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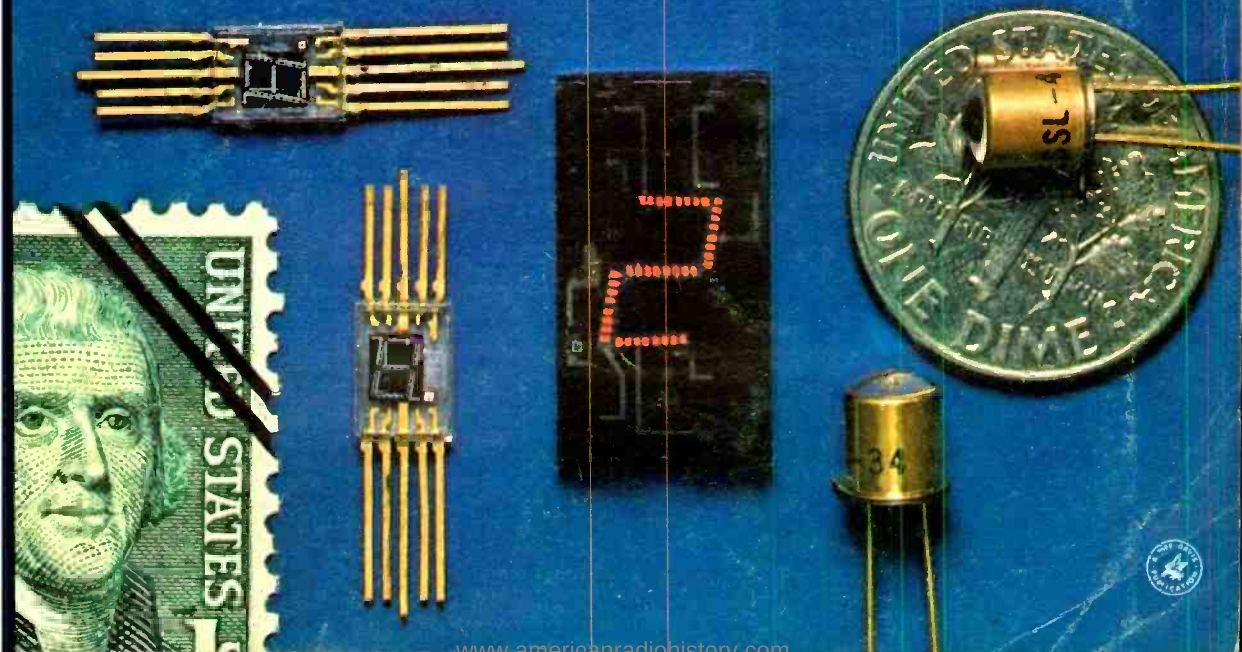

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VOLUME 33 NUMBER 5 **NOVEMBER 1970**

Popular Electronics

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DIRECT & CURRENT

Third in a Monthly Series by Oliver P. Ferrell, Editor

ABOUT READER MAIL

Several years ago, an associate proposed a unique solution to the problem of how to handle reader mail—never answer a single letter! Undoubtedly he was embittered by the seemingly endless flow of letters from POPULAR ELECTRONICS readers.

Trying to answer reader mail is admittedly a moral obligation for the magazine—especially in regard to published material. However, all readers may not be aware that, as much as the staff would like to help solve reader problems, it is frequently impossible. Permit me, on behalf of the staff, a moment to review the problem and explain why some inquiries go unanswered:

1 **Cost.** Answering the average inquiry costs more in manhours than the magazine recoups from a one-year subscription.

2 **Validity.** The average inquiry wants us to change into something else something that has already been published; frequently an incredibly complex redesign of the entire project.

3 **Out of Date.** An amazingly high percentage of inquiries deal with material published 3 to 10 years ago involving projects using components no longer available and lacking substitutions.

4 **Referrals.** The average inquiry is addressed to the author and an answer is expected over the author's signature. Only one out of 20 authors has the time and research facilities to answer reader inquiries; as much as he may appreciate the interest in his work.

5 **Volume.** Last year, POPULAR ELECTRONICS received an average of 900 letters and postcards each month that might be categorized as reader inquiries. (We are not referring here, of course, to the use of the Reader Service Pages.)

In one recent batch of mail, the inquiries included the following samples: design of a recording studio fader console; comparison of various CB transceivers; pleas for free subscriptions; detailed theoretical analysis for a Science Fair project; complaint about absence of Carl & Jerry series; 17 modifications of the "Mini-DVM", 9 requests for clarification of JK flip-flop article; plans for 14 different speaker enclosures; etc., etc.

The above skims the surface of the problem and is written to show that we are aware of the need for a quick advisory service. The staff attempts to answer as many inquiries as time will permit, but those answered are still a fraction of the incoming mail. Any suggestions?

INTERFACE

THE "NEW LOOK"—PRO AND CON

Congratulations! I had long ago decided that you people thought that your readers were either idiots, senile, or both. I am glad to see you doing articles more ambitious than how to add an S-meter to your radio. I especially like the idea of Hirsch-Houck Laboratories checking out all audio projects. One of my pet peeves has always been the very sketchy, incomplete or nonexistent specifications on preamps and power amps.

Double congratulations to Mr. Holt on the "Stereo Scene." I was beginning to think that I was the only person who considered most American-cut discs not worth buying. I long ago switched to EMI and London pressings. I had also dropped all of my audio-type magazine subscriptions since I was getting weary of reading "good buy" test reports for everything on the market.

R. T. TAYLOR
Lincolnton, N.C.

The new format is cold and seems to be a collection of news releases. Missing is the friendliness that we have known for so many years. The typography is excellent, but to this reader it is just plain cold type.

J. A. STAUHS, WA2BNF
Belleville, N.J.

The new "Product Gallery" makes more sense than reproduction of a lot of slick, insipid press releases from the pen of some brainless continuity writer. Go to it!

C. T. WEATHERFORD, JR.
Roscoe, N.Y.

The new cover design is sharp, but the editorial content is insipid! POPULAR ELECTRONICS has taken a posture much like the professional journals in electronics. If the September issue is an example of the plans for the future, your magazine is of no more use to me.

W. C. GANSCOE
Chicago, Ill.

I am pleased with the new look and format, especially the new "Communications" column and your regular column, "The Product Gallery." I feel that POPULAR ELECTRONICS is worth its weight in gold.

R. R. HALL
Madison, Tenn.

Changed format? Yeah, you've done that all right and apparently changed the po-

tential subscriber group since the entire issue says to me, "To hell with you stupid people, now all of us brilliant electronics M.A.'s and PhD's are going to communicate with all of our brilliant colleagues."

You *had* a good thing, and, like I said, you blew it!

R. B. Orford
Rochelle, Ill.

The "New Look" is great ! ! !

Jay Carpenter
Berryville, Va.

I must tell you that your "New Look" is a big disappointment. You have apparently decided to eye the well-padded pocketbook of the hobbyist with more money than know-how.

J. Feagans
Tallula, Ill.

To J. Gordon Holt: Welcome! Welcome! At last someone is saying the things I would like to say in the way I would like to say them. Bravo! Don't change a thing!

Jack O'Ryan
Northfield, Ohio

I have read and subscribed to Popular Electronics for years for two reasons, Hank Bennett's and Herb Brier's columns. Now you simply tell us non-builders to go jump in the lake.

Dr. C. Schwartzbard, WB2IWH
Clifton, N.J.

I congratulate you and your colleagues on the "New Look." I am especially pleased with your entry into the experimental areas of digital and computer equipment. I hope that your "Direct & Current" editorial series will occasionally wax philosophic and deal with the problems related to broadcasting, such as definition, establishments, recognition, maintenance, protection of rights, etc.

N. E. Andrews
Eastonton, N.J.

I have two complaints about your "New Look." First, I like the idea of more unique and sophisticated construction projects, but would like to see one or two simple ones tossed in from time to time.

Secondly, I would like to see Roger Legge's material put back in the magazine.

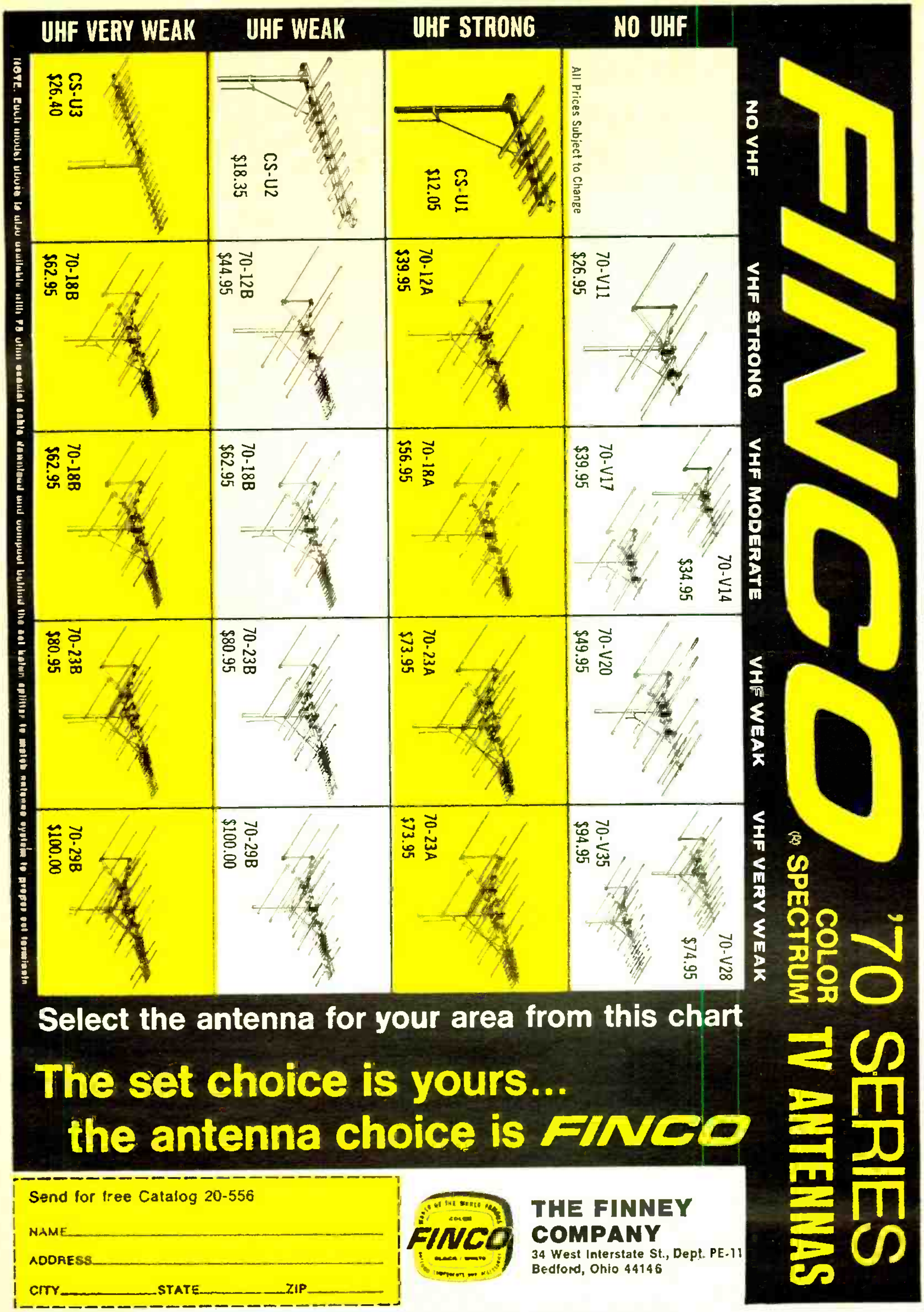
S. Karklin
Pepper Pike, Ohio

Just received your September issue and I'd just like you to know how much I enjoyed it. I was debating whether or not to continue my subscription after it ran out. Not only do I like the new format style, but also appreciate the new content.

D. R. Ward
Middlebury, Conn.

I thoroughly detest your "New Look" for it leaves no great interest to the beginning experimenter. I think you should devote at least one project article in each issue to the

(Continued on page 95)



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NEW LITERATURE

To obtain a copy of any of the catalogs or leaflets described below, fill in and mail the Reader Service blank on page 15.

A colorful, six-page brochure available from *Elpa Marketing Industries, Inc.*, covers the entire line of Thorens Transcription Turntables. Listed are the new TD-150 MKII and the full line of TD-125's. The brochure also lists the company's line of turntable bases, dust covers, mounting frames, tonearm mounting boards, and Thorens maintenance equipment. Each item is illustrated and explained.

