Fig. 1 shows the two basic operating modes of this test set. There is an adjustable 0 to 35-volt d.c. supply and its associated voltmeter circuit. With S2 in the "Charge" mode, the direct-current path for the capacitor being tested is from ground, through *R*10, the center arm of switch S2, the C_x terminals, and then to $+E_c$, the charging-voltage supply. One arm of S2 also connects directly to the indicator tube, *V*1, which will turn on during the charging cycle due to the positive-going voltage across *R*10.

After C_x is fully charged, current through *R*10 drops to zero and the display tube extinguishes. Note that when C_x is open, no current flows and there is no visual indication. Conversely, when C_x is shorted, the full E_c supply voltage is applied to the grid circuit of *V*1 for a continuous bright glow.

Table 1. Characteristics of 6977 indicator tube used for readout.

E_p	65 V (max.)	Length 1 1/16"
$E_{(fil)}$	1 V ±5%	Diameter 7/32"
		Lead length 1 3/4"
$I_{(fil)}$	30 mA	Phosphor display blue
I_p	5 µA (cut-off)	
I_p	580 µA (max. brightness)	

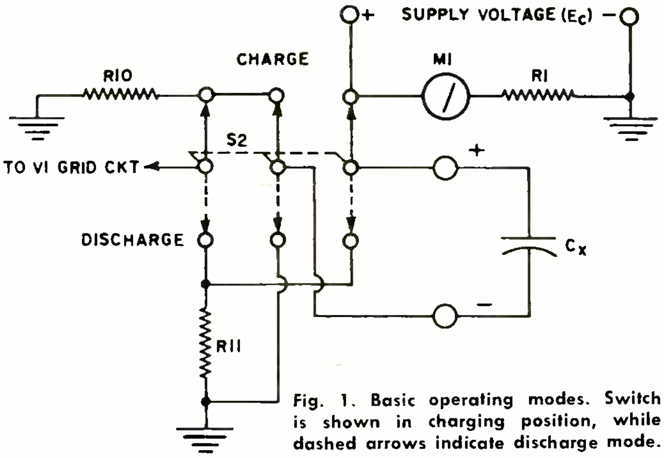


Fig. 1. Basic operating modes. Switch is shown in charging position, while dashed arrows indicate discharge mode.

The next step is to transfer switch S2 to its mid-position (not shown), which opens all of the switch contacts, thereby floating both terminals of capacitor C_x. This allows the capacitor to be isolated for any period of time, to determine its ability to hold a charge. It is a good test of the dielectric and leakage characteristics.

The final step is with switch S2 thrown to the "Discharge" position. Note the voltage polarity across C_x at this time, when it is fully charged. The discharge path is from the negative side of C_x, ground, through the resistor $R11$, and back to the positive side of C_x. Again the display tube is switched across the load resistor, and the voltage is such that $V1$ continues to glow as long as the discharge current flows through $R11$. A good capacitor should indicate equal brightness on the readout in both the charge and discharge modes. The duration will be short for very small capacitors, and will be considerably longer when testing the larger electrolytics.

Four different operating voltages are required in the test set: a +1-V filament supply, +65-V plate supply, −4-V cut-off bias for the 6977 tube, and an adjustable 0-35-V charging supply to provide the working test voltage. To avoid using a multi-winding power transformer and to facilitate a better packaging arrangement, two small inexpensive 117 V to 6 V a.c. (1-A) filament transformers were used in a back-to-back configuration, as shown in Fig. 2.

The breadboard version of this test set with its relatively few components seemed to be a good printed-circuit board project. Printed-circuit tabs were included on the edge of the board to which all external leads were soldered directly (Refer to inside photo and Fig. 3).

The display tube presented somewhat of a mounting problem. The tube is mounted (using a thin bead of epoxy cement) behind a small rectangular opening in the front panel just above the meter. Be careful to orient the tube so that the fine cross-haired side of the tube is exactly centered on the opening and facing the front of the unit.

Testing & Operation

Prior to testing the completed unit, check the voltages on the indicator tube with S2 in its mid-position. These voltages should be within 10% of the specified values. Then transfer S2 to the "Charge" position and adjust the voltage control ($R4$) for some upper scale reading. Using a reasonably accurate external meter, measure the voltage across the C_x terminals on the front panel. It should be the same as that indicated on the internal meter. An external multiplier resistor ($R1$) may have to be used to produce a 40-volt full-scale reading.

Next, observe that the indicator tube is off, with no visual display other than a dim filament glow along the center of the tube. Connect a small resistor across the C_x terminals. Adjust the working voltage for some mid-scale reading and note the steady glow of the display tube. This readout corresponds to the equivalent leakage resistance of a defective capacitor. Try several larger value resistors, and note the less brilliant display, which is equivalent to testing capacitors with less internal leakage. Transferring switch S2 to "Discharge" will not generate a visual readout since the resistors will obviously not hold a charge.

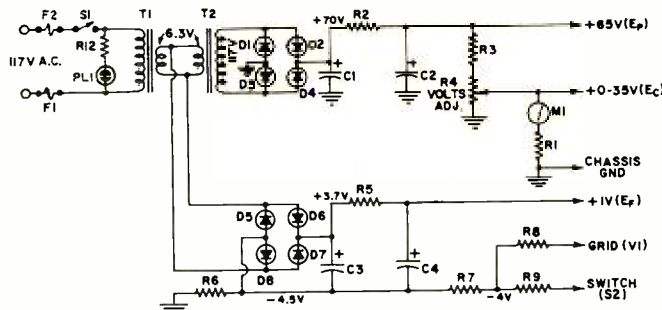
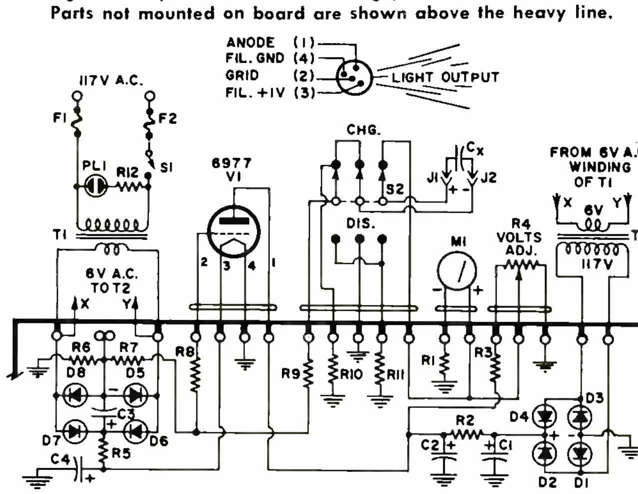


Fig. 2. Power supply uses back-to-back transformers.

A capacitor is now placed across the C_x terminals, observing the correct polarity. The test voltage is then adjusted according to the approximate working voltage of the capacitor, and S2 is switched to "Charge". The display tube should glow brightly in proportion to the charging current, then fade slowly as the capacitor reaches full charge and current drops off to zero. Switch S2 is then transferred from its mid-position which floats the capacitor. The capacitor can be evaluated now regarding its ability to hold a charge for a given period of time. The final step consists of switching S2 to the "Discharge" mode and observing the display tube. The initial heavy discharge will cause a bright glow which will diminish as the capacitor becomes fully discharged, and current flow again decreases to zero.

A shorted capacitor will cause a steady glow in the "Charge" position, and will produce little or no visual display in the "Discharge" position. An open capacitor will produce little or no visual display in either of these modes. When testing very large capacitors in the 1000-μF range, it requires much longer for the charge and discharge cycles. In the "Charge" mode a capacitor is considered to be "leaky" if the display does not fully extinguish after a reasonable time. ▲

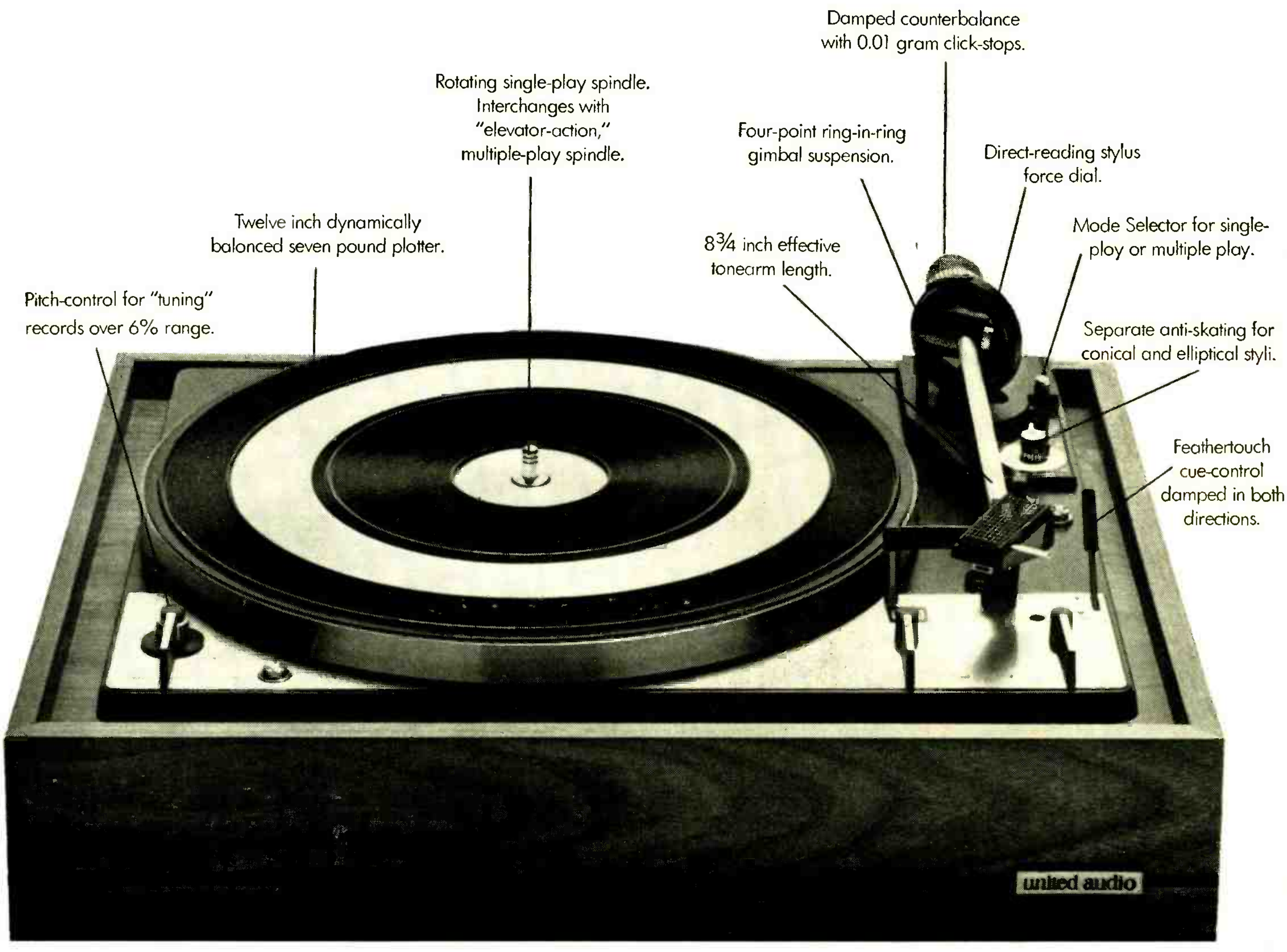
Fig. 3. Complete schematic showing printed-board terminals. Parts not mounted on board are shown above the heavy line.



R1—Multiplier res. for meter (optional, see text)
R2—150 ohm, 2 W res.
R3—1000 ohm, 2 W res.
R4—1000 ohm, 2 W linear-taper pot
R5—100 ohm, ½ W res.
R6—150 ohm, ½ W res.
R7—10,000 ohm, ½ W res.
R8—120,000 ohm, ½ W res.
R9—15,000 ohm, ½ W res.
R10, R11—680,000 ohm, ½ W res, ±5%
R12—22,000 ohm, ½ W res.
C1, C2—10 μF, 150 elec. capacitor
C3, C4—100 μF, 20 V elec. capacitor
S1—S.p.s.t. toggle switch
S2—3-pole, d.t., center-off, lever switch
PL1—NE-51 lamp
F1, F2—½ A, plug-mounted 3AG fuse
J1, J2—Banana terminal post
M1—0-40 V d. c. full-scale meter
D1, D2, D3, D4—1N2070 diode or equiv.
D5, D6, D7, D8—1N1693 diode or equiv.
T1, T2—117 V a. c./6 V a. c. at 1 A trans.
V1—6977 indicator tube (Sylvania, Amperex, or Tung-Sol)
1—3" x 5" x 7" circuit box

Note: PC boards are available at $8.00 each from the author at 7305 Valleycrest Blvd., Annandale, Virginia 22003.

The Dual 1219: the automatic turntable with more precision than you may ever need.



Before the 1219 came on the scene, the Dual 1019 was regarded as the finest automatic turntable ever made. In fact, most hi-fi professionals had long used a 1019 in their personal systems.

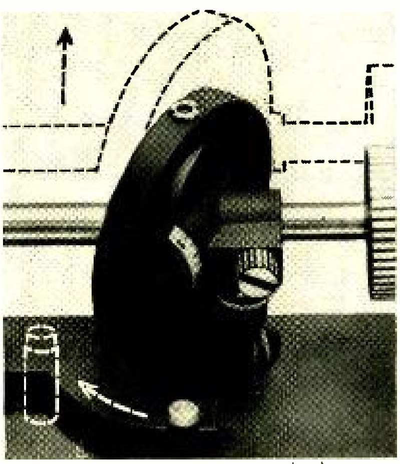
This left new goals for Dual engineers: to overcome, as far as possible, the few design compromises still inherent in automatic turntables.

The new Dual 1219 Professional Automatic Turntable was the result.

The automatic arm that doesn't compromise on single records.

Ideally, every record should be played by a stylus tracking at the same angle as the stylus used to cut the master record (15° from vertical).

With a single-play turntable, that's no problem as the tonearm always tracks at the same angle. But with an automatic turntable, the angle of the tonearm and stylus vary with the height of the stack.



As a compromise, even the best automatic arms have been designed to track at 15° only at the middle of the stack and tilt downward on single records.

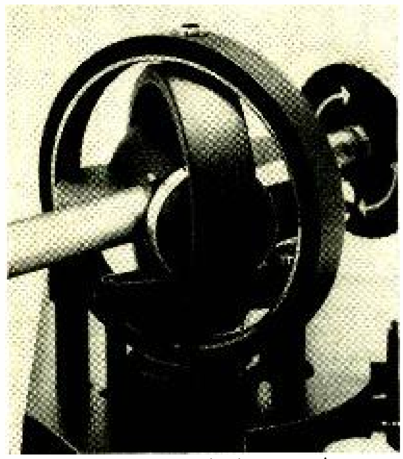
The 1219 eliminates this compromise. In the multiple-play mode, the tonearm tracks at 15° at the middle of the stack. Just like any other automatic tonearm.

But in single play, the tonearm is lowered by the Mode Selector to track precisely at the same 15°. Unlike any other automatic tonearm.

Balanced and pivoted like a precision gyroscope.

Precision gyroscopes must stay balanced and pivot freely in all directions. So should tonearms. That's why the 1219 tonearm is suspended like a gyroscope: centered within a true, four-point gimbal.

The tonearm pivots vertically from an inner concentric ring. Which, in turn, pivots horizontally from a fixed outer ring. No matter which way the arm pivots, it remains in perfect dynamic balance.



And it pivots freely, on four identical bearings whose friction is so low we had to design and build our own instruments to measure it. Friction is a mere 0.015 gram horizontally, only 0.007 gram vertically. Or less.

Anti-skating: different scales for different styli.

Elliptical styli create more skating force than conical styli do.

It's a very slight difference. But measurable in a tonearm with the 1219's low bearing friction.

That's why the 1219's anti-skating system has a separately calibrated scale for each stylus type. The engineering problem was complex, but the solution isn't. You simply dial anti-skating to the same number you set for stylus force.

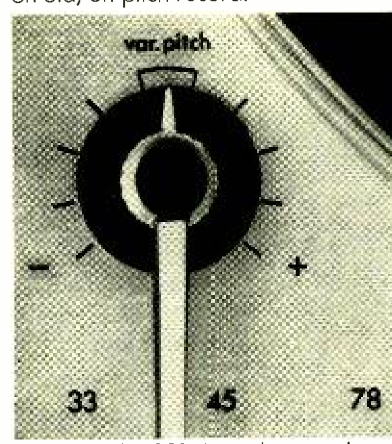
Synchronous speed constancy, plus pitch control.

The 1219's motor has a continuous-pole element that brings the twelve inch, seven pound platter up to full speed in less than half a revolution.

It also has a synchronous element that locks the speed into the line frequency and keeps it there, no matter how line voltage may vary.

Most turntable manufacturers would be glad to offer fast starts and dead-accurate speed and let it go at that.

But there are times when you might not want "accurate" speeds. You might want to match record pitch to a live instrument. Or alter the timing of a record to match that of a home movie. Or play on old, off-pitch record.



With the 1219's pitch control, you have a choice. Because all three speeds can be varied up to 6%, a semitone in pitch. (Sometimes a machine as perfect as the 1219 must adjust to the rest of the world.)

More precision than you need?

There are still more refinements in the 1219. For example: it has the longest of all automatic tonearms, to achieve the lowest tracking error of all automatics: less than one and a half degrees. Its cue control is damped in both directions, so the tonearm moves with equal delicacy whether you're raising or lowering it.

You may well think the 1219 does indeed have more precision than you need. But records and cartridges are being improved all the time. So a turntable can never have too much precision, or too many refinements if it is to stay ahead of them.

The refinements in the 1219 are, however, costly to produce. At $159.50, they may be unnecessary for some music lovers. So Dual offers two less expensive models, at $79.50 and $119.50. With fewer features, but no less precision or reliability.

Our literature will help you decide which Dual you really need.

United Audio Products, Inc.,
120 So. Columbus Ave., Mount Vernon, New York 10553.

Dual

CIRCLE NO. 99 ON READER SERVICE CARD

EW Lab Tested

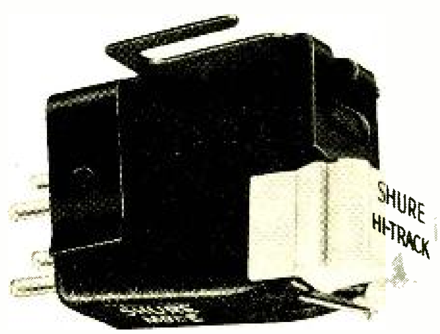
(Continued from page 22)

rated bookshelf models, but its most obvious quality is its lack of flashy or characteristic coloration. It *is* neutral, in the best sense of the word. The A-25 is a new addition to that select group of speakers that are easy to listen to, that do not offend the ears with harsh or unnatural sound, and that produce outstanding definition and low-bass solidity when the music demands it.

Not the least of the A-25's attractions is its low price of $79.95. We have compared it with a number of speaker systems costing two and three times as much, and we must say it stands up exceptionally well in the comparisons. We judge the A-25 to be another feather in *Dynaco's* cap and a continuation of the company's policy of very high quality at moderate cost. ▲

Shure M92E and M93E Stereo Phono Cartridges

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



SHORTLY after *Shure* introduced its "Hi-Track" series of cartridges, we noted at the time that they came very close to matching the performance of the widely acclaimed V-15 Type II, but at a much lower price.

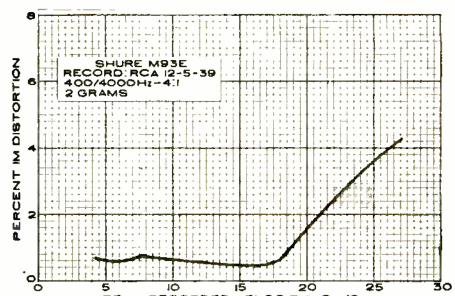
The M92E and M93E use a cartridge body which snaps into an easy-to-mount bracket for simplified installation. The M92E uses a 0.2 x 0.7 mil elliptical stylus, rated for tracking forces from 0.75 to 1.5 grams. The M93E is similar, but has a 0.4 x 0.7 mil stylus designed to operate from 1.5 to 3 grams, and with 1 to 2 dB less tracking ability than the M92E.

The M92E required 1.5 grams in our tracking tests, while the M93E operated at 2 grams. The M92E and M93E had 6.5-millivolt outputs, the highest that we have tested recently. Hum shielding was slightly better than average. The M93E tracked slightly better at 2 grams than the M92E did at 1.5 grams, but both did an excellent job in this regard.

Both cartridges had similar frequency-response characteristics. The cartridges had excellent response up to nearly 20 kHz, with a slight peak in the 13- to 15-kHz region. Their channel separation was excellent up to 10 kHz. The M92E lost separation above 14 kHz, while the separation of the M93E remained at 5 to 10 dB all the way up to 20 kHz.

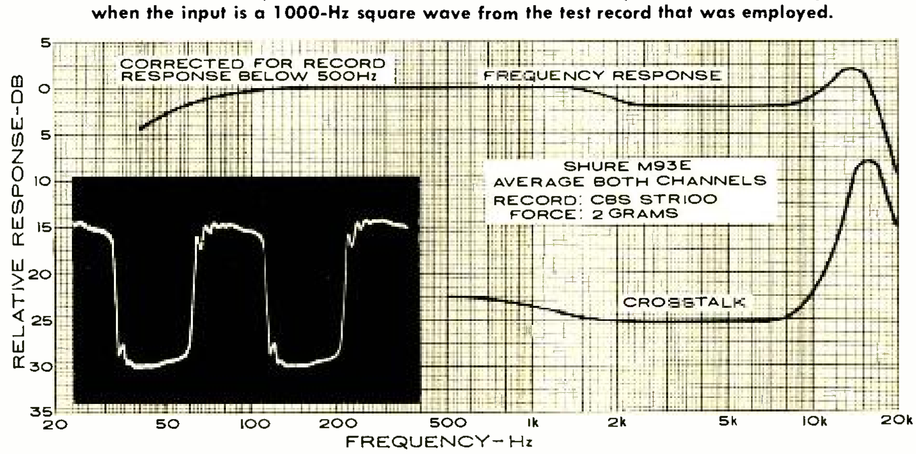
The M92E and M93E were able to track high velocities of 20 to 21 cm/sec at only 2 percent IM distortion. Their square-wave responses were essentially identical, with several cycles of ringing at about 15 kHz. The tone-burst response showed degradation between 15 and 20 kHz.

Price of the *Shure* M92E is $44.95 and of the M93E is $39.95. ▲



IM distortion at various recorded velocies.

Upper curve shows the frequency response of the cartridge, with both channels averaged to obtain the single curve shown. Separation is measured as the difference between the frequency response and the crosstalk curves at the frequency of interest. The square wave at the left shows the output from the cartridge when the input is a 1000-Hz square wave from the test record that was employed.



REPETITIVE RAMP GENERATOR

By ARTHUR BURNS
Project Engineer, Mallory Battery Co.

APPLICATIONS such as the "sweep" tuning of oscillators, filters, and receivers frequently require a repetitive-voltage (no output current) ramp generator. A wide range of ramp periods and output voltages are easily obtained with the circuit shown below.

Basically, the circuit consists of a constant-current generator which linearly charges capacitor *C* to the trigger voltage of the thyristor, *T*. The breakdown of *T* turns on the SCR which then discharges capacitor *C*.

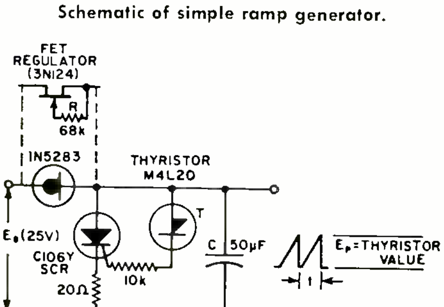
The desired peak voltage of the ramp determines choice of *T*. Suitable thyristors are available from several manufacturers and in a wide range of voltages. Bilateral or unilateral trigger devices may be employed. *Motorola's* M4L3052-54 (8- to 12-volt range) or the M4L29-3 to M4L50A (14- to 57-volt range) are typical and will work well in this circuit.

Having selected the thyristor, a suitable constant-current source is chosen. Field-effect current-regulator diodes such as the *Motorola* 1N5283 through 5314 (regulator currents of 0.22 mA to 4.7 mA) are satisfactory. In general, the smaller the current, the lower the value of *C* required for a given ramp period. (Note: In no case choose a regulator current which exceeds the holding current rating of the SCR or repetitive operation will not occur.) A somewhat lower cost and more flexible arrangement to replace the regulator diode is shown dotted in the diagram. This consists of a self-biased FET regulator whose constant-current level may be varied by the choice of *R*.

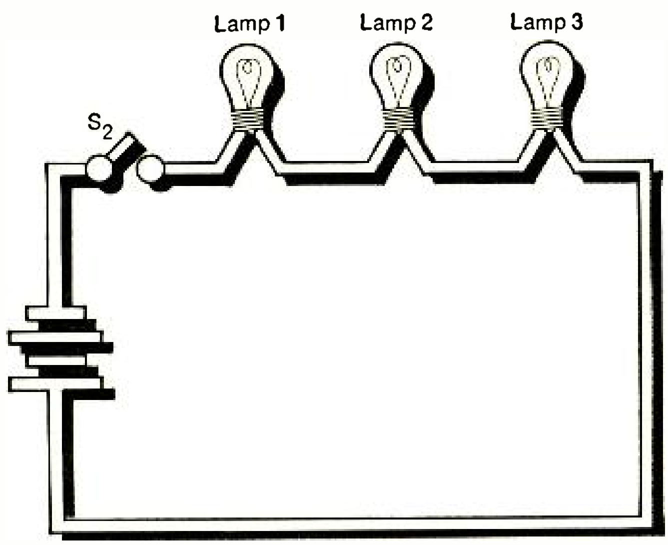
Finally, the required capacitance value for *C* may be determined by the relation: $C = It/V$, where I = current value of the constant-current diode in amperes, t = desired ramp time in seconds, V = breakdown voltage of the thyristor selected, and C = the required capacitance in farads.