Circle No. 75 on Reader Service Page 15

All *International Rectifier* semiconductor devices are presented in a new publication titled "Semiconductor Device Digest." The 20-page, full-color, illustrated "short form" Digest reflects International Rectifier's in-depth product capability. Devices listed include: SCR's, selenium rectifiers, zener regulators, power logic triacs, high-power silicon rectifiers, silicon rectifier assemblies, light-sensitive devices, etc. Each category of semiconductor devices is presented in compact tables and charts that give ratings, parameters, and other important specifications. An additional feature of the Digest is a complete alphanumeric cross-reference index of individual IR device numbers to the corresponding Digest page.

Circle No. 76 on Reader Service Page 15

A "Quick Delivery Identification" system, featuring a three-level popularity grading guide to automatically forecast the availability and required lead time for major component items, is highlighted in a new 36-page shortform catalog, No. 300B, published by *Ohmite Mfg. Co.* The components described in the catalog include resistors, rheostats/potentiometers, trimmer pots, tap switches, variable transformers, relays, solid-state power controls, r-f chokes and various design aids. The new identification system utilizes **bold**- and light-face type and parentheses to indicate product availability based on nationally exhibited usage patterns. Also available with the catalog is a copy of the "Manufacturer's Price Schedule," No. MS-100.

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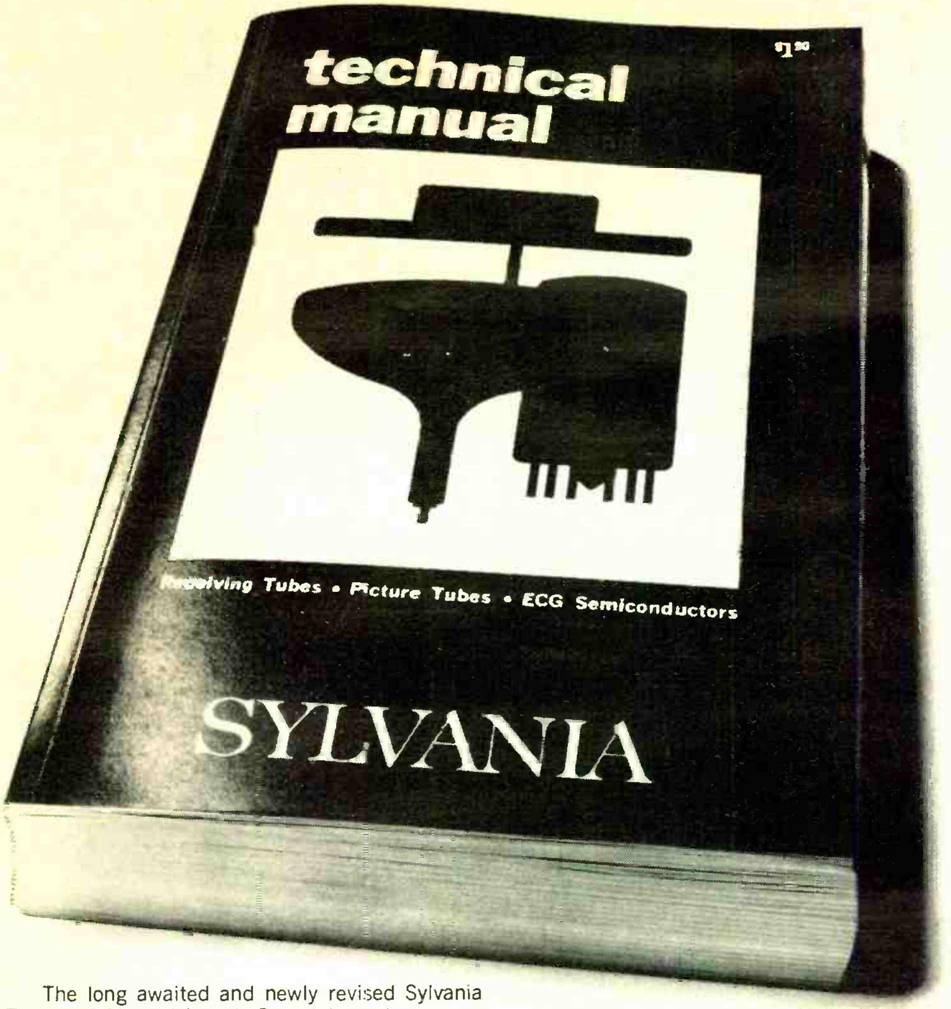

The long awaited and newly revised Sylvania Technical Manual is out. Complete and unexpurgated. The fantasy of every Independent Service Technician. Written anonymously by an agile team of Sylvania engineers. 32,000 components described in breathtaking detail. Including thousands of unretouched diagrams and illustrations. Discover the unspeakable thrill of new color TV Tubes, listed as never before. The ecstasy of 28,000 ECG Semiconductors.

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SEMICONDUCTOR PULSE CIRCUITS WITH EXPERIMENTS

by Brinton B. Mitchell

The technician must have a firm understanding of circuit theory no matter what his position. This book, then, provides the design, analysis, and synthesis information of basic pulse and switching circuits, introducing these circuits in their simplest forms. The text is organized into 20 chapters, each of which presents a typical basic circuit. Circuit discussions include such information as prerequisite theory, a design example, an analysis example, an experiment consisting of a design circuit problem or an analysis circuit problem, and questions covering the material. Throughout the book, the material is geared to a technician level with emphasis on the semiconductor active device as a switch.

Published by Holt, Rinehart and Winston, Inc., 383 Madison Ave., New York, NY 10017. Hard Cover. 379 pages. $10.50.

SERVICING MODERN HI-FI SYSTEMS

by Norman Crowhurst

This is a practical guide to repairing such hi-fi items as tuners, amplifiers, receivers, tape recorders, etc. The author developes a rational and logical method of trouble-shooting virtually any type of hi-fi equipment to find the cause of trouble. Beginning with an analysis of modern system design in comparison with older concepts, new servicing techniques required for solid-state devices, test equipment requirements, testing procedures for components, etc., are then introduced. To aid the technician who is constantly faced with a variety of component types, a chapter is devoted entirely to transistor and diode interchangeability. Also, to provide a thorough understanding of the causes of component failure, another chapter is devoted to protection circuits.

Published by TAB Books, Blue Ridge Summit, PA 17214. 224 pages. $7.95 hardbound; $4.95 soft cover.

ELEMENTS OF ELECTRONICS, Third Edition

by H.V. Hickey & W.M. Villines, Jr.

This is an ideal book for technician-level electronics survey courses with a communica-

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tions emphasis. In its Third Edition, it is one of the few books that provide detailed discussions of both tubes and transistors. One of the special features is the inclusion of a complete and self-contained chapter on the theory, use, and basic circuitry of computers, representing possibly the first time computers have ever been dealt with in an introductory-level textbook. And integrated circuits are explained and detailed coverage is given to thin-film and semiconductor techniques.

Published by McGraw-Hill Book Co., 330 West 42 St., New York, NY 10036. Hard cover. 709 pages. $11.95.

FILTER SYSTEMS AND DESIGN: ELECTRICAL, MICROWAVE, AND DIGITAL

by Yale Jay Lubkin

Using an informal but basically thorough approach, this book is written to extend the working engineer's knowledge of electrical filters and to provide him with tools he can use immediately. The text presents the fundamental concepts of filters; why and how the various kinds originated; what types of problems they solve; and filter limitations. Some of the concepts developed in this book have never before appeared in print, and, while they are rather advanced in nature, they are nevertheless presented in an understandable manner. Aimed at the engineer with curiosity, a job to do, and not much time in which to do it, the book requires little math sophistication. This book is also suitable for senior and graduate level courses on filter theory or as a supplementary text in courses on network analysis.

Published by Addison-Wesley Publishing Co., Inc., Reading, MA 01867. Hard cover. 212 pages. $11.50.

THE PHYSICS OF TRANSMISSION LINES AT HIGH AND VERY HIGH FREQUENCIES, Volume 1

by P. Grivet

From the scientific point of view, a transmission line is an unusual structure in which a variety of seemingly contradictory qualities are united. It is especially valuable as a model because it forms a simple, general example in which travelling, standing, pure, and attenuated waves can all be treated clearly and thoroughly using both circuits and field theory. Although these two dissimilar theories are often regarded as antagonistic, the author believes that a harmonious and fruitful association between them is desirable. His general approach in this book is in terms of circuit theory, but he takes care to show the links with field theory. This book will aid physicists, microwave engineers, and electronics engineers who want familiarization with new elements of circuit theory.

Published by Academic Press, Inc., 111 Fifth Ave., New York, NY 10003. Hard cover. 451 pages. $22.50.

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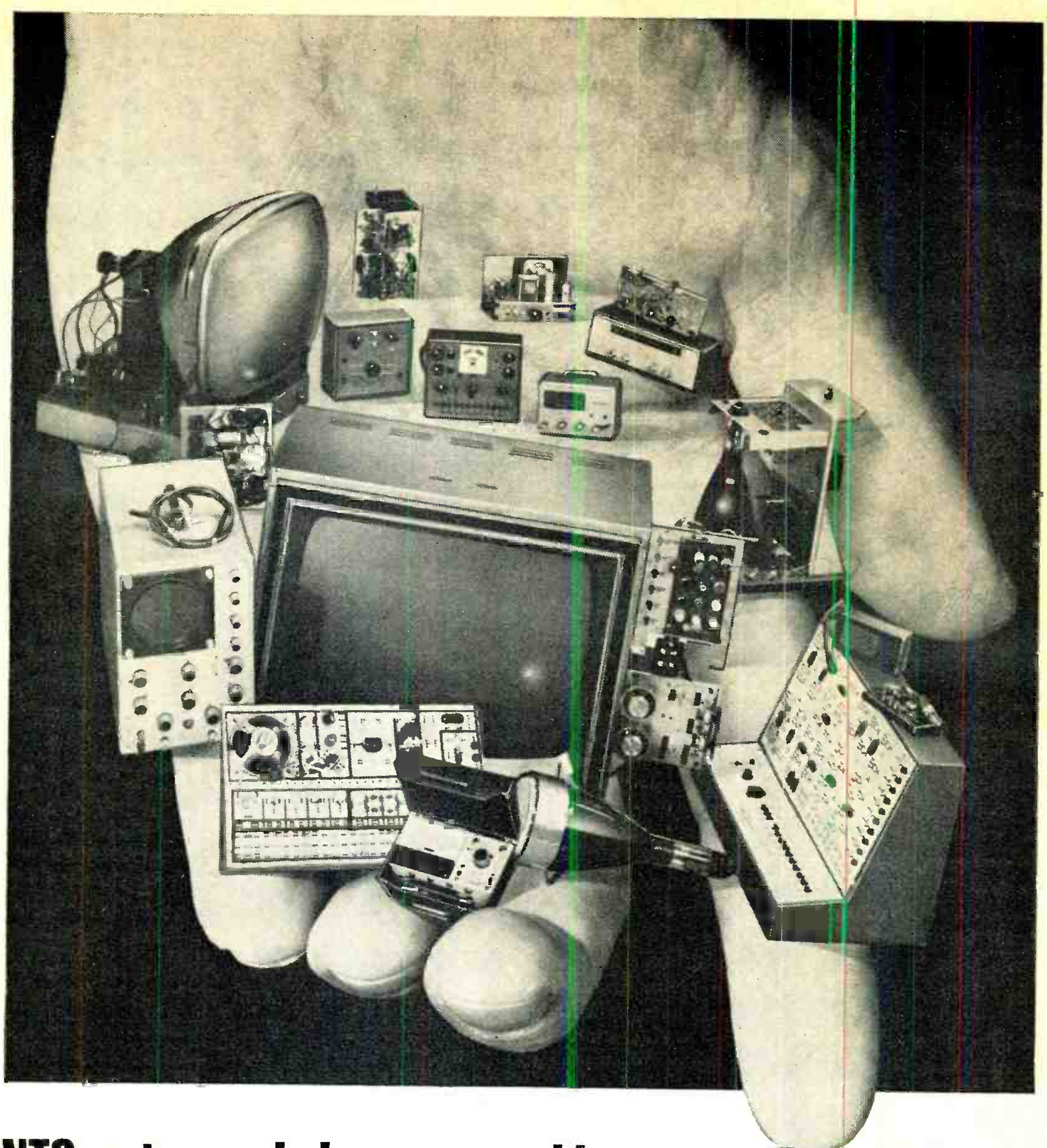

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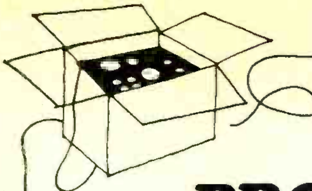
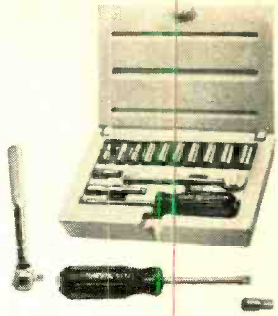


NEW PRODUCTS

Additional information on products described in this section is available from the manufacturers. Each new product is identified by a corresponding number on the Reader Service Page. To obtain additional information on any of them, circle the number on the Reader Service Page, fill in your name and address, and mail it in accordance with the instructions.