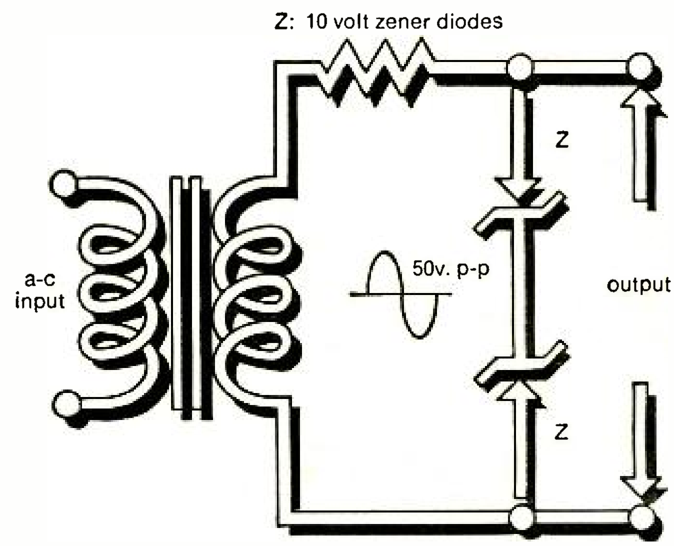
The values shown in the diagram gave a 5-second ramp period with a peak voltage of 20 volts. ▲

Schematic of simple ramp generator.



Can you solve these two basic problems in electronics?





This one is relatively simple:

When Switch S_2 is closed, which lamp bulbs light up?

Note: If you had completed only the first lesson of any of the RCA Institutes Home Study programs, you could have solved this problem.

This one's a little more difficult:

What is the output voltage (p–p)?

Note: If you had completed the first lesson in the new courses in Solid State Electronics, you could have easily solved this problem.

These new courses include the latest findings and techniques in this field. *Information you must have if you are to service today's expanding multitude of solid state instruments and devices used in Television, Digital, and Communications Equipment.*

If you had completed an entire RCA Institutes Home Study Course in Semiconductor Electronics, Digital Electronics, or Solid State Electronics, you should now be qualified for a good paying position in the field you choose. Send for complete information. Take that first essential step now by mailing the attached card.

ANSWERS: Problem 1—they all light up
Problem 2—20 Volts (p–p)

RCA Institutes Autotext learning method makes problem-solving easier... gets you started faster towards a good-paying career in electronics

Are you just a beginner with an interest in electronics? Or, are you already making a living in electronics, and want to brush-up or expand your knowledge? In either case, RCA has the training you need. And Autotext, RCA Institutes' own method of Home Training will help you learn more quickly and with less effort.

Wide Range of Courses

Select from a wide range of courses. Pick the one that suits you best and check it off on the attached card. Courses are available for beginners and advanced technicians.

Electronics Fundamentals
Black & White Television Servicing (Transistorized TV Kit Available)
Color Television Servicing (Color TV Kit Available)
FCC License Preparation
Automatic Controls
Automation Electronics
Industrial Electronics
Nuclear Instrumentation
Electronics Drafting
Computer Programming

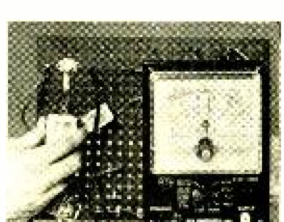
Build and keep this valuable oscilloscope.

Plus these new up-to-the-minute courses

Semiconductor Electronics
Digital Electronics
Solid State Electronics
Communications Electronics

Prepare for good paying positions in fields like these

Television Servicing
Telecommunications
Mobile Communications
CATV
Broadcasting
Marine Communications
Nuclear Instrumentation
Industrial Electronics
Automation
Computer Programming
Solid State
Electronics Drafting



In the new program on Solid State Electronics you will study the effects of temperature and leakage characteristics of transistors.

RCA

Valuable Equipment—Yours To Keep

A variety of RCA Institutes engineered kits are included in your program of study. Each kit is yours to keep when you've completed the course. Among the kits you construct and keep is a working signal generator, a multimeter, a fully transistorized breadboard superheterodyne AM receiver, and the all-important oscilloscope. These 4 kits are at no extra cost. Compare this selection with other home study schools.

Convenient Payment Plans

RCA Institutes offers liberal monthly payment plans to suit your budget.

Classroom Training Also Available

RCA Institutes operates one of the largest technical schools of its kind. Day and evening classes. No previous training is required. Preparatory courses are available. Classes start four times a year.

Job Placement Service, Too!

Companies like Bell Telephone Labs, GE, Honeywell, IBM, RCA, Westinghouse, Xerox, and major radio and TV networks have regularly employed graduates through RCA Institutes' own placement service.

All RCA Institutes courses and programs are approved for veterans under the new G.I. Bill.

Send Attached Postage Paid Card Today. Check Home Study or Classroom Training.

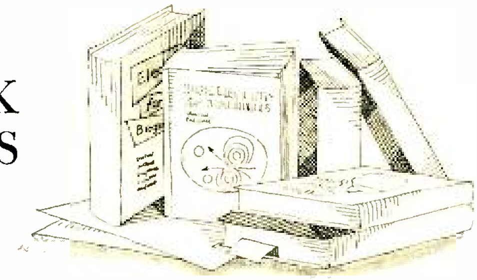
Accredited Member National Home Study Council.

IF REPLY CARD IS DETACHED, SEND THIS COUPON
RCA Institutes Inc.
Home Study Dept. EW-09
320 West 31 Street
New York, N.Y. 10001

Please send me FREE illustrated career catalog.

Name ______________________ Age ______
(please print)
Address ______________________
City ______________ State ______ Zip ______

BOOK REVIEWS



"LASER COMMUNICATION SYSTEMS" by William K. Pratt. Published by *John Wiley & Sons, Inc.*, New York. 266 pages. Price $14.95.

This book is addressed to the practicing physicist, electrical engineer, and students of both disciplines who are interested in the field of laser communications but are lacking one of the background technologies. The text is written at an engineering level and math is used extensively.

The text is divided into 13 chapters and four appendices. It covers an introduction, modulation and demodulation, optical components, modulators, detectors, background radiation, atmospheric propagation, detection noise, detection processes, communication receivers, baseband pulse and digital laser communication systems, subcarrier and heterodyne digital laser communication systems, and optimum system design. The appendices cover polarization, matrix algebra, Gaussian process, Poisson process, and a listing of selected symbols. Each chapter carries a list of references for additional study of the material covered in the chapter.

The author, who was associated with *Hughes Aircraft* from 1959 to 1965, is now Assistant Professor of Electrical Engineering at USC specializing in teaching and research in the areas of video and optical processing and laser communications.

* * *

"KNOW YOUR VOM-VTVM" by Joseph A. Risse. Published by *Howard W. Sams & Co., Inc.*, Indianapolis, Ind. 154 pages. Price $3.50. Soft cover.

This is a revised and updated edition of a work that originally appeared in 1963. It is a simple and straightforward treatment of the two most widely used instruments in electrical and electronics work. For students, experimenters, hobbyists, and others just starting out, the author has included a short review of electrical measurements basics.

The text is divided into nine lavishly illustrated chapters covering v.o.m. and v.t.v.m. construction, applications, repair and maintenance, with the final chapter devoted to solid-state electronic v.o.m.'s. So that the book can be used in classrooms, each chapter carries questions about the material covered, with answers provided.

Even an experienced service technician could probably glean much information from this comprehensive handbook.

* * *

"HOW TO SELECT AND USE HI-FI AND STEREO EQUIPMENT" by Murray P. Rosenthal. Published by *Hayden Book Company, Inc.*, New York. Two volumes, 114 pages & 104 pages. $3.25 each volume. Soft cover.

Volume one covers loudspeakers, enclosures, amplifiers, tuners, and receivers while the second volume deals with record players, tape recorders, and hi-fi troubleshooting. Although the volumes may be purchased separately, the material in both volumes would be of interest to the dedicated audiophile.

The author's style is informed and informal. Even those dipping a toe into the hi-fi pond for the first time will have no trouble understanding just what is involved. After an introductory chapter in which he traces the development of sound reproduction, the author plunges into acoustics, speakers and enclosures, amplifiers and preamps, tuners and receivers, records and record players, tape recorders, and hi-fi troubleshooting. The volumes are lavishly illustrated with photographs of commercial equipment, line drawings, graphs, and schematics.

If you want to acquire hi-fi "know-how" painlessly and in an entertaining manner, these volumes are for you.

* * *

"TRANSISTOR, THYRISTOR & DIODE MANUAL" compiled and published by *RCA Electronic Components,* Harrison, New Jersey. 652 pages. Price $2.50. Soft cover.

This is SC-14 in *RCA's* technical series and contains the latest available information on basic technology, operating principles, characteristics and ratings, applications, and the testing of its semiconductor devices. It is prepared specifically for use by circuit designers, students, experimenters, and others interested in the operation and application of semiconductor devices.

The text section consists of twelve chapters with over 200 pages of basic information on the devices while the technical data section provides data and design curves, basing diagrams, and tabular material on more than 900 semiconductor devices.

* * *

"THE RADIO AMATEUR'S HANDBOOK" by The Headquarters Staff. Published by *American Radio Relay League,* Newington, Conn. 06111. 610 pages plus tube and catalogue sections. Price $4.00 (in U.S.). Soft cover.

This 46th Edition of the Handbook contains a lot of new material and much revised and updated data. Although prepared especially for beginning and advanced radio amateurs, a lot of the information will be useful to engineers and electronics technicians as well.

Among the subjects receiving treatment for the first time are dual-gate MOSFET's, solid-state product detectors, transistorized oscillators, audio amplifiers, mixers, i.f. and r.f. amplifiers, and d.c. amplifiers. There are numerous new construction projects including universal-type power supplies for all voltage ranges from 3 to 1000; solid-state transceivers; transmitting and transceiving converters for SSB; and transmitting equipment for the 160-meter band.

The popular tube-base diagram section has been upped to 576 illustrations in this edition while the text as a whole contains over 1300 diagrams, charts, graphs, schematics, and photos.

* * *

"ELECTRICAL PRINCIPLES OF ELECTRONICS" by Angelo C. Gillie. Published by *McGraw-Hill Book Company,* New York. 720 pages. Price $11.50.

This is a revised and updated version of the author's 1961 volume written for electronics technicians. It provides a comprehensive background in d.c.-a.c. electrical principles for those enrolled in two-year electrical or electronics technology courses. First-year algebra is prerequisite for the first part of the text with the rest of the necessary mathematical skills to be acquired by the student as he progresses in his other courses.

The text is divided into three main sections covering the characteristics of d.c. circuits, characteristics of sinusoidal circuits, and characteristics of complex waveform circuits. Since the book is intended for classroom instruction, the text carries large numbers of problems, questions, examples, for the student to work. Six appendices carry the table of natural logs, table of common logs, table of natural trigometric functions, table of exponential functions, capacitor codes, and schematic symbols so that the student can have all his reference material at hand during the course without reference to other texts. ▲

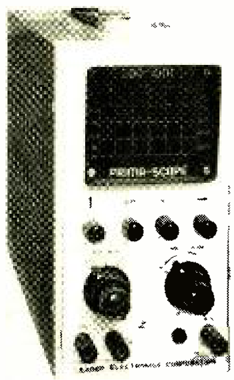
NEW PRODUCTS & LITERATURE

For additional information on items identified by a code number, simply fill in coupon on Reader Service Card. In those cases where code numbers are not given, may we suggest you write direct to the manufacturer.

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

FIELD SERVICE SCOPE

The new LBO-31M oscilloscope has been designed for field use as well as for multichannel monitoring applications. Its narrow 4" chassis allows many scopes to be placed side by side for



maximum density while its 1-MHz bandwidth makes it suitable for applications in the video region.

Vertical axis sensitivity is 80 mV p-p/cm at 1 kHz and response is −3 dB, 3 Hz to 1 MHz. Horizontal axis sensitivity is 2.5 V p-p/cm with response −3 dB, 3 Hz to 400 kHz. Sweep frequency is 10 to 100,000 Hz. The scope operates from 105-125 volts, 50/60 Hz. It measures 7" h. x 4" w. v 12" d. and weighs 11 pounds. Leader

Circle No. 1 on Reader Service Card

5-CHANNEL R/C SYSTEM

A new R/C system for control of model planes, boats, and cars has been introduced as the GD-19. The complete system includes transmitter, receiver, four servos, and rechargeable battery packs for both transmitter and receiver.

The transmitter features Kraft control sticks with thumb lever coarse adjustment plus trim controls that do not change stick centering, and can be ordered on five different frequencies in each of the three different bands: 27, 53, or 72 MHz. There is a locking "on-off" switch to prevent accidental turn-on.

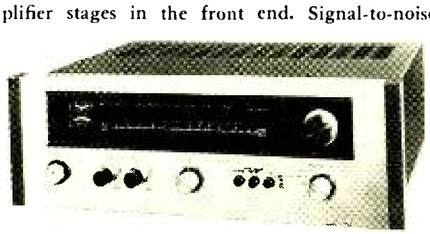
The receiver weighs just 2.3 ounces and measures only 25/32" h. x 2" w. x 27/32" d. It features three ceramic filters in the i.f. for high selectivity and extra reliability.

Purchase of the complete system brings with it a soldering iron to be used in the construction. Details on the system or the various individual components will be forwarded on request. Heath

Circle No. 2 on Reader Service Card

AM-FM STEREO TUNER

The TX-900 AM-FM stereo tuner is all solid-state and features three FET's and two r.f. amplifier stages in the front end. Signal-to-noise



ratio is approximately 60 dB at 30% modulation. For inadequate signal inputs, a special noise filter can be used to eliminate unwanted multiplex broadcast noise.

A time-switching demodulator is used in the multiplex circuit while additional selectivity is provided in the i.f. secton through the use of two crystal filters. Four integrated circuits are employed in this section.

The tuner features dual tuning meters for accurate tuning and a large multi-color illuminated dial for easy tuning. It has a brushed chrome panel and end pieces of Brazilian rosewood. Pioneer

Circle No. 3 on Reader Service Card

COMMERCIAL SOUND SPEAKER

The Model FX-52 super-low-resonance commercial speaker is designed for virtually invisible ceiling installation. Grille screens as small as 6 inches in diameter can be used, for distributed sound systems, where extremely small baffles are desired. The unit features a removable universal bracket, to permit end transformer mounting for shallow spaces or back transformer mounting for deep spaces of small diameter. The speaker is completely weatherproof.

The Model FX-52 has an 8-ohm voice coil but is also available with optional pre-integrated constant-voltage transformers for 70-V or 25-V line circuits. Jensen

Circle No. 4 on Reader Service Card

4-BAND BC/SW RECEIVER

An inexpensive all-transistorized table-model broadcast and short-wave radio receiver has just been introduced as the Model S-120A. Accord-

ing to the company, short-wave reception is boosted up to 200% over conventional sets, including both c.w. and SSB, because of special advanced circuitry and the b.f.o. incorporated.

The receiver is designed to operate from 117-V a.c., 50/60 Hz. It is housed in a communications-type steel cabinet with full front-panel controls and a large, easy-to-read multi-color-coded dial scale marked with countries broadcasting on short-wave. The receiver measures 12" wide x 5½" high x 5" deep.

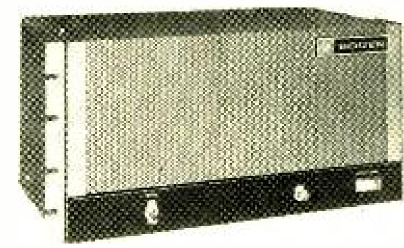
Frequency coverage is 0.54-31 MHz in four bands: standard AM broadcast (550-1600 kHz); SW #1 (weather, marine, and ham, 2.0-5.0 MHz); SW 2 (4.8-11.5 MHz); and SW #3 (11.0-30.0 MHz). Hallicrafters

Circle No. 5 on Reader Service Card

BOOSTER AMP FOR P.A.

The new solid-state booster amplifier, Model NTB250, is designed to provide both high power and high reliability in public-address systems requiring continuous coverage of large areas such as airports, stadia, and large industrial plants.

The unit can deliver up to 350 watts of output



power for continuous duty at less than 5% harmonic distortion, between 50 and 12,000 Hz, at ambient temperatures to +70° C (158° F). For higher output power, it is possible to parallel several of the boosters.

A special feature of the amplifier is a 120-volt a.c. power output which, when coupled with a variable-frequency signal generator, provides a source of variable frequency power for industrial applications such as shake tables and motors.

The NTB250 has a patented short and overload protection circuit which operates automatically. The amplifier normally operates from a 120-V a.c. source but may also be operated from a 24-volt d.c. power supply. Both high- and low-impedance inputs are provided. Output terminals include 8 ohms, 25 volts, and 70 volts, balanced or unbalanced. Bogen

Circle No. 6 on Reader Service Card

HIGH-VOLTAGE PROBE

The new HVP-5 high-voltage probe contains a built-in voltmeter that eliminates the need for any additional equipment. Voltages up to 30 kV can be measured. Barrier sections are provided to isolate the high-voltage tip from the handle and meter sections.

Its lightweight and compact construction makes it suitable for TV technicians and engineers who must measure high-voltage circuits frequently. Eico

Circle No. 7 on Reader Service Card

DIGITAL MULTIMETER

The Type 340 digital multimeter reads a.c. and d.c. voltages, a.c. and d.c. current, and resistance. A unique input-amplifier technique eliminates circuit loading at all times. According to the company, the constant high input impedance of the unit does not disturb the circuit being measured at any time.

The configuration stations the instrument in a secure, horizontal position at an ideal workable angle. It never needs tilting or propping for better visibility. All controls are by key command. The 3-pound instrument is completely self-contained with no plug-ins or other extras to buy.

Only one probe (supplied) is necessary for all measurement functions. The instrument measures 6" wide x 9" long x 5½" high, including the integral handle. The readout display consists of three "Nixie" type plug-in tubes. Digilin

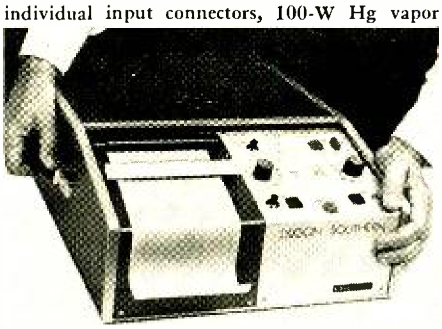
Circle No. 8 on Reader Service Card

DIRECT-READING OSCILLOGRAPH

Dixson Instruments, Box 1449, Grand Junction, Colorado 81501 has just introduced a compact 6-channel direct-reading oscillograph as the Visigraph Series 100.

The unit records on photosensitive paper 4¾" wide at a writing speed in excess of 40,000 in/s. Eight paper speeds, from 0.02 to 48 in/s, are provided. The instrument's magazine will accommodate up to 150 feet of standard-base paper or 295 feet of thin-base paper.

Standard features on the Series 100 include individual input connectors, 100-W Hg vapor



lamp with independent power supply, event marker, and paper supply indicator.

A data sheet on this new oscillograph will be forwarded upon letterhead request direct to the company.

SOUND-LEVEL METER

B & K Instruments, Inc., 5111 West 164th Street, Cleveland, Ohio 44142 is now offering the Model 2204 impulse precision sound-level meter which meets the proposed international standard for measuring impulsive sounds as short as 200 microseconds. A "hold" circuit freezes maximum meter deflection after the noise burst has passed.

The instrument has "A," "B," "C," and the new "D" weighing networks for precise sound-level measurements. Interchangeable meter scales and linear response permit use of any of the firm's accelerators for direct reading of vibration levels.

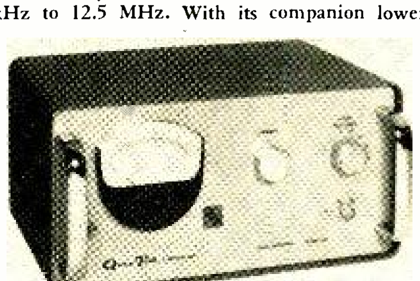
The meter is suitable for all noise investigations, even when impulse transient noise is predominant; vibration measurements; audiometer calibration; and acoustic measurements over a frequency range from 2 to 70,000 Hz.

The Model 2204 comes with a 1-inch microphone, flexible extension cable, windscreen, random incidence corrector, and adapters for microphones and accelerometers.

For more information on this instrument, write on your business letterhead direct to the company.

RANDOM-NOISE GENERATOR

Quan-Tech Laboratories, Inc. of 43 South Jefferson Road, Whippany, New Jersey 07981 is now marketing the Model 421 random-noise generator which is designed to meet the need for an accurately calibrated noise source flat from 10 kHz to 12.5 MHz. With its companion lower



frequency Model 420, stable noise sources are now available for the frequency range from d.c. to 20 MHz.

The instrument meets the requirements of the CCIR recommendations for measurement of the performance of multiplex radio-relay telephony systems. A technical data sheet is available to those requesting it on their business letterheads.

TWO-WAY PORTABLE

A new, lightweight "Handie-Talkie" FM two-way portable radio is now available with 5 watts r.f. power output. It joins the 1.8-watt unit announced by the company in January.

HT-220 units with capabilities for private line, selective call, remote speaker microphones, and multiple frequency (up to six frequencies) as well as universal and surveillance models are now available. Two of the company's monolithic IC's are used in the unit to provide up to 50% size reduction over the previous HT-200.

The standard 1.8-watt version measures 6.95" long x 2.75" wide x 1.16" thick and weighs 21 ounces. The new 5-watt model is the same height and width but is 1.69" thick and weighs 28.5 ounces. All models in the line are available in the 150.8-170 MHz range. Motorola Communications.

Circle No. 9 on Reader Service Card

COMPACT MUSIC SYSTEM

The new Model 135 compact music system includes an AM-FM stereo receiver, a deluxe Garrard automatic turntable with Pickering cartridge and diamond stylus, and two of the company's

XP-60B speaker systems. Each speaker uses a 10" woofer to extend bass response down to 35 Hz, while a 3" tweeter takes over the frequencies from 1000 to 20,000 Hz.

The unit incorporates a number of component-type features including 2-μV FM tuner sensitivity, two FET's, two IC's, and a time-division multiplex circuit. Fisher

Circle No. 10 on Reader Service Card

FM-STEREO RECEIVER

The Model 342C FM stereo receiver features 45 W/ch dynamic power at 4 ohms and 33 W/ch continuous power at 0.8% distortion. At 8 ohms power is 25 W/ch. Response is 14-25,000 Hz ± 1 dB while the FM usable sensitivity is 1.9 μV.

This compact unit includes tape monitoring facilities, automatic stereo switching, and a light that goes out when a station is perfectly tuned in. A companion unit with AM circuitry as well as FM is available as the Model 382-C. H. H. Scott

Circle No. 11 on Reader Service Card

23-CHANNEL TRANSCEIVER

The Model 14-523 5-watt, 23-channel CB transceiver is now available for distribution. All 23 channels may be worked (synthesized). The double-superhet receiver has a mechanical filter.

An "S" meter and r.f. meter are installed on the rubber safety front panel and the transceiver comes complete with mounting hardware and press-to-talk ceramic microphone. The unit can be used as a p.a. amplifier with an external speaker.

The mobile unit can be used as a portable by adding the "Portapack" or as a base station with the Model 14-510 solid-state a.c. power supply. Claricon

Circle No. 12 on Reader Service Card

CARTRIDGE PLAYER/RECEIVER

A complete home music center featuring a solid-state AM-FM stereo receiver and an 8-track stereo cartridge player has been introduced as

the Model 3800-SX. The system is housed in a walnut wood cabinet which has room for a record player to be mounted. Matching speakers are designed to be plugged into the control center. Atlas-Rand

Circle No. 13 on Reader Service Card

MANUFACTURERS' LITERATURE

JAPAN ELECTRONICS DIRECTORY

The Japan Light Machinery Information Center, 437 Fifth Avenue, New York, New York 10016 has announced publication of a 16-page directory of "United States Offices of Japanese Electronics Manufacturers."

The booklet was published to help American companies locate sources for electronics products and parts. Among the companies listed are manufacturers of consumer electronics products, hi-fi sets and components, auto radios and tape players, communications systems, electronic computers, measuring and indicating equipment, radar equipment, automatic control systems, bio-physiological electronic systems, transformers, relays, coils, capacitors, and other electronic devices and components.

Copies of the directory are obtainable by sending a self-addressed, stamped (6 cents) #10 envelope for each copy desired. Requests should be addressed to Electronic Manufacturers' Directory at the above address.

"RECORDING BASICS"

A 24-page booklet, designed to help improve sound quality of home tape recordings, is now available as "Recording Basics."

The free illustrated booklet offers tips on selecting magnetic tapes, recording techniques, and recording procedures in non-technical terms. It also defines various types of tape recorders and illustrates the proper techniques for editing and splicing magnetic tapes as well as maintenance tips for recorders. 3M

Circle No. 14 on Reader Service Card

CONDENSED SWITCH CATALOGUE

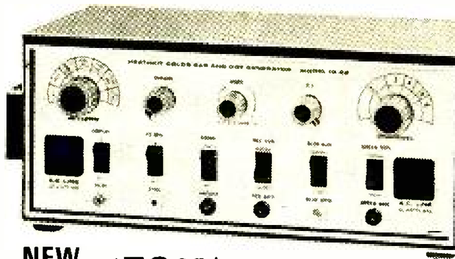
Cherry Electrical Products Corporation, 1650 Old Deerfield Road, Highland Park, Illinois 60035 has issued a handy "Design Engineer's Precision Switch Selector Guide," accordion-folded to pocket size.

In the 12 pages are photographs, cutaway illustrations, brief descriptions, and specifications for 75 different switches.