XCELITE SOCKET WRENCH SET—An interesting and quite useful innovation in socket wrenches is a new set from *Xcelite Inc.,* in which a plastic-handled nutdriver can also be used as an extension for a reversible ratcheting handle. The ratchet handle (with a fully enclosed mechanism) fits into a socket on top of the plastic driver. A conventional 2″ extension fits on the ratchet on either end of the spinner/extension so that the reach of the assembled components can be varied from 1½″ to 9¼″. Nine sockets have hex sizes from 3/16″ through ½″. Two dual-purpose sockets, with openings of ¼″ and 5/16″ fit both square and hex nuts, bolts, pipe plugs, etc. The No. 1001 set comes in a snap-lock molded plastic case.

Circle No. 78 on Reader Service Page 15

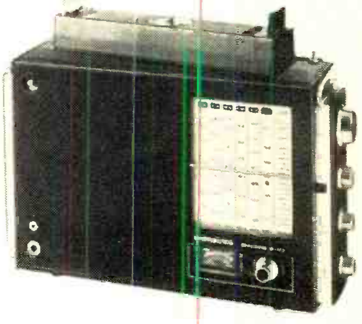


TANDBERG STEREO TAPE DECK—For those who want a quality tape recorder but are willing to forego some of the frills and doodads to get it at a moderate price, *Tandberg of America, Inc.* has introduced a new Model 3000X. With four heads (record, playback, erase, and crossfield), it operates at 1⅞, 3¾ or 7½ in/s. For the highest speed, the frequency response is 40 to 20,000 Hz ±2 dB, and wow and flutter are better than 0.07% rms. Crosstalk attenuation at 1000 Hz, stereo, is 50 dB. The crossfield system uses a separate bias head that thoroughly magnetizes and reduces the on-tape recording zone as well as wavelength dependability losses in the function.

Circle No. 79 on Reader Service Page 15

UNIMETRICS MULTI-BAND RECEIVER—For the boatman, hunter, or pilot trying to home in on a signal, the Omniband-VI, made by *Unimetrics, Inc.,* has a 180° rotating radio directional finder antenna. The solid-state receiver has six bands: 180-380 kHz (longwave); 540-1600 kHz (standard AM); 1.6-4.0 MHz (AM marine); 88-108 MHz (standard FM); 108-136 MHz (VHF/AM aircraft); 147-174 MHz (VHF/FM marine, weather, public service, etc.). Variable squelch, battery/ac power, 4″ speaker, and battery strength indicator are also included.

Circle No. 80 on Reader Service Page 15



BITRAN DIGITAL READOUTS—Ready-to-use seven-segment digital readout devices from *Bitran* are available with 2 through 8 digits as well as several special symbols. Model 400 readouts have one side of each lamp common and the other terminated at printed circuit board. Model 500 includes the RCA CD2503E decoder drivers which re-

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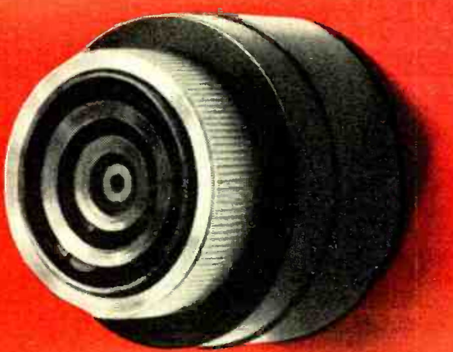

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CAN INFRARED OR LASERS FIND CLEAR AIR TURBULENCES?

Everyone associated with flying—including the passengers—expects and knows how to avoid air turbulences associated with changes in barometric pressures such as storm centers. Most such disturbances are accompanied by clouds and are visible. Not so with other turbulences which have plagued air travel for years and for which some sort of solution is only now beginning to appear.

LATE IN WORLD WAR II when first frequently reported by military fliers, jet streams were dismissed by ground-based meteorologists as delusions. Earlier, "air pockets" that aviators of the 1940's said they hit had been chalked up to over-active imaginations.

Now clear air turbulence, or CAT, has mushroomed into the world spotlight. It's definitely linked with jet streams, lee waves created by mountain ranges, and other still-mysterious kinds of turbulence. Even the basic concept of the "air pocket" has been revived—with its label changed to "microcosmic atmospheric cell."

Government agencies, private industry, and research organizations are all trying to zero in on CAT.

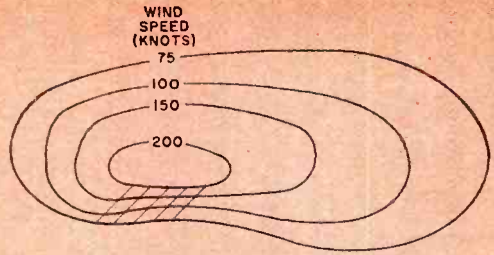
Just what is this unseen phenomenon that bears a feline title?

In December, 1966, the U.S. Department of Commerce brought together a National Committee for Clear Air Turbulence. Meteorologists, pilots, physicists, and safety officials immediately found they didn't even agree on a definition of their target. From their parley came an official description: CAT consists of "all turbulence in the free atmosphere of interest in aerospace operations that is not in or adjacent to visible convective activity."

Less precise but more vivid descriptions come from veteran pilots who have had several bouts with severe CAT. One describes the encounter as "like having a pneumatic jack hammer work on your plane." Another says that a jet in the paws of CAT reacts like a car roaring over a cobblestone street at high speed.

Many but not all occurrences of CAT stem from interaction of two different kinds of wind shear. One is horizontal—caused by friction between masses of air moving side by

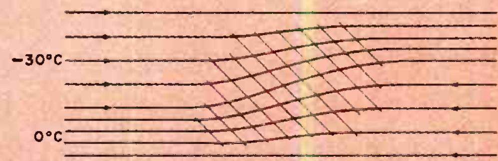
BY WEBB GARRISON



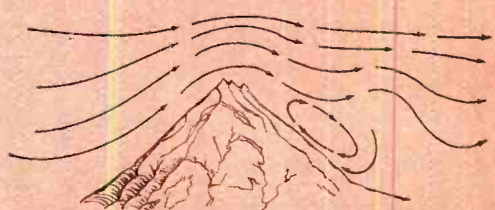
At left is a cross section of the jet stream where different layers of air move in the same direction but at different speeds. Greatest turbulences occur where the layers are close together.

Disturbances occur if two air streams of different temperature and velocity are flowing in different directions, one above the other, such as slow westerlies near ground under jet stream.

THREE KINDS OF CAT



Favorite spot for CAT to hide is on the lee side of mountain ranges. Thus they may be found, for instance, up and down Atlantic Coast, east of Appalachians, and east of Rockies where plains begin.



side at different speeds. The other is vertical and is created by friction between two air masses (again moving at different speeds) that flow in relatively distinct levels, one above the other.

When first recognized to be real rather than imaginary, CAT was thought to be met at altitudes between 20,000 and 40,000 feet. Now it is known to be found as low as 6,000 feet and as high as 80,000.

New interest in it stems partly from the fact that more sophisticated instruments are just now beginning to show how deadly it can be. As late as 1964, it was suspected of having caused some spectacular crashes but had not been convicted. Last year CAT was implicated in at least eleven crashes by civilian planes. Its most formidable threat to military craft is linked with air-to-air refueling operations.

Costly programs aimed at detecting CAT and discovering what forces produce it, and why, aren't based on the relatively few crashes it now causes, however. More and more small planes are being flown by private individuals and corporations. These craft are particularly vulnerable to sudden assaults by CAT.

There's every indication that the supersonic transport (SST) will also be vulnerable in ways different in degree and kind from today's planes. Rapid cycles of vibration are likely to be set up in the SST by choppy jolts and severe lateral gusts that would simply buffet a B-52. Supersonic transports will be especially likely to encounter CAT during climb and descent—roughly 20% of the flight profile. Structural failure can result unless stresses associated with CAT are fully understood and taken into consideration by designers.

As a result the CAT which never purrs has become the subject of an all-out search. Answers are being sought to questions on subjects ranging from the nature of atmospheric energy exchanges to the optimum wavelength at which to capture radiation emitted by CO_2.

Lacking the hardware produced by today's electronic technology, neither the quest for basic understanding of CAT nor attempts to detect it quickly and accurately could be undertaken.

Radar Tried First. Before the existence of CAT as a special meteorological phenomenon was positively established, some searchers tried to locate it with radar. Their efforts were futile.

A break came in 1962. RCA technicians tracking missiles with C-band radar sets operating above 5,000 MHz noticed that they were getting substantial backscatter on some days when skies were clear. Could these unexpected echoes point to areas where CAT is found?

Working with U.S. Army meteorologists at Fort Monmouth, N.J., engineers added a low-noise amplifier to their radar. Early results made them jubilant; a clear, rapidly changing line on radarscopes seemed to mark the tracks of the CAT.

A press release of this era gloated that "Once they are certain they have cornered CAT, avoiding its dangerous attack will be a simple matter for the careful pilot."

In practice, it has proved to be anything but simple. Part of the difficulty lies in the size of the zone in which CAT hides. It's likely to be 400 to 500 miles long, more than 100 miles wide and two or three miles thick. A typical CAT region, on the other hand, is minute in global terms. It is seldom more than 50 to 100 miles long, 10 to 20 miles wide, and a mere 1,500 to 2,000 feet thick.

Ground-based radars such as the ultra-sensitive ones at Wallops Island, Virginia, do pick up clear-air echoes. Such echoes presumably stem from scattering caused by variations in the refractive index and hence point to atmospheric levels associated with CAT.

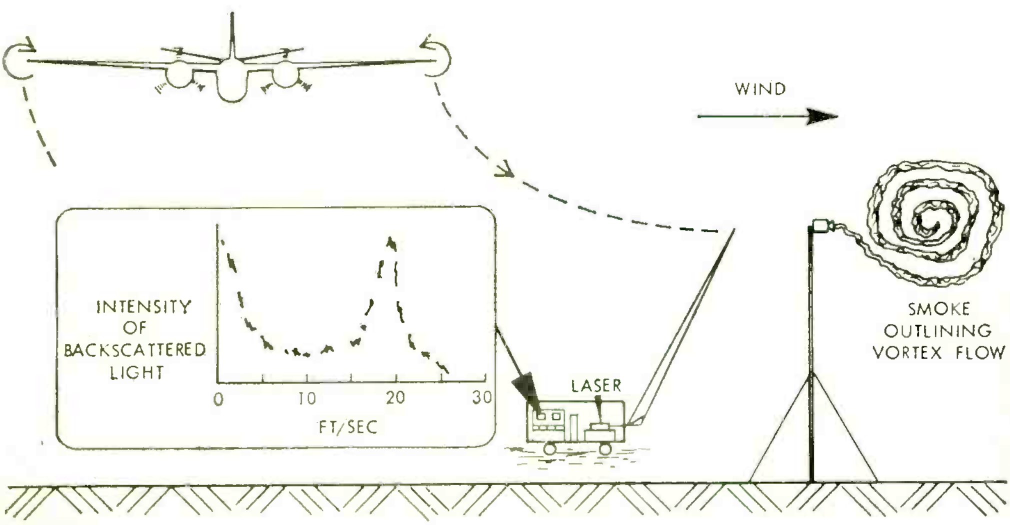
A world-wide network of radar facilities equal to or better than those on Wallops Island would be necessary for ground-based remote detection of CAT. Even if such a network were available, computer systems with which to retrieve data in time to warn a jet pilot are far in the future. Radar's chief contribution will probably be in the area of basic understanding of CAT rather than location of turbulent areas.

This spring at the National Center for Atmospheric Research, Boulder, Colorado, fine metal chaff was dropped into the path of winds blowing over the mountains. Two Doppler radars, pointed into turbulent areas at different angles, were used to gain data. Physicist Roger Lhermitte hopes eventually to build up a three-dimensional picture of the dynamic structure of the atmosphere in target areas studied.

Outcome of the trial won't be known until all the data have been analyzed. If Lhermitte and his colleagues succeed in finding just how a turbulent area reacts, groundwork for more precise detection will have been laid.

Air-borne radar has proved useless in the search for CAT. No matter how violent its currents may be, clear air includes no solids of sufficient size to register on sets small enough to be mounted in aircraft.

Thermal Sensors Employed. Many rapidly moving air currents, including the jet streams, vary from the temperature of sur-



Schematic diagram of the laser doppler technique used for remote measurement of wind velocity; trailing vortex detection experiment. Varying wind velocities are one of the chief causes of CAT. (NASA diagram.)

rounding air masses by a few degrees. At least in theory, air-borne infrared sensors should pinpoint such differences—effectively subduing CAT.

North American Aviation and Barnes Engineering Company have tossed their hats in the ring in a race to develop a workable thermal sensor. Both companies had prototype systems in operation by 1967.

Electronics engineer Edward Flint of North American developed a compact infrared sensor suitable for mounting on top of a plane. Capable of scanning 45° on each side of the flight path, the instrument could detect temperature variations of less than one degree Fahrenheit in atmospheric carbon dioxide 20 to 40 miles away.

Using a Canadian T-33 jet trainer, Barnes flight-tested an instrument that used a thermistor bolometer as the sensing element. Scanning was accomplished by means of the rocking etalon assembly of a Fabry-Perot spectrometer.

Both devices worked—up to a point. Each revealed changes of temperature within distant air masses. Neither came anywhere near the then-desired range of 25 miles. Both suffered from a defect that hasn't yet been overcome: the infrared signal is passive. That is, it conveys no information about intensity of turbulence or size of the area affected. Greatly refined and recently patented, the Barnes instrument has logged enough hours on Pan Am and other commercial planes to demonstrate that it can be of great help to pilots.

Stable data were first obtained in May, 1969. That month the Barnes IRCAT was used on two long-distance flights: PA72 from New York to Frankfurt on the 20th; PA ONE from London to New York on the 29th.

In the joint program between Barnes and Pan Am, the approach utilized has been the straight horizontal forward look in the 15-micron CO_2 band of the infrared region at a volume of air ahead of the aircraft. Very recent findings indicate that a "two color" system tuned in to both CO_2 and O_3 would probably give more accurate information about defamation of the tropopause by vertical air mass movement. Before such a system can be put to test, additional new instrumentation will be required.

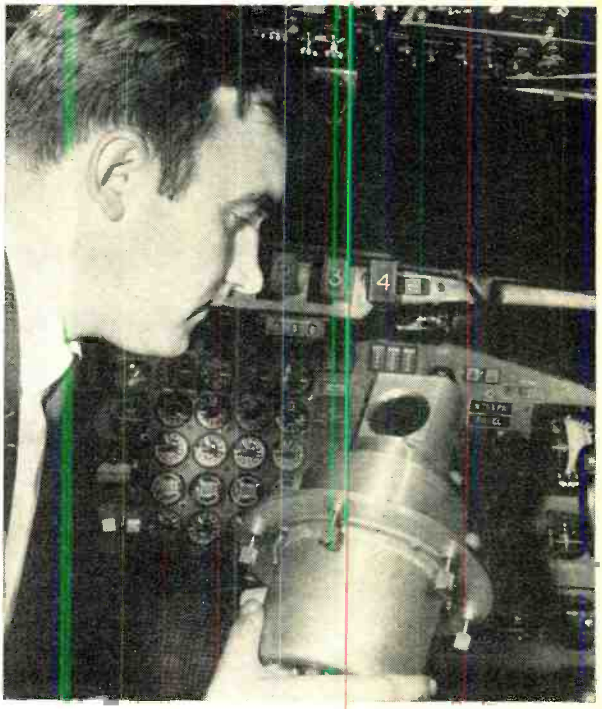
Range of the best detectors being used at present is far short of that required for an SST cruising at 2000 mph.

New Role for Laser. Some pioneer searchers for CAT deliberately rejected attempts at detection by means of temperature variations. They set out, instead, to find ways by which atmospheric discontinuities may be directly observed. Laser radar, now commonly called lidar (LIght Detection And Ranging) seemed to offer intriguing possibilities.

At Stanford Research Institute, M. G. H. Ligda developed pulsed-ruby-laser radar especially for atmospheric research. His system didn't perform as expected, so the Navy awarded Stanford a contract for a more complex one that employed four-headed lidar.

From this instrument and its successors, NASA's Marshall Space Flight Center moved to a laser-Doppler technique. Small particles that are caught up in a turbulent air mass create a Doppler effect by which the frequency of scattered light is shifted a trifle before it returns to a receiver.

At Marshall, physicist Robert M. Huffaker has developed an optical Doppler system which he says has proved itself in feasibility studies. He hopes to have an airborne version in operation early in 1971. The system operates on much the same principle as conventional Doppler radar. Instead of radio frequency, however, it employs a coherent



Sensing head of the Barnes infrared system for spotting CAT in cockpit of a Pan-Am Boeing 707.

Infrared sensor of the Barnes IRCAT is mounted on the top of Pan-Am plane to spot CAT. So far data gathered looks good.

pulse from a carbon dioxide laser. As a result, the resolution of the instrument is about 10,000 times better than that of today's conventional Doppler radar on aircraft. Radiation employed is at 10.6 microns—out of the visible spectrum.

Most other laser systems aimed at CAT detection have been dismissed, says Huffaker, because they "just would not work." He expects to find the CO_2 laser-Doppler far more effective than "passive" systems that seek to infer turbulence from an indirect measurement such as temperature or intensity of back scattered light.

Low-frequency infrasonic waves, created when energy is released into air by various causes, is used by General Telephone & Electronics and Washington State U. to get data that will find CAT.

Error-producing Factors. Past experience suggests the possibility or even probability that the latest device aimed at trapping CAT will run into unexpected complicating factors. That has been the case with all equipment produced so far.

At first it was hoped that CAT could be trapped by means of conventional instruments used to measure velocity of ordinary kinds of wind. This approach proved vastly oversimplified: instruments distorted the flow to such an extent that interpretation of results was uncertain even after a plane had passed through CAT in search of data.

Radiosonde networks, extremely useful in many branches of meteorology, proved ineffective with CAT. Because this kind of turbulence is essentially a small-scale phenomenon, it usually eludes the wide-meshed radiosonde network.

Even jet streams have proved uncooperative. Early tests with a heavily instrumented T-33 were scheduled to take place from a base in Alberta, Canada. High-altitude streams are commonly found at this latitude in mid-autumn. However, operations had to be shifted to California because the jet stream abruptly changed its course.

Radiometric detection, the most promising technique that has been flight-tested, has its problems, too. Unless temperature inversions are tilted with respect to the sensor, it usually fails to respond to them. Cumulonimbus clouds render present models of the IRCAT blind.

A great many false alarms, some of them produced by exhausts of jets that were miles away, indicated to Barnes engineers that they were using a wavelength too far away from the center of absorption of CO_2. Now the chosen wavelength is centered at approximately 14.1 microns. This increases attenuation and minimizes detection of phenomena not associated with turbulence—but also shortens the range of the instrument.

Early tests of North American Autonetics' system (infrared) produced a great many false readings. Examination showed that some of them were produced by bodies of insects that splattered on the sensor window during climb and descent.

A relatively small mass of air whose temperature differs from that of air around it may not be sensed by the best infrared equipment now available. That's because the instrument integrates contributions from a volume of air thirty to forty miles ahead of the plane rather than measuring temperature at a given distance. When positive and negative contributions cancel one another, IRCAT can't spot microscale disturbances that are linked with CAT.

Even sharp pitching or banking so that infrared sensors looked toward the ground produced a high percentage of false alarms in early tests. This factor has been largely controlled by use of an automatic deactivation circuit that operates from aircraft attitude gyro signals. After four or five "generations" of refinement, even the best infrared detectors do not meet needs expected to become increasingly urgent as planes become faster.

Single Solution Unlikely. No one is absolutely sure that the shock wave ahead of an SST won't destroy the coherence of a laser beam. Growing evidence suggests that even if the laser-Doppler instrument now in development performs as well in flight as in wind tunnels, it probably won't defeat CAT singlehandedly.

Until that instrument or others on the drawing board are operational, the general consensus is that the Barnes IRCAT remains the most effective detector available. Though it can perform as a remote sensor when clear conditions exist along the flight path, it too has limitations.

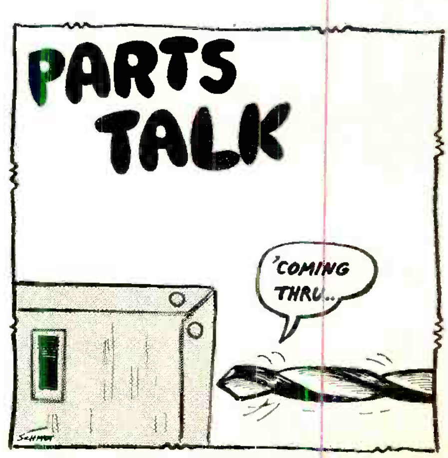
Presently, even IRCAT doesn't give navigators a clear picture of how far ahead temperature-linked turbulence is—or how severe it may be. Clouds and haze reduce the optical path length of the IRCAT and cut its range of detection. Under hazy conditions produced by ice the range becomes very short.

To make things worse, CAT probably isn't universally linked with temperature gradients. Atmospheric electrical phenomena, still largely shrouded in mystery, may be associated with many turbulent areas too clear for detection by air-borne radar.

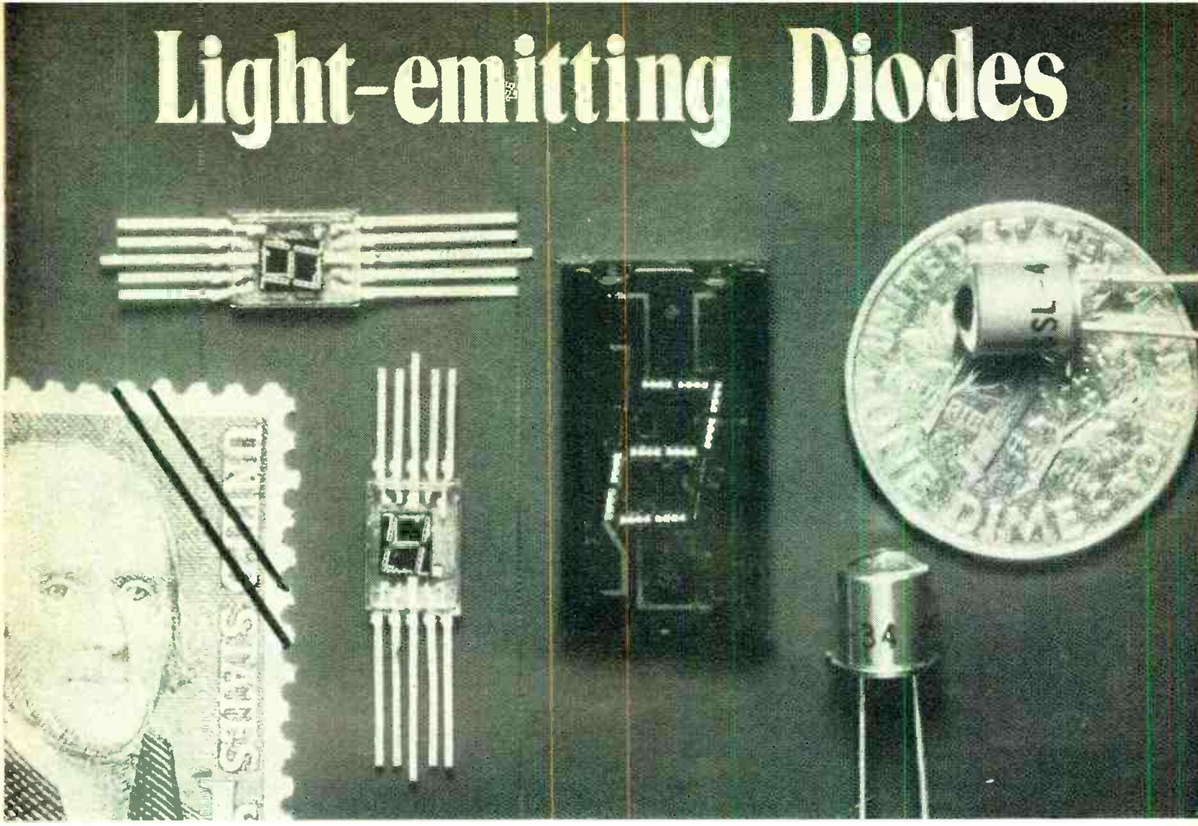
Australian scientists have suggested (but haven't conclusively demonstrated) that, when CAT occurs in a thermally stable environment, gravity waves or Helmholtz waves somehow break down into random turbulent eddies. No detectors now in use are designed to pinpoint energy changes of this sort.