Included are 67 coil-spring snap-action switches consisting of subminiatures and miniatures, general-purpose, low-torque, light-force,

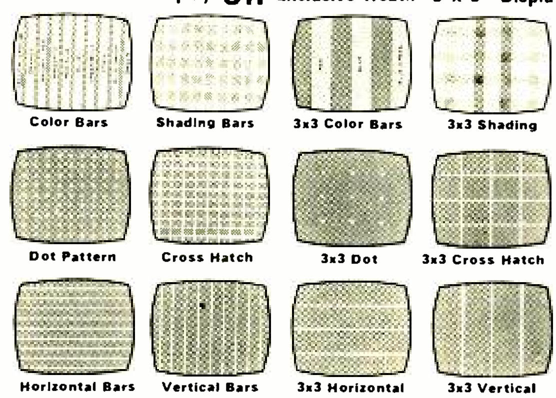
(Continued on page 102)

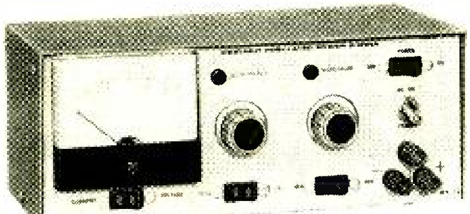
8 Exciting New Kits



NEW
Kit IG-28 $79.95*

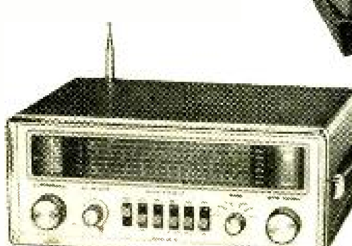
Standard 9 x 9 Display OR Exclusive Heath "3 x 3" Display





NEW
Kit IP-28
$47.50*

NEW
Kit ID-29
$29.95*



NEW
Kit GR-78
$129.95*

NEW
Kit GD-209A
$149.95*

NEW Heathkit Color Bar-Dot Generator... Advanced Integrated Circuitry Produces 12 Patterns Plus Clear Raster, Eliminates Divider Chain Instability Forever

The new IG-28 is the signal source for all color and B&W TV servicing. No other instrument at any price will give as much stable, versatile TV servicing capability. Its solid-state circuitry produces dots, cross hatch, vertical and horizontal bars, color bars, and shading bars in the familiar 9x9 display ... plus exclusive Heath 3x3 display of all these patterns ... plus a clear raster that lets you adjust purity without upsetting AGC adjustment. Fifteen J-K Flip-Flops and associated gates count down from a crystal controlled oscillator, eliminating divider chain instability and adjustments. And for time-saving convenience the IG-28 has variable front panel tuning for channels 2 through 6. Plus & minus going video signals at the turn of a front panel control ... for sync, in-circuit video or chroma problems, use the front panel sync output. Two front panel AC outlets for test gear, TV set, etc. Built-in gun shorting circuits and grid jacks too. Add any service-type scope with horizontal input and you have vectorscope display capability as well. Fast, enjoyable circuit board-wiring harness construction. You can't beat the Heathkit IG-28 for versatility or value ... put it on your bench now. 8 lbs.

NEW Heathkit 1-30 VDC Solid-State Regulated Power Supply

The new modestly priced IP-28 is an excellent power supply for anyone working with transistors. Compact Heathkit instrument styling with large, easy-to-read meter ... two voltage ranges — 10 V., 30 V.... two current ranges — 100 mA, 1 A. External sensing permits regulation of load voltage rather than terminal voltage. Adjustable current limiting prevents supply overloads and excessive load current. Convenient standby switch. Fast, easy assembly with one circuit board and wiring harness. Order yours today! 9 lbs.

NEW Heathkit Solid-State Auto Tune-Up Meter ... Measures Dwell, RPM And DC Voltage

The new Heathkit ID-29 is most versatile ... really three automotive test instruments in one. Measures Dwell on all 4-cycle, 3, 4, 6, or 8 cylinder engines ... measures RPM in two ranges, 0-1500 and 0-4500 ... measures DC voltage from 0 to 15 volts. And no batteries are needed ... running engine provides both signal and power. Easy to use ... on both 6 and 12 volt system without changing leads. Lightweight and easy to carry ... its black polypropylene case has a built-in lead storage compartment and is resistant to virtually everything. Fast, simple assembly ... only about 5 hours. The perfect accessory for the handyman, emergency road service personnel or shop mechanics ... order your ID-29 now. 4 lbs.

NEW Heathkit GR-78 Solid-State General Coverage Receiver... Tunes 190 kHz To 30 MHz In Six Bands

The new GR-78 combines wide coverage, superior performance and portability with sharp styling to provide a remarkable value in general coverage receivers. Tunes AM, CW & SSB signals from 190 kHz to 30 MHz in six switch-selected bands. The all solid-state circuit employs modern FET's in the RF section and 4 ceramic filters in the IF to deliver maximum sensitivity and sharp selectivity. Bandspread Tuning is built-in, and can be calibrated for either Shortwave Broadcast or Amateur Bands. Completely portable ... comes with a nickel-cadmium rechargeable battery pack and built-in charger that operates from 120 or 240 VAC and 12 VDC. Many built-in features ... 500 kHz crystal calibrator ... switchable Automatic Noise Limiter ... switchable Automatic Volume Control ... Receiver Muting ... Headphone Jack and many more. Order yours today. 14 lbs.

NEW Heathkit Deluxe Radio-Controlled Screw-Drive Garage Door Opener Semi-Kit

The next best thing to a personal doorman. The "wireless" factory assembled transmitter operates up to 150 feet away. Just push the button and your garage door opens and the light turns on ... and stays on until you're safely inside your home. The giant 7 ft. screw mechanism coupled with the ¼ HP motor mean real power and reliability and the adjustable spring-tension clutch automatically reverses the door when it meets any obstruction ... extra safety for kids, pets, bikes, even car tops. Assembles completely without soldering in just one evening. Easy, fast installation on any 7' overhead track (and jamb & pivot doors with accessory adapter). Order yours now. 66 lbs.

Adapter arm for jamb & pivot doors, Model GDA-209-2, $7.95*

From The Leader HEATHKIT®

NEW Heathkit Ultra-Deluxe "681" Color TV With AFT . . . Power Channel Selection & Opt. RCA Hi-Lite Matrix Tube

The new Heathkit GR-681 is the world's most advanced Color TV with more built-in features than any other set on the market. Automatic Fine Tuning on all 83 channels . . . power push button VHF channel selection, built-in cable-type remote control . . . or you can add the optional GRA-681-6 Wireless Remote Control any time . . . plus the built-in self-servicing aids that are standard on all Heathkit color TV's. Other features include high & low AC taps to insure that the picture transmitted exactly fits the "681" screen, automatic degaussing, 2-speed transistor UHF tuner, hi-fi sound output, two VHF antenna inputs, top quality American brand color tube with 2-year warranty. With optional new RCA Matrix picture tube that doubles the brightness, Model GR-681MX only $535.00.

GRA-295-4, Mediterranean Cabinet shown **$124.95***

Heathkit "295" Color TV

With Optional RCA Matrix Tube . . . with the same high performance features and built-in servicing facilities as GR-681 above . . . less AFT, VHF power tuning and built-in cable-type remote control. You can add the optional GRA-295-6 Wireless Remote Control at any time. New optional RCA Matrix tube doubles the brightness, Model GR-295MX, $485.00.

GRA-295-1, Contemporary Walnut Cabinet shown **$64.95***

Both the GR-681 and GR-295 fit into the same Heath factory assembled cabinets; not shown Early American style at $109.95*

NEW Deluxe Heathkit "581" Color TV With AFT

The new Heathkit GR-581 will add a new dimension to your TV viewing. Brings you color pictures so beautiful, so natural, so real . . . puts professional motion picture quality right into your living room. Has the same high performance features and exclusive self-servicing facilities as the GR-681, except with 227 sq. inch viewing area, and without power VHF tuning or built-in cable-type remote control. The optional GRA-227-6 Wireless Remote Control can be added any time you wish. And like all Heathkit Color TV's you have a choice of different installations . . . mount it in a wall, your own custom cabinet, your favorite B&W TV cabinet, or any one of the Heath factory assembled cabinets.

GRA-227-2, Mediterranean Oak Cabinet shown **$109.95***

Heathkit "227" Color TV

Same as the GR-581 above, but without Automatic Fine Tuning . . . same superlative performance, same remarkable color picture quality, same built-in servicing aids. Like all Heathkit Color TV's you can add optional Wireless Remote Control at any time (GRA-227-6). And the new Table Model TV Cabinet and roll around Cart is an economical way to house your "227" . . . just roll it anywhere, its rich appearance will enhance any room decor.

GRS-227-5, New Cart and Cabinet combo shown **$54.95***

Both the GR-581 and GR-227 fit into the same Heath factory assembled cabinets; not shown, Contemporary cabinet $64.95*

NEW Heathkit Deluxe "481" Color TV With AFT

The new Heathkit GR-481 has all the same high performance features and exclusive self-servicing aids as the new GR-581, but with a smaller tube size . . . 180 sq. inches. And like all Heathkit Color TV's it's easy to assemble . . . no experience needed. The famous Heathkit Color TV Manual guides you every step of the way with simple to understand instructions, giant fold-out pictorials . . . even lets you do your own servicing for savings of over $200 throughout the life of your set. If you want a deluxe color TV at a budget price the new Heathkit GR-481 is for you.

GRA-180-1, Contemporary Walnut Cabinet shown **$49.95***

Heathkit "180" Color TV

Feature for feature the Heathkit "180" is your best buy in color TV viewing . . . has all the superlative performance characteristics of the GR-481, but less Automatic Fine Tuning. For extra savings, extra beauty and convenience, add the table model cabinet and mobile cart. Get the value-packed GR-180 today.

GRS-180-5, Table Model Cabinet & Cart combo **$42.50***

Both the GR-481 and GR-180 fit the same Heath factory assembled cabinets; GRA-180-2, Early American Cabinet $94.95*.

Add the Comfort And Convenience Of Full Color Wireless Remote Control To Any Rectangular Tube Heathkit Color TV . . . New Or Old!

Kit GRA-681-6, for Heathkit GR-681 Color TV's **$64.95***
Kit GRA-295-6, for Heathkit GR-295 & GR-25 TV's **$69.95***
Kit GRA-227-6, for Heathkit GR-581; GR-481 & GR-180 Color TV's **$69.95***

Now There Are 6 Heathkit® Color TV's To Choose From

2 Models In 295 Sq. Inch Size

NEW Kit GR-681 With AFT **$499.95*** (less cabinet)

Kit GR-295 **$449.95*** (less cabinet)

2 Models In 227 Sq. Inch Size

NEW Kit GR-581 with AFT **$419.95*** (less cabinet)

Kit GR-227 NOW ONLY **$379.95*** (less cabinet & cart)

2 Models In 180 Sq. Inch Size

NEW Kit GR-481 with AFT **$359.95*** (less cabinet)

Kit GR-180 NOW ONLY **$329.95*** (less cabinet & cart)

Reception Is Simulated On All Sets Shown

NEW FREE 1970 CATALOG!

Now with more kits, more color. Fully describes these along with over 300 kits for stereo/hi-fi, color TV, electronic organs, electric guitar & amplifier, amateur radio, marine, educational, CB, home & hobby. Mail coupon or write Heath Company, Benton Harbor, Michigan 49022.

HEATHKIT® a Schlumberger subsidiary

HEATH COMPANY, Dept. 15-67
Benton Harbor, Michigan 49022

☐ Enclosed is $__________, plus shipping.

Please send model (s)__________
☐ Please send FREE Heathkit Catalog. ☐ Please send Credit Application.

Name__________

Address__________

City__________ State__________ Zip__________

*Mail order prices; F.O.B. factory. Prices & specifications subject to change without notice. CL-365R

CIRCLE NO. 131 ON READER SERVICE CARD

high-capacity, stacks, momentary and maintained contact, open and enclosed, single- and double-pole, with lever and roller actuators. Also illustrated are four different types of gold "cross-point" contact switches for low-energy circuits and two new leverwheel and thumbwheel rotary switches.

A request on your letterhead, addressed to Frank Amendola at the company, will bring a copy of this catalogue.

VARIABLE INDUCTORS

An engineering handbook available from Sangamo Electric Company, P.O. Box 359, Springfield, Illinois 62705, describes the company's new Type NV-4 communications-grade variable inductors. These components are designed for printed-circuit board mounting and have a recommended frequency range of 500 to 50,000 Hz.

The 16-page handbook contains listings giving nominal inductance values, tuning ranges, and d.c. resistances for the several hundred standard versions of the NV-4. Physical characteristics are described and several pages of technical information is provided.

When you make your request on your company letterhead, please specify Bulletin 5104.

REPLACEMENT CAPACITORS

A 12-page booklet which lists an extensive line of capacitors which meet virtually every service need for a replacement is now available.

Entitled "The Replacers," the guide lists twist-prong electrolytics, tubular electrolytics, miniature electrolytics, dipped-paper Mylar, ceramic discs, dipped mica, wax-filled capacitors, and capacitor assortments. The material is presented in easy-to-use tabular form for ready reference. Cornell-Dubilier

Circle No. 15 on Reader Service Card

TEST-EQUIPMENT CATALOGUE

An 8-page catalogue giving complete specifications on the firm's line of test equipment is now available. Included are vectorscopes, color-bar generators, oscilloscopes, picture-tube analyzers, in-circuit transistor analyzer, transistor TV sweep-circuit analyzer, CB analyzer and frequency meter, power supplies, and accessories. Lectrotech

Circle No. 16 on Reader Service Card

HAND TOOLS & SETS

A four-page, full-color catalogue 166 supplement has just been issued containing complete descriptions and specifications on all professional hand tools and sets added to the line since publication of the latest general catalogue.