Inflight remote detectors, regardless of type, will probably have to be supplemented by ground-based CAT detectors. Bigger and bigger information networks will have to be developed. Ultimately, a global system continually receiving and rapidly processing data from great numbers of satellite-borne CAT detectors may become essential.

Some of these things are far in the future. But by refining and combining a variety of systems, experts in government and industry hope for a major break-through in the 70's. When it comes, small private craft and big supersonic ones will receive warnings in time to avoid the CAT that strikes from its invisible lair. —30—



Light-emitting Diodes



NEW SEMICONDUCTORS FOR READOUT AND COMMUNICATION

One of the least known but most fascinating of semiconductor devices is the light-emitting diode (LED). Until quite recently, these devices were too expensive for widespread use; however, technological advances in their fabrication now make possible moderately low prices so that they are attractive to the electronics experimenter.

The first recorded instance of light being generated by a "diode" was in 1907 when H. J. Round touched a pair of battery wires to a crystal of silicon carbide. Much to his surprise, flashes of yellow light were emitted at the contact region of one of the battery wires—he had accidentally discovered the LED. Unfortunately, his discovery was forgotten and not until the early 1950's did scientists once again study semiconductor light emission. At that time several patents were applied for covering LED's made from silicon or germanium—common semiconductor materials. One of these patents not only described the principle of the LED but listed several fascinating uses for the device. Among them were light-beam communication systems, light "radar", and light-beam alignment devices.

Unlike the 1907 silicon carbide cat whisker diode, the 1950's LED's emitted infrared light (see Fig. 1). The invisible beam was desirable but researchers began a concentrated effort to fabricate LED's in the visible range. The first company to market any kind of LED was Texas Instruments, Inc. Their diodes included infrared emitters made from gallium arsenide (GaAs) and visible emitters made of gallium arsenide phosphide (GaAsP). These diodes were expensive; but their appearance on the commercial market in 1962 whetted the appetites of design engineers—and of course was of great interest to other semiconductor manufacturers. While scientists at IBM and Bell Telephone performed basic research on the devices (especially visible emitters), General Electric, Monsanto, Electro-Nuclear Labora-

COVER STORY BY FORREST M. MIMS, III

"He's a good worker. I'd promote him right now if he had more education in electronics."

Could they be talking about you?

You'll miss a lot of opportunities if you try to get along in the electronics industry without an advanced education. Many doors will be closed to you, and no amount of hard work will open them.

But you can build a rewarding career if you supplement your experience with specialized knowledge of one of the key areas of electronics. As a specialist, you will enjoy security, excellent pay, and the kind of future you want for yourself and your family.

Going back to school isn't easy for a man with a full-time job and family obligations. But CREI Home Study Programs make it possible for you to get the additional education you need without attending classes. You study at home, at your own pace, on your own schedule. You study with the assurance that what you learn can be applied to the job immediately.

CREI Programs cover all important areas of electronics including communications, radar and sonar, even missile and spacecraft guidance. You're sure to find a program that fits your career objectives.

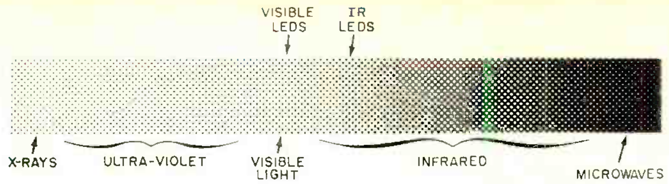


Fig. 1. Most infrared LED's emit light at a wavelength of about 0.9 microns of the electromagnetic spectrum. Visible LED's may emit from 0.53 microns to the limit of visible region at about 0.75 microns.

tories and others began competing with TI.

Since the LED has an almost unlimited lifetime and because of its low operating current, many claims were made for its potential in flat screen television, indicator lamps, night lights, and even as a source of room lighting. The extremely fast modulation capability of the LED made possible several demonstrations of voice communications permitting two parties to converse over a beam of invisible infrared light for clear weather distances of several miles.

How Does It Do It? The LED is different from conventional incandescent lamps because the latter give off light as a byproduct of heat. That is, the filament must first be heated to incandescence before light is produced. This, of course, is the reason for placing incandescent filaments in evacuated or gas-filled glass bulbs. If the filament were exposed to oxygen, it would quickly be consumed. Not so with LED's; they operate with or without the presence of air. In fact, the main reason LED's are placed in containers is to protect the rather delicate contact wires. Often, in fact, the LED is simply protected by a layer of clear epoxy which serves both as a protective cover and a lens. Since the LED produces far more light than heat, it is a more efficient source of light than the incandescent lamp.

Production of light by an LED comes under the broad heading of "electro-luminescence." Luminescence describes light produced by means other than incandescence. Since luminescing bodies are generally at the temperature of their environment, they are sometimes referred to as sources of "cold light." Fireflies, many species of fish, rotting wood, marsh gas, and many other objects are sources of luminescent light.

Light from an LED is the result of stimulation by a small electric current. As is the case with all luminescent bodies, the light is a result of sub-atomic events. The cause of these events may be chemical, as with the firefly, or electrical as with the LED.

Light Generation. In the LED, emission of light is called "pn junction luminescence." As shown in Fig. 2, light is emitted at the junction of an LED when electrons which have been stimulated to higher than normal energy levels move across the junction and fall back into their normal places. The energy loss resulting when an electron reoccupies its normal slot in an atom is accompanied by the emission of a photon of light at a wavelength related to the difference in energy between the two bands. Since junction luminescence involves the combination of electrons with holes, physicists often refer to the effect as "recombination radiation."

The sub-atomic physics of semiconductor light emission can be highly efficient. But the mechanisms of bringing the light to the sur-

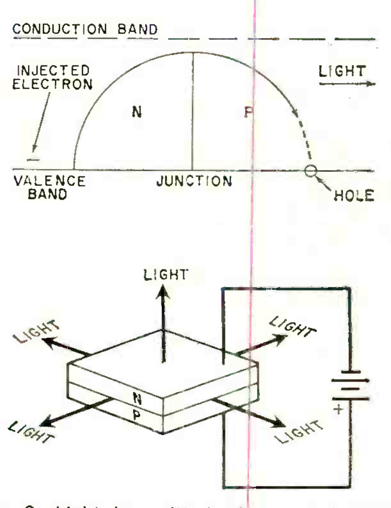


Fig. 2. Light is emitted when an electron crosses the np junction interface and falls from the excited to the unexcited state.

face and the application of electrical current to the diode can be terribly inefficient. Sources of inefficiency are:

1. Internal absorption of light within the p or n region of the semiconductor following its emission at the junction.

2. Reabsorption of light which is reflected back into the diode due to the "critical interface" problem.

3. Resistance at the electrical contacts and in the semiconductor.

Many of these inefficiencies have been partially resolved as a result of years of research. Consider, for example, the critical interface problem. Since most semiconductors have a high index of refraction, they tend to reflect light at air-semiconductor interfaces. The effect is similar to that of an observer looking through a glass window and seeing his own reflection as well as objects on the other side of the window. The effect results in the loss of light that is generated at the junction.

An ingenious solution to the problem was suggested by early research and was first used commercially by Texas Instruments. It consists of forming the light emitting region of the diode into a dome. Since the light is only bent and not reflected back into the diode, all light reaching the surface is emitted (see Fig. 3). Unfortunately, the dome approach does have its drawbacks—the longer path that the light must travel before being emitted causes more internal absorption than in planar emitters. Also, grinding domed diodes is an expensive process.

In an effort to gain the benefits of both planar and domed diodes, many manufacturers now coat planar diodes with a transparent dome of epoxy which essentially serves the same purpose of the semiconductor dome.

PHYSICS OF LIGHT EMITTING DIODES

Modern atomic physics tells us that electrons within the confines of a particular atom are allowed to occupy only discrete energy levels or bands. Energy levels between the outer two bands, the valence and conduction bands, are separated by a region called the forbidden gap. Under special conditions of doping, an electron may occupy one or more levels within the forbidden gap for relatively brief periods of time. The forbidden gap plays an important role in semiconductor light emission, since transitions from the conduction to the valence band provide the mechanism for photon generation.

An efficient way to cause transitions between the valence and conduction bands is to pump or inject electrons into the n region of a semiconductor diode. If a sufficient number of electrons is injected, the potential barrier at the junction of the n and p regions will be overcome and current will flow through the diode. Having crossed the junction barrier, the injected electrons seek their equilibrium point and drop from their excited position in the conduction band to the valence band. In essence, the electrons drop into holes or regions in a band where there is an electron deficiency.

The act of electrons combining with holes is called recombination and results in the magic of pn junction electroluminescence or light emission. An electron falling from a high to a low level releases the energy which propelled it over the junction as heat, light, or some of each. Heat emission is accompanied by vibrations in the crystal lattice and if left uncontrolled, results in thermal destruction of the diode. Heat emission predominates in indirect band gap semiconductors such as silicon and germanium. The forbidden gap in such materials permits an electron falling from the conduction to the valence band to loiter briefly at one or more levels. Transitions between the various levels in the forbidden gap may result in either light or heat emission.

It is interesting to note that an ordinary silicon or germanium diode emits a minute quantity of infrared light when forward biased. However, light emission in such diodes is far less efficient than heat production and development of practical semiconductor light emitters followed research with direct band-gap materials.

Gallium arsenide GaAs is normally a direct band-gap material. Since electrons injected into a GaAs diode recombine with holes without pausing at intermediate levels within the forbidden gap, light emission is very efficient and production of heat is generally limited to contact resistance and bulk absorption of some of the emitted light within the semiconductor.

GaAs diodes are so efficient as light emitters that scientists chose them as candidates for early work concerning the feasibility of fabricating semiconductor lasers. In the fall of 1962, researchers at G.E., IBM, and MIT announced almost simultaneously lasers made from specially prepared GaAs diodes. In a future issue of POPULAR ELECTRONICS, the operating principles and characteristics of the diode laser will be described.

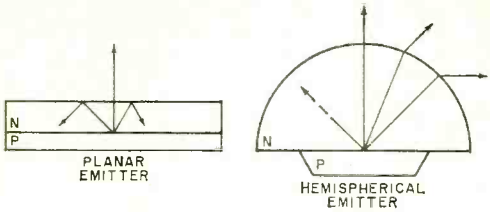


Fig. 3. The critical interface problem. Much more light is emitted by hemispheric diode but some is lost in the thick n-region. Some planar emitters are provided with a reflector to give greater light output.

How Are They Made? As mentioned earlier, the LED usually consists of a pn junction of one type of semiconductor, the most common being gallium arsenide. A typical diode may consist of a small wafer of positively charged (p) material in intimate electrical contact with a metal header similar to a transistor case. Before it is mounted on the header, the wafer is given a thin top layer of negatively charged (n) GaAs by either diffusion or epitaxial growth. The p portion of the finished wafer is connected to one of the wire leads of the header, resulting in a true pn junction diode.

To collect the light output from the wafer in an efficient manner, a metal can with a lens or flat window at one end is welded to the header. The can also serves as protection (see Fig. 4).

How Are They Used? Now that we know something about the history, physics, and mechanical construction of the LED, what are its applications other than those found in the lab-

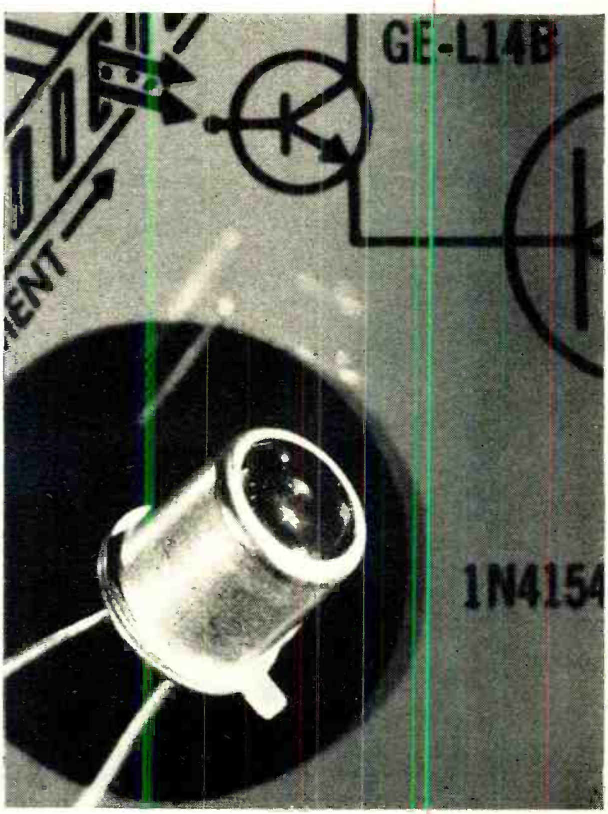


Fig. 4. In practical applications, the LED is mounted within a metal enclosure, similar to a transistor, for mechanical protection. A transparent window permits the light to exit from one end of the enclosure.

oratory? Especially, how can the experimenter use these tiny sources of "cold light."

An important military use of the LED is as a covert source of illumination for night vision devices. The usefulness of the Army's starlight scope is greatly enhanced by invisible infrared illumination supplied by one or more LED's. Another military use is in covert communications. The Navy, for example, has several types of infrared, line-of-sight LED voice communicators for ship-to-ship and ship-to-shore.

Recently, commercial applications of the LED have been revealed at an unprecedented rate. Several companies are mass producing tiny alpha-numeric displays consisting of arrays of LED's. These displays operate at a much lower voltage than conventional mechanical, incandescent, cathode ray, or gas-discharge displays.

One manufacturer has demonstrated a complete VOM in a probe! Using several of the new numeric displays, the futuristic unit is similar in size to a standard scope probe. Volts and ohms are read directly from the small light display. The Hamilton Watch Company will market a digital watch using LED numeric displays, and Bell Telephone is hard at work on new types of blue, green, yellow, and red LED's for use in home telephones. Infrared LED's are being used in several types of new intrusion alarms. One company even markets a complete line of LED voice communicators and burglar alarms.

One of the most unusual applications of the infrared LED is as a light source for small mobility aids for the blind. Such devices may eventually be marketed at a price comparable to most hearing aids.

An important result of all these new uses for LED's is a large drop in price. LED's are available for under $2.50 each in small quantities. This price is competitive with that of miniature, long-life indicator lamps. And of course, the LED offers sturdier packaging, a million-hour lifetime, and far less current consumption.

Only a year ago, the cheapest infrared LED retailed for $18.00. At least five manufacturers now offer GaAs LED's for under $7.50. These devices are far more efficient than visible LED's and are therefore usable in experiments in secret communications.

To sum up then, the LED is superior to the conventional filament lamp in the following ways:

1. Response time is extremely fast—most LED's operate in a fraction of a second rise and fall times. Some LED's can reach a speed of 100 MHz.

2. Because it is a solid-state device, an LED has no warm-up time, is completely free of microphonics, is just about impervious to mechanical vibration and other environmental conditions, and is usually of very small size and weight.

3. The LED light output is nearly monochromatic—far from being a laser—but close enough to have most of its light in a relatively narrow bandwidth. This makes it possible to use optical filters to reduce ambient noise.

4. The LED is a low-impedance device with forward characteristics similar to those of a conventional silicon diode and it can be driven from ordinary low-voltage supplies with conventional transistor circuitry.

Elsewhere in this issue you will find a unique construction article for a low-cost LED communicator. Other projects using LED's will appear in future issues. —30—

MORE INFORMATION

For more information about commercial light emitting diodes, write to one of the following manufacturers:

Electro-Nuclear Laboratories
115 Independence Drive
Menlo Park, CA 94025

Miniature Lamp Department
General Electric Company
Nela Park
Cleveland, OH 44112

Monsanto Electronic Special Products
10131 Bubb Road
Cupertino, CA 95014

Radio Corporation of America
Electronic Components and Devices
Harrison, NJ 07029

Texas Instruments
Semiconductor-Components Division
Box 5012
Dallas, TX 75222

Fairchild Semiconductor
313 Fairchild Drive
Mountain View, CA 94040

Hewlett-Packard
1501 Page Mill Road
Palo Alto, CA 94304

Motorola Semiconductor Products
Box 20912
Phoenix, AZ 85036

Sharp Electronics Corporation
178 Commerce Road
Carlstadt, NJ 07072

An excellent booklet on LED's is sold by the General Electric Company for $2.00. Called the "Solid State Lamp Manual," it describes in detail theory, characteristics, and applications.

OPPORTUNITY AWARENESS

Thoughtful Reflections On Your Future

Eighth in a Monthly Series by David L. Heiserman

The Sacred Club of Engineers

I am sick and tired of losing out on good engineering assignments and promotions because I don't have a college degree. Six years ago, I earned an Associate Degree from a two-year technical college. I graduated with honors, but since I don't have a bachelor's or master's, the job openings that I go for seem to be snapped up by junior engineers with 10% of my experience. Sure, I am making a living wage, but I am also at a dead end. How do I break into the sacred club?

● Since you have kept abreast of the field with specialized home study courses, I must assume that you have no aversion to further scholastic endeavors. Have you attempted to convince your employer to subsidize your college education? Many employers are perfectly willing to give their people time off to attend college classes. Some of them pay part or all of the tuition.

It is an unfortunate situation, but at the moment, it appears easier for employers to screen out people who might not be able to do the job than to test and interview people who might do the job predicated on lesser education, but more experience.

It's sad, but the only way around the problem at this moment is to pick up some more "formal" credentials. Besides getting your bachelor's degree, a fine credential is a Professional Engineer's certificate from your state. Many states don't require Professional Engineers to have a college degree, since they are given an examination—which you should find relatively easy to pass. Also consider membership in the Institute of Electrical and Electronics Engineers and other professional societies.

In his new book, *Education and Jobs: The Great Training Robbery*, Ivar Berg says that an ever increasing percentage of workers spend their time on jobs requiring less formal education than they have. This may be true. Statistics are beginning to show that the less educated, but more experienced employees have a lower turnover rate and a better aptitude for the job than the over-educated engineer.

Which School is Best?

I want to take a home-study course in electronics. However, all of the home-study schools claim that they are the best in terms of training, laboratory materials, job placement, etc. Isn't there some way to rate these schools?

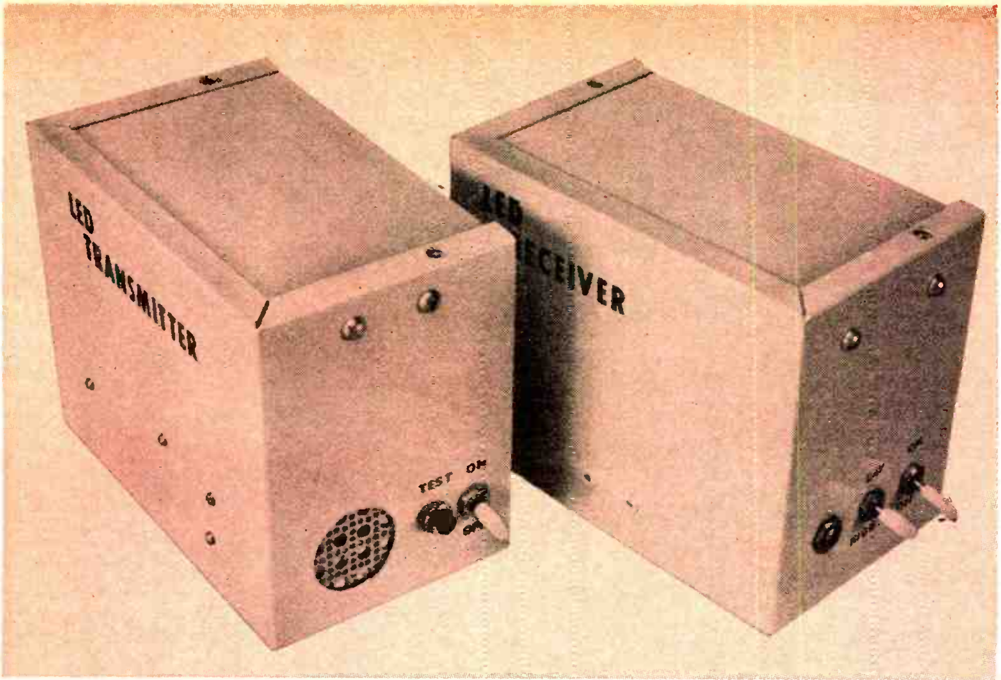
● If you read between the lines in the school advertisements, you will see subtle differences. And, it is because of these differences that is is impossible to objectively "rate" one school above another.

The best electronics home study school for you is the one that has a teaching objective that matches your career goal. You should try to make up your mind exactly what you want to study before contacting the home study schools. Then, write for literature from the schools that advertise lessons to fit your objective. If you have a firm goal in mind, you can narrow down the number of possible schools that can be of any help.

Note that one home study school may emphasize radio and TV repair as its primary teaching objective. Another school will attempt to reach a different kind of student; possibly one already employed in electronics. The course outlined for the latter school may not even mention television. A third school may emphasize communications and may be aiming at helping you get an FCC license.

If you know what you want to study beforehand—which is not as impossible as it may sound—there will be a much smaller chance that you'll be swayed from your conviction by flashy sales literature or the sometimes over-eager sales representative.

As far as a school's business reputation is concerned, you can always depend on a school that has been approved by the National Home Study Council. —30—



ASSEMBLE AN LED COMMUNICATOR—
THE OPTICOM

PRIVATE COMMUNICATIONS VIA AN INVISIBLE LIGHT BEAM

This optical communications system is a very practical and useful application of the light-emitting diode, the theory of operation of which is discussed elsewhere in this issue. The communicator operates at 9400 angstroms and has a range of over 1000' in darkness. Both the transmitter and receiver are simple to build and use relatively easy-to-find components.

Looking for a totally private, jam-proof, interference-free communications system? Try the "Opticom," the low-cost younger brother of the POPULAR ELECTRONICS Laser Communicator.

Using a light-emitting diode (see the article on page 35) in the transmitter and phototransistor in the receiver, the Opticom is a voice-modulated infrared optical communicator. It operates at 9400 Angstroms and has a range of over 1000 feet in darkness. The range is considerably less in daylight; but, depending on the angle of the sun and the cloud cover, it can easily reach 100 feet without the use of special filters or light shields.

The key to the amount of range obtainable is in the lenses used at the transmitter and receiver. In the prototype, simple, low-cost lenses were used. Employing a pair of binoculars or a low-cost telescope at each end would greatly increase the operating range.

Transmitter. The circuit of the transmitter is shown in Fig. 1. During voice operation, *Q1* and *Q2* provide amplification and impedance matching between the 20-mV signal from the crystal microphone and *Q3*. The am-

BY FORREST M. MIMS, III AND HENRY E. ROBERTS

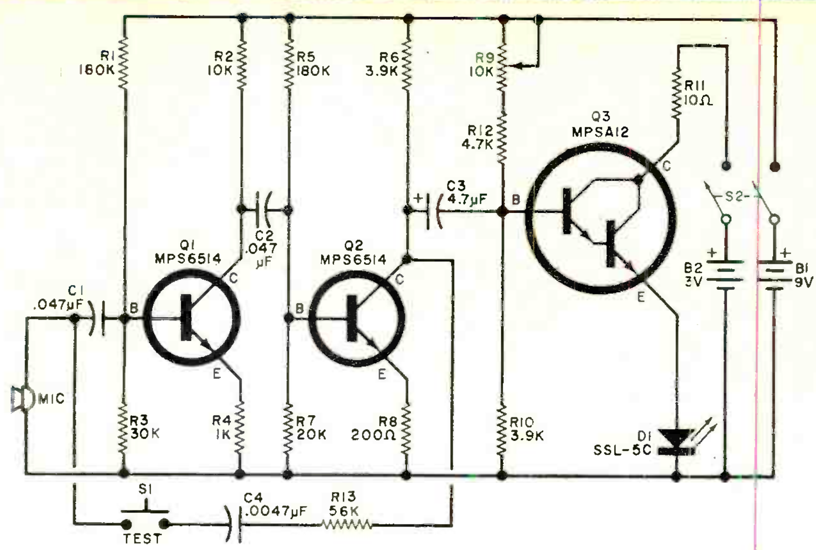


Fig. 1. The LED transmitter consists of a two-stage audio amplifier driving a Darlington modulator. When S1 is depressed, the audio amplifier is converted to an audio oscillator, used for making the original optical setup.