A large number of nonmagnetic, nonsparking, rust- and corrosion-resistant, beryllium-copper tools are shown along with nutdrivers, Phillips-type screwdrivers, metric handtools and sets, and convertible screwdriver sets. Xcelite

Circle No. 17 on Reader Service Card

HAND TOOLS FOR INDUSTRY

A 24-page catalogue (SR-76) offers an extensive line of hand tools for industry, production and assembly line, maintenance, service, or home workshop use. The catalogue is reproduced in two colors with all product illustrations shown in "woodcut line" technique to permit distributors to pick up the artwork for use in the own catalogues.

Contents include hundreds of sizes and styles of screwdrivers, nutdrivers, ratchet tools, pliers, wrenches, electrical testers, steel tapes, as well as snap rings, snap-ring pliers, blind rivets, and carded tools. Vaco

Circle No. 18 on Reader Service Card

NEW SWITCH BULLETIN

Grayhill Inc., P.O. Box 373, LeGrange, Illinois 60525 has just issued a 20-page bulletin (S-305) which lists the newest switches in its line.

Included are miniature rotary switches for printed-circuit applications, taper tamper-proof key lock versions, isolated positions and spring-return styles, miniature push-button switches for printed-circuit mounting, lighted push-button switches, and bi-pin lamp sockets. Complete technical data and specifications are provided on each item.

For a copy of this supplement, write the firm direct on your business letterhead.

CRYSTAL BULLETIN

K-W Industries, Inc., P.O. Box 508, Prague, Oklahoma 74864 has issued a crystal bulletin which contains a list of quartz crystals in the range from 50 kHz to 200 MHz. Complete dimensional data and ordering information for standard and custom units are included along with the completely revised chart listing specifications on all military-type crystals.

Those desiring a copy of this bulletin should write on their business letterheads direct to the company at the above address.

LASER APPLICATIONS

A 16-page illustrated brochure on laser applications is now available from Laser Nucleonics, Inc., 123 Moody Street, Waltham, Mass. 02154.

There are more than 50 pictures illustrating the various applications of laser technology in action. Single-shot laser etching of circuits, patterns, welds, etc. is described while a complete section is devoted to resistor trimming.

In hole drilling, the illustrations show the state of the art while welding portion covers special feasibility studies done for an auto maker.

Copies of the brochure will be supplied only on letterhead request.

DISCRETE-DEVICE CATALOGUE

A complete listing of the company's discrete devices is included in a new 64-page, 1969 condensed catalogue just issued.

The catalogue presents key parameters and package outline dimensions, along with a numerical index that quickly locates the device of interest. The listings are grouped by applications for the user's convenience. They include diodes, small-signal transistors, dual transistors, field-effect transistors, power transistors, communication devices, SCR's specialty diode products, and electro-optical devices.

The catalogue will be forwarded on letterhead request direct to Fairchild Semiconductor, 313 Fairchild Drive, Mountain View, California 94040.

CASSETTE TAPE DATA

A colorful 8-page technical manual providing complete performance specifications on SD cassette tape is now available for distribution.

In addition to listing the unique features of these new cassettes, the manual includes hysteresis loops, comparison charts, electro-magnetic characteristics, dimensions, and performance data.

Information on using and storing the cassettes is also included. TDK Electronics

Circle No. 19 on Reader Service Card

PHOTO CREDITS

Page	Credit
22	Dynaco, Inc.
40	Hazeltine Corp.
44, 45, 46	Synthane-Taylor Corp.
48, 49	RCA
52, 53, 54 (top)	Amphenol Industrial Div.
54 (bottom), 55	AMP, Inc.
60	Sanders Associates
78	B&K
80 (top)	Leader Electronics Corp.
80 (bottom)	Hewlett-Packard
86	Shure Brothers, Inc.

ELECTRONICS MARKET PLACE

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

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

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

FOR SALE

JUST starting in TV service? Write for free 32 page catalog of service order books, invoices, job tickets, phone message books, statements and file systems. Oelrich Publications, 4040 North Nashville Avenue, Chicago, Ill. 60634.

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

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

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

INVESTIGATORS, LATEST ELECTRONIC AIDS. FREE LITERATURE. CLIFTON, 11500-J NW 7th AVE., MIAMI, FLORIDA 33168.

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

ADVERTISING SHORTHAND IN THIS AD:
A: As is, as received from a large prime. **C:** Overhauled, new parts & tubes as needed, then calibrated by a Secondary Standards Lab: with dated sticker.

HI-SENSITIVITY UHF RECEIVER:
375-1000 MHz. If previous owner had not lost the attenuator calibration charts, it would be a $2852.00 **Stoddart NM50A RFI Meter!** But he did, so we are selling as a simple rcvr w/pwr sply, dipole holder, 3 pairs dipoles & book. Zi 50 ohms. IF 60 MHz. Bandwidth 1 to 1.8 MHz. Sensitivity as a 2-terminal tuned voltmeter is 10 uv. Grtd exc. cond....**275.00**

ULTRA-WIDE-BAND RECEIVER:
38-1000 MHz: AN/ALR-5: Late postwar AM/FM Countermeasures rcvr. Has S-Meter; variable IF Atten. & passband (0.2 or 2 MHz from 30 MHz center): AF, Video & Pan. outputs. New, modified for 120 v 60 Hz, Includes new (Method II pack) 4-band plugin converter .038-1 GHz. 4 Type-N plugs automatically select correct ant. as bands are switched. Sensit. at —6 db setting: 6½ uv thru 132 MHz. 13 thru 780 MHz & 45½ at 1 GHz. **BRAND NEW.** with book & mating pwr-input plug. **275.00**

A FEW ITEMS FROM OUR AUDIO LIST:
Hewl-Pack 202A Function Generator: .008 to 1200 Hz. Sine, Triangle, Square. $663 value. **C**...**275.00**
Hewl-Pack 650A Oscil.: 10Hz to 10 MHz. Sine. VTVM & step-attenuator in output. **C**..............**295.00**
Impedance Bridge: Gen. Radio 1603A; universal application 20 to 20,000 Hz, 1% accurate..**C**..**195.00**
Q Meter 20 to 250,000 Hz: Freed 1030A. A $1250.00 value for only..**C**......................**595.00**
Audio Spectrum Display: Panoramic LP-1 sweeps 20 to 22,500 Hz, linear or logarithmic..**C**......**595.00**
LP-1aBZM later model, adds markers..**C**....**850.00**
Band-Pass Filters: 20 to 200,000 Hz: Pair of **SKL #300's.** $1196 value..**C**..or a **Krohn-Hite 330M** for 20 to 20,000 Hz..**C**..either setup only......**299.50**

A FEW VTVM's FROM OUR LIST (All **C**):
HP 400C: AC to 2 MHz, .001-300v FS's......**99.50**
HP 400D: Same but to 4 MHz............**150.00**
HP 400HR: Same, rack mtg mirror scale....**195.00**
HP 400LR: Same, rack, linear db scale......**195.00**
HP 410B: Ohms, DC, AC, RF with probe....**150.00**
HP 411A RF 3% accuracy to 700 MHz....**270.00**
HP 412AR: Rack, precision DC I, E, R......**275.00**
Bruel-Kjaar 2409: Self-calib. AF..........**197.50**
Ballant. 305AR: Rack, peak-to-peak..........**49.50**
Ballant. 320A: Latest TRUE RMS meter......**325.00**
Keithly 200B electrom. ac/dc uv, mv, v......**110.00**
Millivac DC: Chopper-stab. amp. type..........**79.50**
Mill. DC/RF w/probes, hi-sensitivity..........**149.50**
For Meter-Calibrating Pwr Splies & Differential Voltmeters, ask for Cat. 29 sheets. For Precision D'Arsonval & Dynamometer Meters, ask for 18d sheets.

FAIRCHILD SOLID-STATE SCOPES all w/dual-trace plugins 25 & 50 mc, w/delayed time-base plugins, w/books, w/recent NBS-traceable calib. 100% grtd. Low as **825.00**

See our AUGUST ad Page 85 for some **DIGITAL COUNTERS** and some **SIGNAL GENERATORS.**

WE PROBABLY HAVE THE BEST INVENTORY OF GOOD LAB TEST EQUIPMENT IN THE COUNTRY. BUT PLEASE DO NOT ASK FOR CATALOG! ASK FOR SPECIFIC ITEMS OR KINDS OF ITEMS YOU NEED! WE ALSO BUY! WHAT DO YOU HAVE?

R. E. GOODHEART CO. INC.
Box 1220-A, Beverly Hills, Calif. 90213
Phones: Area 213, office 272-5707, messages 275-5342

FREE ELECTRONICS PARTS FLYER. Large catalog $1.00 deposit. **BIGELOW ELECTRONICS, BLUFFTON, OHIO 45817.**

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

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

EUROPEAN wholesale new products catalog. $1.00 refundable. Deecow, 10639 Riverside, North Hollywood, Calif. 91602.

JAPAN & HONG KONG DIRECTORY. Electronics, all merchandise. World trade information. $1.00 today. Ippano Kaisha Ltd., Box 6266, Spokane, Washington 99207.

RECTIFIERS, transistors, other components. Free Catalog. Lowest Prices. Electronic Components Co., Box 2902E, Baton Rouge, La. 70821.

FREE Catalog low priced, high performance subminiature listening devices direct from manufacturer. Dealers welcome. Emery W 10, 156 Fifth Avenue, New York, N.Y. 10010.

ULTRA-SENSITIVE AND POWERFUL METAL DETECTORS—join the many who are finding buried coins, minerals, relics and artifacts. Don't buy till you see our **FREE** catalog of new models. Write Jetco, Box 132-EW, Huntsville, Texas 77340.

REPAIR YOUR OWN T.V. TUNERS—Color—Transistor—VHF—UHF. Earn to $1,700 monthly. No customer headaches. Simple, complete course. First of its kind. Copyrighted. Years in preparation. Six sections, 33 chapters. All field-tested. Jigs, fixtures, adapters, "setting-up." Special probes. Quick-checks. How alter and use test sets. Repairs without equipment. Unique power supplies. Fast-fix luxuries. Equipment you can build. Professional tricks. Illustrated schematics, pictures, drawings, sketches. Plans for all items. Troubleshooting. Alignment. All tests and adjustments. Common mistakes. How and where to buy parts. Specific repairs common problems. Index of all tuners. Much, much more. Programmed teaching. Major course: Details, Introduction, plus two sample lessons $1. Optional condensed courses (Complete in themselves): VHF $9.50, UHF $4.50, Transistor Tuners $4.50. **TV TUNER SERVICE,** Frank Bocek, Box 3236W, Redding, Calif. 96001.

NEW heavy duty CD ignition system. Details free. Kit, $28.95; assembled, $39.95. Delta International, Ltd., Box 1946Z, Grand Junction, Colo. 81501. Dealers invited.

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

PSYCHEDELIC strobes 200 flashes per-min. $14.95, guaranteed. Zipcom, 5620 W. 12, L.R., Arkansas 72204.

SENCORE TEST EQUIPMENT UNBELIEVABLE PRICES. FREE CATALOG AND PRICE SHEET. FORDHAM RADIO, 265 EAST 149TH STREET, BRONX, N.Y. 10451.

FM Background Music! Miniaturized adapter connects to any FM radio tuner. Brings in hidden commercial-free programs. Performance guaranteed. $29 postpaid. K-Lab, Dept. Z, Box 572, S. Norwalk, Conn. 06856.

SELF-SERVICE tube tester panels, Reliable Electronics $5.00, Mercury $10.00, Eveready battery tester $2.00. Write for information and color picture. John Kirby, 3606 Delmar, Indianapolis, Indiana 46220.

POCKET monitor receiver, crystal controlled, low priced. Free catalog. JMD Electronics, 328 Madison Avenue, West Hempstead, N.Y. 11552.

PROXIMITY switch. Detects nearness of human body. Free information. Claremont Products, 860 Reed, Claremont, Calif. 91711.

DIAGRAMS, service manuals. TV, radio, HiFi, $1.06. Technical Services Associates, Box 1167, Berkeley, Calif. 94701.

TYPEWRITERS, ADDING MACHINES, NEW. $10.00 and less above dealer cost, save $60.00 and more. American made, home, student, and executive line machines. Lowest prices anywhere for top quality guaranteed machines. Details 50¢ coin refundable. Barr Typewriter Sales, Box 347-A, Newcastle, California 95658. 26 years of satisfied customers.

SURPLUS Electronic Equipment catalogue 10¢. Bob-Frank Electronics, P.O. Box 1327, Harrisburg, Pa. 17105.

PLANS AND KITS

INTEGRATED CIRCUIT KITS: COMPUTER, AUDIO, Others. New catalog free. **KAYE ENGINEERING,** Box 3932-B, Long Beach, California 90803.