PARTS LIST TRANSMITTER

B1—9-volt battery
B2—Two 1½-volt C cells
C1,C2—0.047-μF, 10-volt capacitor
C3—4.7μF, 10-volt electrolytic capacitor
C4—0.0047-μF, 10-volt capacitor
*D1—Light-emitting diode (GE SSL-5C)**
R1,R5—180,000-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R3—30,000-ohm, ¼-watt resistor
R4—1000-ohm, ¼-watt resistor
R6,R10—3900-ohm, ¼-watt resistor
R7—20,000-ohm, ¼-watt resistor
R8—200-ohm, ¼-watt resistor
R9—10,000-ohm, 1-watt potentiometer (Mallory MLC 14L or similar)
R11—10-ohm, ½-watt resistor
R12—4700-ohm, ¼-watt resistor
R13—56,000-ohm, ¼-watt resistor
S1—Normally open pushbutton switch
S2—Dpst slide or toggle switch
Q1,Q2—MPS6514 or HEP728 transistor
Q3—Darlington transistor (Motorola MPSA12)
Misc.—Suitable chassis, miniature crystal microphone, lens, battery holders, battery clips, mounting hardware, cement, wire, solder, etc.
**Available from Miniature Lamp Department, General Electric Co., P.O. Box 2422, Cleveland, OH 44112, $7.05, plus postage.*
Note—The following are available from MITS, 4809 Palo Duro N.E., Albuquerque, NM 87110: etched and drilled PC board, $2.50; PC board and all electronic items except switches, microphone, and batteries, $12.00; complete kit of all parts including lens, chassis, switches, and microphone, $17.00; all postpaid.

plifier formed by *Q1* and *Q2* is coupled to provide a low-frequency cutoff to minimize 60-Hz response. Darlington emitter follower *Q3* supplies bias current to the LED from *B2*. Potentiometer *R9* provides an unmodulated current-level adjustment for the LED and should be set so that ½ volt is read across *R11*. From Ohms law, ½ volt across 10 ohms indicates a current level of 50 milliamperes. This is well below the 100-mA capability of the SSL-5C LED without a heat sink.

Tone operation is provided by connecting the feedback circuit comprised of *R13* and *C4* to the input of *Q1* through *S1*. With *S1* depressed, the amplifier formed by *Q1* and *Q2* oscillates at about 500 Hz and supplies 100% modulation to the LED.

The transmitter circuit is assembled on a printed circuit board as shown in Fig. 2. In installing the semiconductors, use care—particularly with the LED, whose leads should have a heat sink attached while soldering. Make sure that the window of the LED is parallel to the PC board.

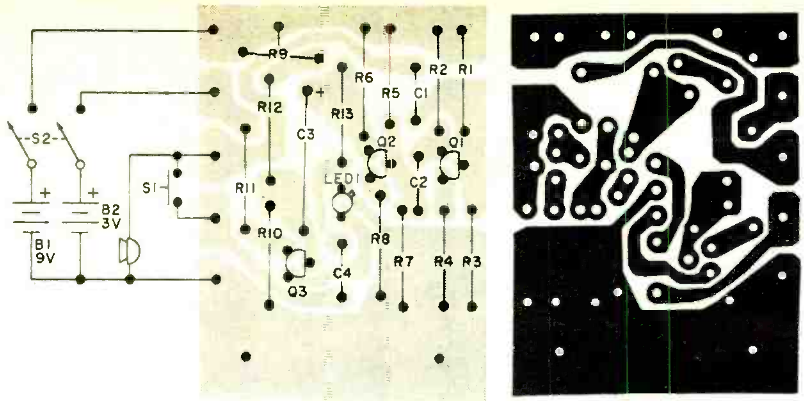
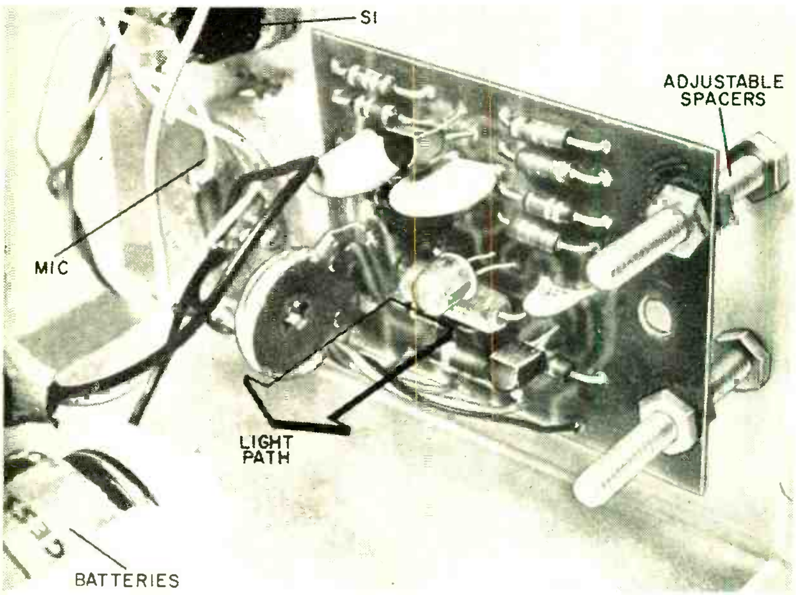
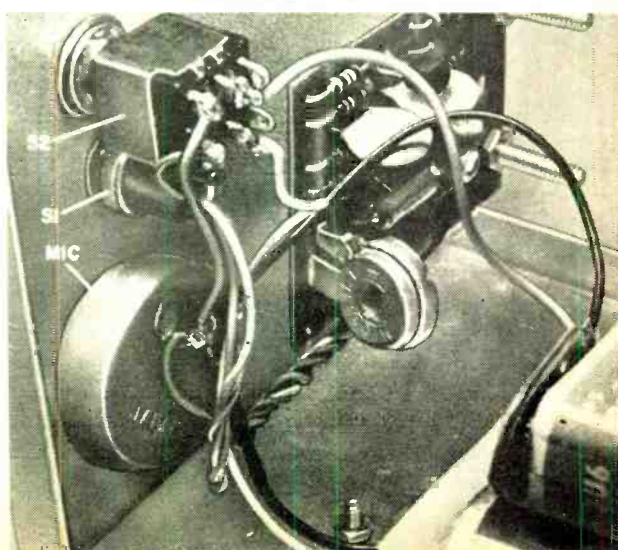
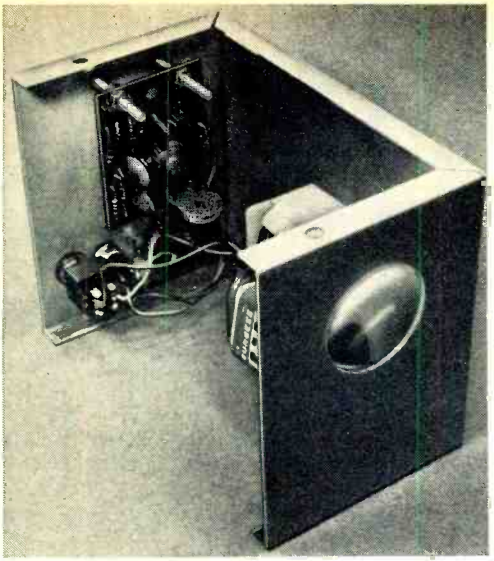


Fig. 2. The PC board foil pattern is shown actual size. When installing the components, use a heat sink on the LED (D1) and make sure that the window is facing the component side of the board. Make the board larger than the foil pattern to allow mounting holes.

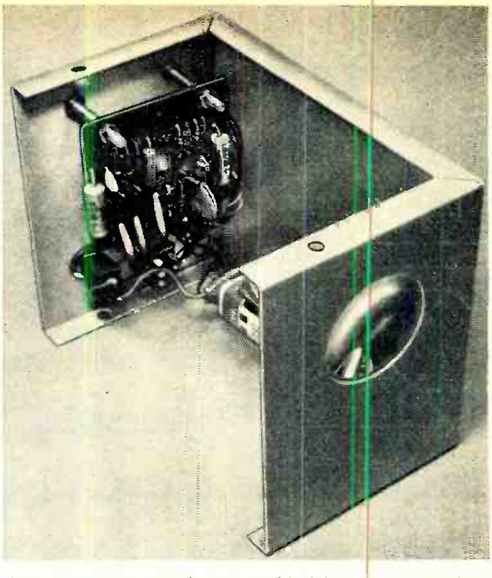


Assemble the transmitter on four adjustable spacers so that the window of the LED can be placed at the focal point of the lens. When assembling complete chassis be sure to mount the batteries so that they do not obstruct light path between the LED and the lens. Although the prototype has the microphone on chassis, a remote mike can be used. Even S2 can be mike-mounted push-to-talk switch. Oscillator switch S1 is rarely used, so can remain mounted on chassis.





In assembling the transmitter, arrange the board and lens mounting so that the LED window is on the center line of the lens. The text explains how to adjust the board to make the lens focus at the window of the light-emitting diode on board.



The receiver must be assembled in a manner similar to the transmitter—with the window of Q1 at the focal point of the lens. In both receiver and transmitter, once the focus has been attained, a drop of cement on screws will prevent slippage.

Receiver. A schematic of the receiver circuit is shown in Fig. 3. Phototransistor *Q1* passes a current proportional to the light intensity at its active surface. In essence, light replaces *Q1*'s base lead. Since *Q1* is quite light sensitive, even a moderate level of ambient illumination will drive it into saturation. Transistors *Q2* and *Q3* provide a dynamic load for *Q1*, preventing saturation or cutoff and extending useful daylight receiving range. The FET, *Q4*, matches the high impedance of the detection circuit to the audio amplifier formed by *Q5* and *Q6*. The complete receiver circuit provides a voltage gain of about 400.

A foil pattern and component layout for the receiver printed circuit board are shown in Fig. 4. Be very careful when installing phototransistor *Q1* because it has a plastic package and the leads are fragile. The collector of this transistor is indicated by a small arrow on the bottom. Place the transistor through the 0.175" hole at the center of the receiver board (domed window to the component side), be sure the leads are properly oriented, and then solder them to the correct points. Use a clip-on heat sink when installing all semiconductors.

Assembly. Once both boards have been completed and checked for possible wiring errors, the system is ready for packaging. You can use the arrangement described here or you can strike out on your own. If, for example, you need only a 15-to-20-ft. range, an optical system is not required. All you have to do is aim the two boards at each other, depress the transmitter Test pushbutton, and align the two units. Then release the button and talk.

If you want a night range of up to 1000', you must use a lens at both transmitter and receiver. Obtain two low-cost magnifying lenses at least one inch in diameter and remove the lenses from their housing or frames. Measure the focal length of each lens by placing it in the beam of a fairly distant light source. The sun is ideal, but an overhead lamp, about 10 feet away will do. The focal length is determined by placing the lens at a distance from a piece of white paper so that the smallest recognizable image is displayed on the paper. Measure the distance between the lens center and the paper—this is the focal length. The chassis to be used should be long enough so that, with the lens mounted at one end and the PC board carrying the LED or phototransistor at the other, the distance between the two can be adjusted to the focal length of the lens.

The chassis used must have a cover so that the interior is dark when the system is in use.

Drill four holes for mounting the PC board

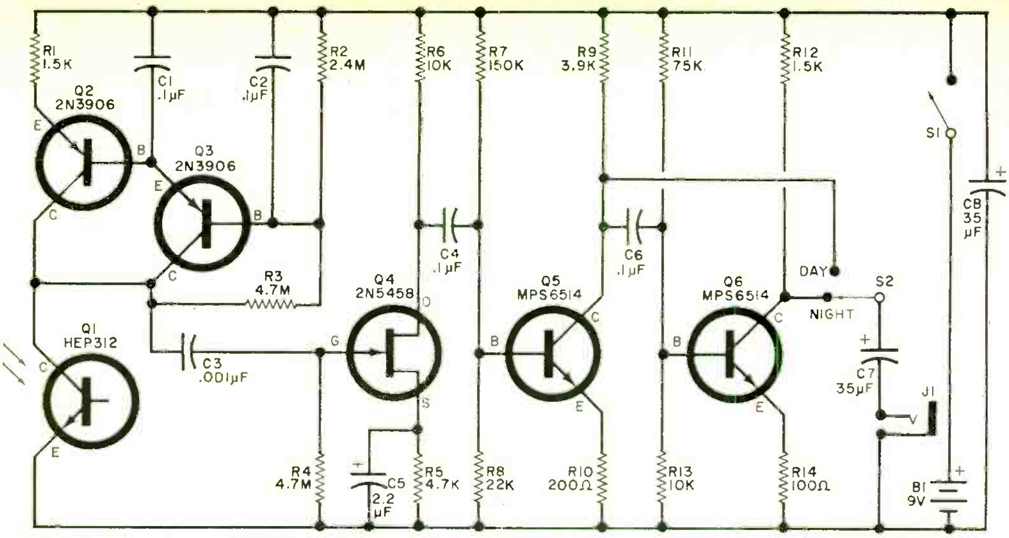


Fig. 3. Consisting of an audio amplifier driven by a phototransistor circuit, the receiver can use either two or three audio stages for day or night operation. There is no actual base connection to Q1 as this function is performed by light from LED.