LATEST ARCTURUS SPECIALS

- Color focus rectifiers, 14,000 P.I.V. at 1 MA, 99¢ each. 6.5 KV—79¢.
- Color TV yokes 70° & 90° types. Fit almost all sets: $9.95 each.
- 1700 Transistor types—39¢ each.
- DS-501, 2N278 power transistor types. Cat. #349, 69¢ each.
- HEP170, Motorola HV/Current epoxy silicon rectifiers, 2.5 amps at 1,000 PIV, 49¢ each.
- Fully transistorized UHF tuners. Fit most sets. Cat. #UHF567, $4.95 each.
- UHF tuners, 1 tube type. Fit most sets. Cat. #UHF3, $3.95 each.

Complete listings of electronic items at similar bargain prices are available. Write for our latest catalog. Minimum order $5.00, plus postage.

ARCTURUS ELECTRONICS CORP.

502-22nd St., Union City, N.J. 07087 Dept. EW
Phone 201 · UN4 5568

CIRCLE NO. 148 ON READER SERVICE CARD

$1 PEP $1

Dollar Sale
EACH PACKAGE
MONEY BACK GUARANTEE

1 AMP
Silicon Rectifier
Choice of Package
Bullet-Glass-Min-Metal
☐ 20-50V ☐ 5-800V
☐ 17-100V ☐ 4-1000V
☐ 12-200V ☐ 3-1200V

1.5 AMP
☐ 18-50V ☐ 5-800V
☐ 15-100V ☐ 4-1000V
☐ 10-200V ☐ 2-1200V

3 AMP
☐ 15-50V ☐ 4-600V
☐ 10-100V ☐ 3-800V
☐ 8-200V ☐ 2-1000V
☐ 5-400V ☐ 1-1200V

5 AMP
☐ 10-50V ☐ 4-400V
☐ 8-100V ☐ 3-800V
☐ 6-200V ☐ 2-1000V
☐ 5-300V ☐ 1-1200V

8 AMP STUD
☐ 6-100V ☐ 3-400V
☐ 4-200V ☐ 2-800V

12 AMP STUD
☐ 5-100V ☐ 2-800V
☐ 3-500V ☐ 1-1000V

20 AMP STUD
☐ 4-50V ☐ 2-500V
☐ 3-100V ☐ 1-1000V

40 AMP STUD
☐ 3-50V ☐ 1-300V
☐ 2-100V

60 AMP STUD
☐ 2-50V ☐ 1-1000V

ZENER—DIODES
250-400 MW
1 EA 4V-6V-8V-10V

1 WATT
1 EA 4V-6V-8V-10V

2 WATT
12 to 60V
CHOICE OF THREE

3 WATT
10 volt three for $1.00

10 WATT
12 to 60V THREE

SILICON-CONTROLLED RECTIFIER
TO-5 PACKAGE
☐ 5-50V ☐ 3-200V
☐ 4-100V ☐ 2-400V

7 AMP
☐ 4-50V ☐ 2-200V
☐ 3-100V ☐ 1-1000V

20 AMP
☐ 2-50V ☐ 1-300V

GENERAL PURPOSE GERMANIUM TRANSISTOR
SIMILAR to 2N404
8 UNITS

RADIATION FREE TUBE FOR COLOR TV
50,000 Volts. Replaces RCA 3A-3A or equivalent. Guaranteed for life of set or 5 years. Eliminates heat to prolong life of other tubes.
$8.99 each

SPECIAL
INTEGRATED CIRCUITS

Dual 4 Input Nand Gate Digital	**$1.50**
Quad 2 Input Nand Gate Digital	**$1.50**
J K Flip Flop Master Slave Digital	**$1.75**
Linear I C Operational Amp 709C Type	**$1.75**

POWER TRANSISTOR
85 Watt Similar to 2N-212-1724-1208
1 Unit........**$1.00**

$1 HOBBY CORNER SPECIALS $1

SILICON RECT LOW V
1 AMP
☐ 50 units **$1.00**

3 AMP
LOW VOLTAGE
☐ 35 units **$1.00**

STUD MOUNT
15 AMP
☐ 25 units **$1.00**

COMPUTER DIODES
FAST SWITCHING
NO TEST
☐ 100 units **$1.00**

HALF POUND
Rect. Diodes. Transistors Etc. Each different
$1.00

NO SALES TAX—WE PAY POSTAGE
OTHER PRODUCTS ON REQUEST

PARK ELECTRONIC PRODUCTS

P.O. Box 78, N. Salem, N.H. 03073
603-893-0276

LET US TRY TO HELP YOU WITH YOUR ENG PROBLEMS

CIRCLE NO. 118 ON READER SERVICE CARD

ELECTRONICS ENGINEERING AND INSTRUCTION

LEARN ELECTRONIC ORGAN SERVICING at home. All Makes including transistors. Experimental kit—troubleshooting. Accredited NHSC. Free Booklet. **NILES BRYANT SCHOOL,** 3631 Stockton, Dept. A, Sacramento, Calif. 95820.

R.E.I.'s famous (5) week course for the First Class Radio Telephone License is the shortest, most effective course in the nation. Over 98% of R.E.I. graduates pass F.C.C. exams for 1st class license. Total tuition $360.00. Job placement free. Write for brochure Radio Engineering Incorporated Schools, 1336 Main Street, Sarasota, Florida 33577—or 3123 Gillham Road, Kansas City, Missouri 64109—or 809 Caroline Street, Fredericksburg, Virginia 22401—or 625 E. Colorado Street, Glendale, California 91205.

DEGREE in Electronics Engineering earned mostly by correspondence. Free brochure. Dept. G-9, Grantham School of Engineering, 1505 N. Western Ave., Hollywood, California 90027.

ELECTRONICS! Associate degree—29 months. Technicians, field engineers, specialists in communications, missiles, computers, radar, automation. Start February, September. Valparaiso Technical Institute, Dept. N, Valparaiso, Indiana 46383.

FCC First Class License in six weeks—nation's highest success rate—approved for Veterans Training. Schools in Dallas, Atlanta, Chicago, New Orleans, Minneapolis and Houston. Write Elkins Institute, 2603C Inwood Road, Dallas, Texas 75235.

F.C.C. License training by correspondence. G.I. Bill approved. Money-Back Warranty. Free brochure. Write: Dept. Z-9, Pathfinder School of Electronics, 1505 N. Western Ave., Hollywood, Calif. 90027.

TUBES

TUBES—33¢ each. Year guarantee. Tuner Cleaner $1.00. Free catalog. Cornell, 4213-W University, San Diego, Calif. 92105.

TUBES, SEMICONDUCTORS, ELECTRONIC EQUIPMENT & COMPONENTS. Quality merchandise only! Serving engineers. Purchasing Agents, TV/HiFi Servicemen and Hams for 20 years. Write for Catalog or call 212-WA 5-7000. **BARRY ELECTRONICS,** 512 Broadway, New York, N.Y. 10012.

RECEIVING & INDUSTRIAL TUBES, TRANSISTORS, All Brands—Biggest Discounts. Technicians, Hobbyists, Experimenters—Request **FREE** Giant Catalog and **SAVE! ZALYTRON,** 469 Jericho Turnpike, Mineola, N.Y. 11501.

TUBES—lowest prices in the world. Hard to get British, German, foreign and American obsolete and present day special purpose transmitting tubes. Send for giant tube and parts catalog. United Radio Co., Dept. W-56 Ferry St., Newark, N.J. 07105.

WANTED

QUICKSILVER, Platinum, Silver, Gold. Ores Analyzed. Free Circular. Mercury Terminal, Norwood, Mass. 02062.

QUICK CASH . . . for Electronic Tubes, Semiconductors, Equipment (Receivers, Transmitters, Scopes, Vacuum Variables, etc.) Send lists now! Write: **BARRY ELECTRONICS,** 512 Broadway, New York, N.Y. 10012 (212-WA 5-7000).

DO-IT-YOURSELF

PROFESSIONAL ELECTRONICS PROJECTS—$1.00 up. Catalog 25¢. **PARKS,** Box 25665A, Seattle, Wash. 98125.

TAPE AND RECORDERS

BEFORE renting stereo Tapes, try us. Postpaid both ways — no deposit — immediate delivery. Quality — Dependability — Service — Satisfaction—prevail here. If you've been dissatisfied in the past, your initial order will prove this is no idle boast. Free Catalog. Gold Coast Tape Library, Box 2262, Palm Village Station, Hialeah, Fla. 33012.

TAPEMATES make available to you **ALL 4-TRACK STEREO TAPES—ALL LABELS**—postpaid to your door—at tremendous savings. For free brochure write: **TAPEMATES,** 5727 W. Jefferson Blvd., Los Angeles, California 90016.

RENT 4-track open reel tapes—all major labels—8,000 different—free brochure. Stereo-Parti, 55 St. James Drive, Santa Rosa, Calif. 95401.

TAPE RECORDER SALE. Brand new nationally advertised brands, $10.00 above cost. Amazing discounts on stereo components. Arkay Electronics, 1028-B Commonwealth Ave., Boston, Mass. 02215.

STEREO TAPES: CARTRIDGES, CASSETTES, REELS, 33% DISCOUNT. UNAVAILABLE ELSEWHERE. MAIL 20¢—CATALOGS. STAR RECORDINGS-EW, BOX 1055, EL PASO, TEXAS 79946.

CASSETTE blanks, also educational and language, accessories and recorders. Literature—— write **CASSETTES UNLIMITED,** P.O. Box 13199-W. Pittsburgh, Pa. 15243.

TAPES . . . blank recording . . . pre-recorded music. Catalog 10¢. Tower, Lafayette Hill, Pa. 19444.

STEREO TAPES, save 20, 30% and more, postpaid anywhere U.S.A. We discount batteries, recorders, tape/cassettes, 80-page catalog 25¢. **SAXITONE TAPES,** 1776 Columbia Road, N.W., Washington, D.C. 20009.

Electronics World SUBSCRIBER SERVICE

Please include an address label when writing about your subscription to help us serve you promptly. **Write to:** Portland Place, Boulder, Colorado 80302

CHANGE OF ADDRESS: Please let us know you are moving at least four to six weeks in advance. Affix magazine address label in space to the right and print new address below. If you have a question about your subscription, attach address label to your letter.

TO SUBSCRIBE:
Check boxes below.
☐ New ☐ Renewal
☐ 5 years $26
☐ 3 years $18
☐ 1 year $7

SPECIFY:
☐ Payment enclosed—You get 1 extra issue per year as a BONUS!
☐ Bill me later.

AFFIX LABEL
state city address name
please print
zip-code
If you have no label handy, print OLD address here.

Add'l postage: $1 per year outside U.S., its possessions & Canada.

name please print 0202
address
city
state zip-code

U.S. GOV'T ELECTRONIC SURPLUS

■ **Nationally Known-World Famous SURPLUS CENTER offers finest, most expensive, Government Surplus electronic units and components at a fraction of their original acquisition cost.**

ORDER DIRECT FROM AD or WRITE FOR CATALOGS

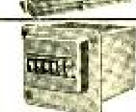
COMPUTER TRANSISTORS ON HEAT SINKS

IBM Computer Quality Units

● **(#22-928)** -- Unit consists of one 150-watt power transistor on heavy, ribbed aluminum heat sink. Many experimental uses. (1 lb.)
Cost Gov't Over $10.00 **$1.99**

● **(#22-915)** -- Unit consists of two 150-watt power transistors, 3 pots, several diodes, capacitors, resistors, etc. on heavy, ribbed aluminum heat sinks. Ideal for use as motor speed control. (4 lbs.)
Cost Gov't Over $45.00 **$4.91**

RUNNING TIME METER

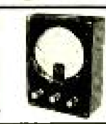


● **(#DX-104)** -- Use to record number of operating hours of electric lights and electrical devices such as refrigerators, furnaces, etc. Records total hours, tenths and hundredths up to 9,999.99 hours. For 115-volt, 60-cycles. Size 4¼" x 1½" x 2½". Shipping weight 2 lbs. **$5.69** Cost Over $29.00

12 and 24-VOLT TRANSFORMER

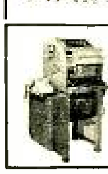
● **(#15-920)** --General Electric 115-volt, 60-cycle to 12 and 24-volts @ 750-watts. Capacity 42-amps. @ 24-volts, 64-amps. at 12-volts. Useful for battery chargers, running DC motors, etc. 7" x 5" x 5". (18 lbs.)
Cost Gov't Over $35.00 **$16.72**

EXPANDED SCALE 0 - 15 DCVM



● **(#21-900)** -- Brand new, expensive voltmeter reads 9.5 to 16-volts DC and 5 to 8-volts. Very useful for automotive and aircraft battery charge indicator, etc. D'Arsonval movement, black phenolic case. (3 lbs.)
List $32.50 **$12.95**

SURPLUS TELETYPEWRITERS

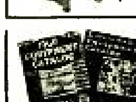


Orig. Cost Over $1500.00

SPECIAL
$249.50

● **(ITEM #22-936)** -- Used but excellent teletypewriters, Model 15 complete with A.T. Co. Data-Com. Permits using teletypewriter over regular long distance connection. Complete with AC power supply, control telephone, etc. Wt. 160 lbs. Size 22" x 22" x 42".

● Also have limited number Model 19 Teletypewriters with perforator, Data-Com, etc. Write for Sale price.



SEND 25¢ COIN OR STAMPS FOR CATALOGS
All Items FOB **Money Back Guarantee**

SURPLUS CENTER
DEPT. EW-109 **LINCOLN, NEBR. 68501**

CIRCLE NO. 101 ON READER SERVICE CARD

OLD radio programs on tape $8.00 for 6 hours. Catalog for 50¢. Don Maris, 824 Owl, Norman, Okla. 73069.

STEREO TAPE TRANSPORT. Made for leading manufacturer, two speed, pause control, 7" reel, automatic tape lifters, with record, playback and erase heads. No case. Send check or M.O. for $17.50 to Stereo Center, 218 Columbia Street, Utica, New York 13502.

OLD RADIO PROGRAMS on tape. Jack **ARMSTRONG,** Whistler, Gangbusters, hundreds more. Sample 2-hr. $6.00, 4-hr. $9.00. Catalog $1.25 or free with sample. **NOSTALGIA,** 9875 S.W. 212 St., Miami, Fla. 33157.

RECORDS

SPECIAL INTEREST RECORDS AVAILABLE, PRODUCED BY THE EDITORS OF THE WORLD'S LEADING SPECIAL INTEREST MAGAZINES. SEND FOR FREE CATALOG. RECORD CATALOG-EW, ZIFF-DAVIS PUBLISHING COMPANY, ONE PARK AVENUE, NEW YORK, N.Y. 10016.

OLDIES—45 RPM—original hits. Over 4000 available. Catalog 25¢. C & S Record Sales, Box 197, Wampsville, N.Y. 13163.

POPULAR organ albums factory direct. Concert Recording, Lynwood, Calif. 90262.

HIGH FIDELITY

FREE! Send for money saving stereo catalog #E10W and lowest quotations on your individual component, tape recorder or system requirements. Electronic Values, Inc., 200 West 20th Street, N.Y., N.Y. 10011.

HI-FI Components. Tape Recorders at guaranteed "We Will Not Be Undersold" prices. 15-day money-back guarantee. Two-year warranty. No Catalog. Quotations Free. Hi-Fidelity Center, 239 (L) East 149th Street, New York 10451.

DON'T THROW YOUR OLD CARTRIDGE AWAY. Send us $50.00 and any old used cartridge and we will ship you via air Prepaid anywhere any one of the following Top Stereo Cartridges: Shure V-15 Type II, Empire 999VE, ADC 10EMK II, Stanton 681EE. Write for lowest quotations all stereo components. Send $1.00 for our discount catalog. **DEFA ELECTRONICS,** 2207 Broadway, New York, N.Y. 10024.

HI-FI components, tape recorders, sleep learnequipment, tapes. Unusual Values. Free catalog. Dressner, 1523 R Jericho Turnpike, New Hyde Park, N.Y. 11040.

HI-FI EQUIPMENT—GET Our **"ROCK BOTTOM"** prices on **NAME BRAND** amplifiers—tuners—tape-recorders — speakers **FRANCHISED — 60 YEARS IN BUSINESS.** Write for this month's specials—**NOW!** Rabson's 57th St., Inc., Dept. 569, 119 W. 57th St., New York, New York 10019.

LOW, LOW quotes: all components and recorders. Hi-Fi, Roslyn, Penn. 19001.

DON'T THROW YOUR OLD CARTRIDGE AWAY. Send us $19.95 and any old cartridge. We will ship **PREPAID** any one of the following top rated elliptical diamond stereo cartridges **NEW:** Shure M75E, M91E, M92E, Empire 888E, Pickering V15AME3, XV15 ATE, ADC 660E, 550E. Write for lowest quotations all stereo components. Send $1.00 for our discount catalog. **DEFA ELECTRONICS,** 2207 Broadway, New York, N.Y. 10024.

GOVERNMENT SURPLUS

JEEPS Typically From $53.90 . . . Trucks From $78.40 . . . Boats, Typewriters, Airplanes, Multimeters, Oscilloscopes, Transceivers, Electronics Equipment. Wide Variety, Condition, 100,000 Bid Bargains Direct From Government Nationwide. Complete Sales Directory and Surplus Catalog $1.00 (Deductible First $10.00 Order). Surplus Service, Box 820-K, Holland, Michigan 49423.

PERSONALS

MAKE FRIENDS WORLDWIDE through international correspondence. Illustrated brochure free. Hermes, Berlin 11, Germany.

SECRET LOANS BY MAIL. Borrow $100 to $1500 for any good reason in absolute privacy. No interviews, no endorsers, no co-signers. Fast service. Write Dial Finance Co., Dept. K-594, 410 Kilpatrick Bldg., Omaha, Nebraska 68102.

HYPNOTISM

FREE Hypnotism, Self-Hypnosis, Sleep Learning. Catalog! Drawer H400, Ruidoso, N.M. 88345.

HYPNOTIC Sleep Learning recordings produce fabulous results. Details free. ASR Foundation, Box 7021eg Henry Clay Station, Lexington, Kentucky 40502.

PHOTOGRAPHY—FILM, EQUIPMENT, SERVICES

SCIENCE Bargains—Request Free Giant Catalog "CJ"—148 pages—Astronomical Telescopes, Microscopes. Lenses, Binoculars, Kits, Parts, War Surplus bargains. Edmund Scientific Co., 300 Edscorp Bldg., Barrington, New Jersey 08007.

EMPLOYMENT INFORMATION

FOREIGN and USA job opportunities available now. Construction, all trades. Earnings to $3,000.00 monthly. Paid overtime, travel, bonuses. Write: Universal Employment, Woodbridge, Conn. 06525.

EMPLOYMENT OPPORTUNITIES

CENTRAL INTELLIGENCE AGENCY. VARIOUS EMPLOYMENT OPPORTUNITIES, U.S., OVERSEAS. INFORMATION, FORMS, INSTRUCTIONS, $1.00. WESTERN DISTRIBUTORS, BOX 6293-F, SAN JOSE, CALIFORNIA 95150.

EDUCATIONAL OPPORTUNITIES

LEARN ACCIDENT INVESTIGATION. Train at home to earn $750 to $1,000 monthly. Car furnished. Expenses paid, No selling. No college needed. Full or spare time. Men urgently needed. Free placement service. Write for **FREE** information. No obligation. Universal Schools CZ-10, 6801 Hillcrest, Dallas, Texas 75205.

USED Correspondence Courses and Books sold and rented. Money back guarantee. Catalog free (Courses Bought). Lee Mountain, Pisgah, Alabama 35765.

LEARN WHILE ASLEEP, Hypnotize! Strange catalog free. Autosuggestion, Box 24-ZD, Olympia, Washington 98501.

INVENTIONS WANTED

YOUR Metal-Plastic products made in Japan. Low cost. Information 10¢. P.O. Box 487-E, Miami, Florida 33156.

INVENTORS! Receive free invention analysis at no risk to you. Send for **FREE** disclosure form today. New York Invention Service, Dept. 19, 160 Broadway, New York, N.Y. 10038.

PATENT Searches including maximum speed, full airmail report and closest patent copies, $6.00. Quality searches expertly administered. Complete secrecy guaranteed. Free Invention Protection forms and "Patent Information." Write Dept. 23, Washington Patent Office Search Bureau, 711 14th Street, N.W., Washington, D.C. 20005.

INVENTORS! Sell your invention for cash or royalties! Our client manufacturers eagerly seek new items. Patented. Unpatented. Financial assistance if needed. 25 years proven performance. For free information, write Dept. 25, Gilbert Adams, Invention Broker, 80 Wall St., New York, N.Y. 10005.

STAMPS

RUSSIA high-value collection. 32 different Russia—some over 50 years old! Commemoratives. Czarist Issues, Airmails, catalog price $2.50. Special get-acquainted offer—all for only 10¢! H. E. Harris, Dept. GG-54, Boston, Mass. 02117.

PINEAPPLE, mangoes, triangles, gorilla, Greenland, 25 others 10¢ Approvals. Lichvar, 11808 Princeton, Cleveland, Ohio 44105.

MAGAZINES

BACK DATE MAGAZINES! Send needs. Midtown, Box 917-EW, Maywood, N.J. 07607.

BUSINESS OPPORTUNITIES

FREE CATALOGS. Repair air conditioning, refrigeration. Tools, supplies, full instructions. Doolin, 2016 Canton, Dallas, Texas 75201.

I MADE $40,000.00 YEAR by mailorder! Helped others make money! Start with $10.00—Free proof. Torrey, Box 318-N, Ypsilanti, Mich. 48197.

JAPANESE Electronics New Products Monthly! Specimen copy $1, deductible. Dee, 10639-W Riverside, North Hollywood, Calif. 91602.

FREE BOOK "990 Successful Little-Known Businesses." Work home! Plymouth 345-M, Brooklyn, New York 11218.

CLASSIFIED ADVERTISING ORDER FORM

Please refer to heading on first page of this section for complete data concerning terms, frequency discounts, closing dates, etc.

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30
31	32	33	34	35

_____ Words { @ .50 Reader Rate / @ .85 Commercial Rate } = $_____

Insert _____ time(s) Total Enclosed $_____

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

SIGNATURE _____

WORD COUNT: Include name and address. Name of city (Des Moines) or of state (New York) counts as one word each. Zip Code numbers not counted. (Publisher reserves right to omit Zip Code if space does not permit.) Count each abbreviation, initial, single figure or group of figures or letters as a word. Symbols such as 35mm, COD, PO, AC, etc., count as one word. Hyphenated words count as two words. EW-1069

MAILORDER! How to prepare your own catalog for pennies . . . without merchandise investment! Free catalog! Obie, 5711-EO 14th, Brooklyn, New York 11219.

$75.00 THOUSAND, home addressing! Longhand. Typewriter. Information, send stamped self-addressed envelope. Brewster, Box 1348-SK, Clearwater, Florida 33517.

MUSICAL INSTRUMENTS

SWISS musical movements. Electrical, Mechanical. Spielman, 131 West 42nd, New York, N.Y. 10036.

RUBBER STAMPS

RUBBER ADDRESS STAMP $2.00. SIGNATURE $3.50. FREE CATALOG. JACKSON, BOX 443-G, FRANKLIN PARK, ILL. 60131.

MISCELLANEOUS

WINEMAKERS: Free illustrated catalog of yeasts, equipment. Semplex, Box 122-76, Minneapolis, Minn 55412.

COLLECT political campaign buttons. A fascinating hobby! Free 45 page photo list. Buttons, Etc., Box 1460W, Los Gatos, CA. 95030.

AS YOU SCAN THESE COLUMNS, more than 170,000 monthly buyers of **ELECTRONICS WORLD** are doing the same. These men are all Electronics Professionals—individuals involved actively in electronics from a business or hobby viewpoint—they are doubly interested in those advertisements which will enhance their careers or their leisure hours. They look to the pages of the **ELECTRONICS MARKET PLACE** for prime sources of products and services of interest to them. They will buy from you if your advertising appears regularly in their favorite magazine. Send copy and payment now using the handy order form printed in these columns. Or, if you want additional information write today to: Hal Cymes, Classified Advertising Manager, **ELECTRONICS WORLD,** One Park Avenue, New York, New York 10016. **REMEMBER:** December issue, on sale November 18th, closes October 1st.

ABOUT YOUR SUBSCRIPTION

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

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

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

ELECTRONICS WORLD OCTOBER 1969

ADVERTISERS INDEX

Printed in U.S.A.

It's easy to spot the new Musicaster IA. Look! Listen!

All that's left of the great old Musicaster* is the size and the mounting hardware. Everything else is changed — and it's all for the best.

Start with the silicone-treated weatherproof speaker. Changed from an 8″ to a 12″ Radax.* With smoother response, better bass, yet the same high efficiency and 30 watt power handling. Protected by a ¼″ Acoustifoam* weather barrier sandwiched behind the grille.

The enclosure is new, too. By using a one-piece glass-filled polyester housing, we saved two pounds overall, without reducing strength or utility. The peripheral ducted port combines with a fiberglass-filled interior to smooth and extend bass response.

And don't overlook the importance of good looks. The clean, contemporary lines of the new Musicaster will get you quick architectural approval where other uglier speakers would be banned out of sight.

The net effect is a great music speaker that also does full justice to voice. The ideal combination for so many of your multi-purpose sound installations. And the mounting bracket still doubles as a handle for portable use.

Finally, you can choose from two models, the basic Musicaster IA at $69.90 net, or the Musicaster IIA with horn-loaded T35B tweeter for extended highs and outstanding uniform polar response at only $88.50 net. Both cost a little less than the old Musicaster; but they give you much more to sell. Prove it to yourself today.

**Electro-Voice Trade Marks*

ELECTRO-VOICE, INC., Dept. 1096N
629 Cecil Street, Buchanan, Michigan 49107

Electro-Voice®

A SUBSIDIARY OF GULTON INDUSTRIES, INC.

FOR INFORMATION ON E-V PRODUCTS:

Microphones
CIRCLE NO. 111 ON READER SERVICE CARD

PA Speakers/Accessories
CIRCLE NO. 112 ON READER SERVICE CARD

Musician's speakers/microphones
CIRCLE NO. 113 ON READER SERVICE CARD

High Fidelity speakers/electronics
CIRCLE NO. 114 ON READER SERVICE CARD