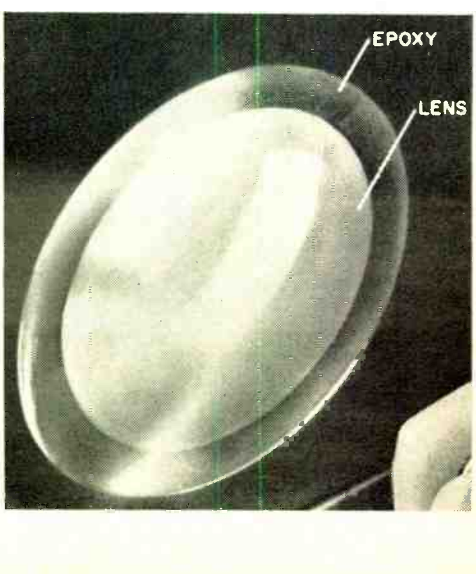
PARTS LIST
RECEIVER

B1—9-volt battery
C1,C2,C4,C6—0.1-µF, 10-volt capacitor
C3—0.001-µF, 10-volt capacitor
C5—2.2-µF, 10-volt electrolytic capacitor
C7,C8—35-µF, 10-volt electrolytic capacitor
J1—Earphone jack and plug
Q1—HEP312 phototransistor
Q2,Q3—2N3906 or HEP715 transistor
Q4—2N5458 or HEP801 FET
Q5,Q6—MPS6514 or HEP728 transistor
R1,R12—1500-ohm, ¼-watt resistor
R2—2.4-megohm, ¼-watt resistor
R3,R4—4.7-megohm, ¼-watt resistor
R5—4700-ohm, ¼-watt resistor
R6,R13—10,000-ohm, ¼-watt resistor
R7—150,000-ohm, ¼-watt resistor
R8—22,000-ohm, ¼-watt resistor
R9—3900-ohm, ¼-watt resistor
R10—200-ohm, ¼-watt resistor
R11—75,000-ohm, ¼-watt resistor
R14—100-ohm, ¼-watt resistor
S1—Spst slide or toggle switch
S2—Spdt slide or toggle switch
Misc.—Suitable chassis, lens, battery connectors, battery clips, mounting, hardware, cement, earphone (250 ohms or more), solder, wire, etc.
Note—The following are available from MITS, 4809 Palo Duro N.E., Albuquerque, NM 87110: etched and drilled PC board, $2.75; PC board and all electronic items except switches, earphone and batteries, $11.00; complete kit of all parts including lens, chassis, switches, and earphone, $15.00; all postpaid.

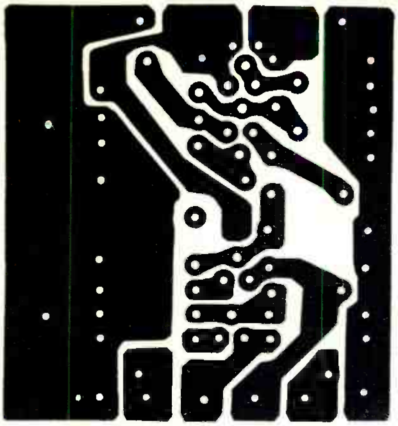
in one end of the chassis. Temporarily mount the chassis with four screws and nuts to allow for adjustments. Make measurements to determine the location of the center of the light-sensitive semiconductor with respect to its location on the chassis wall.

The center of the lens must be in the same position on the opposite end. Make the hole for the lens about ¼" smaller in diameter than the lens.

The crystal microphone and two switches for the transmitter are mounted on the same



The lens hole should be slightly smaller than the lens. Use epoxy cement to mount the lens to inside of the chassis to prevent accidental loosening.



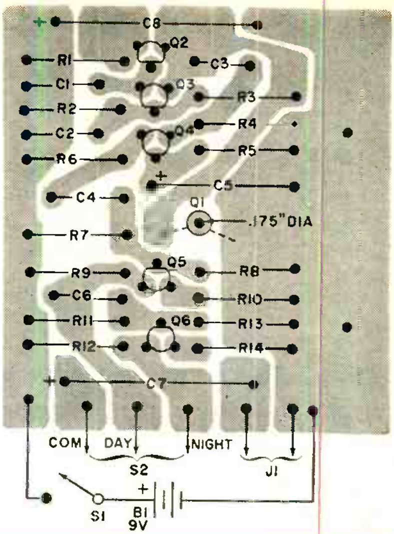


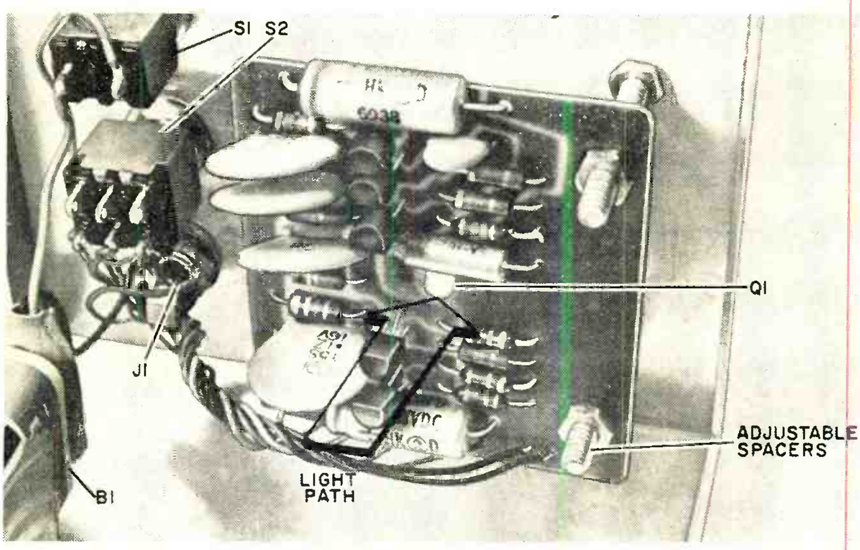
Fig. 4. When mounting Q1 make sure the window is facing the component side of the PC board. Connect collector to the foil that goes to R3 and Q1, and the emitter to the large common foil adjacent to the Q1 hole.

end as the PC board on the transmitter chassis. Cut a clean hole for acoustic access to the microphone, which is cemented to the inside of the chassis. The battery clips are mounted within the chassis, in a location where the batteries do not interfere with the light path from the lens to the LED.

On the receiver chassis use similar locations for the two switches and the earphone jack. Before mounting any components on the chassis, make sure that all mounting holes have been drilled and deburred; and, if desired, paint the chassis. Mount the PC boards with long screws to permit adjustment of focus. Put nuts on the screws on both sides of the boards to permit making the adjustment and locking the board in place.

When the wiring is complete and before mounting the lenses, test the units by aiming

(*Continued on page* 98)



Like transmitter, assemble receiver board on four adjustable spacers so that the window of Q1 is at the focus of the lens. Once again, make sure batteries do not obstruct light.

ASSEMBLE A DIGITAL MEASUREMENTS LAB

MAIN FRAME POWER SUPPLY AND READOUT WITH 20-MHz FREQUENCY COUNTER MODULE (MORE PLUG-IN MODULES TO COME)

This article is the first in a series on the construction of an integrated, modern, digital readout instrument having a common main frame (with power supply and readout) which is capable of accepting a variety of individual plug-in units. The use of the plug-in module concept makes it possible to have digital test equipment of high accuracy at a very economical cost.

THE PRIMARY PURPOSE of most electronic measuring instruments is to provide a numerical indication of the level or value of the quantity being measured. It matters little whether the measurement is in volts, amperes, ohms, Hz, or elapsed time; only the accuracy of the measurement is important. Since the readout device and the measuring instruments do not necessarily have to be connected, why not have a "modularized" type of measurement system—with a highly accurate digital readout (with a power supply) on a main frame and measurement modules that can be plugged in?

The "Digital Measurements Lab" is such a system; and its hallmarks are economy, accuracy and flexibility. In this issue of POPULAR ELECTRONICS, are assembly instructions for the main frame, which houses the readout and power supply, and one measurement module, a 20-MHz Frequency Counter. In future articles, other modules, which can be added at little additional cost, will be described. These will include a Dual-Slope Volt-Ohmmeter and a Capacitance Meter.

The Digital Measurements Lab employs

BY DANIEL MEYER

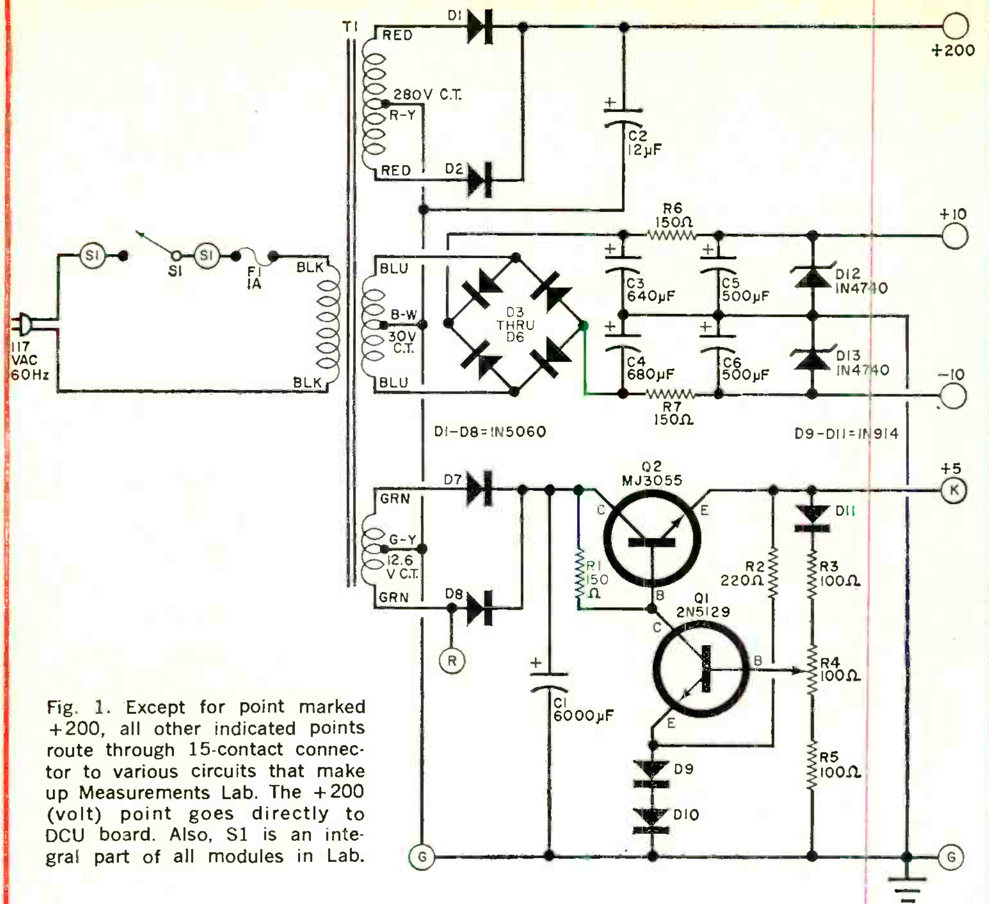


Fig. 1. Except for point marked +200, all other indicated points route through 15-contact connector to various circuits that make up Measurements Lab. The +200 (volt) point goes directly to DCU board. Also, S1 is an integral part of all modules in Lab.

PARTS LIST MAIN FRAME

C1—6000-µF, 10-volt electrolytic capacitor
C2—12-µF, 250-volt electrolytic capacitor
C3,C4—640-µF, 25-volt electrolytic capacitor
C5,C6—500-µF, 15-volt electrolytic capacitor
D1-D8—400-PIV, 1-ampere silicon rectifier (1N5060 or similar)
D9-D11—DHD800 (General Electric) or IN914 silicon rectifier
D12,D13—IN4740 zener diode
F1—1-ampere fuse
Q1—2N5129 transistor (National Semiconductor or Fairchild)
Q2—MJ3055 transistor (Motorola)
R1,R6,R7—150-ohm, ½-watt, 10% tolerance resistor
R2—220-ohm, ½-watt, 10% tolerance resistor
R3,R5—100-ohm, ½-watt, 10% tolerance resistor
R4—100-ohm printed circuit type potentiometer
S1—Spst switch (see Frequency Counter Parts List)
T1—Power transformer (117-volt primary/280-volt, center-tapped (at 20 mA); 30-volt, center-tapped (at 100 mA); and 12.6-volt, center-tapped (at 1.5 ampere) secondaries
1—"Utilogic" 3½-digit display and counter kit
Misc.—Main frame chassis and cowling; control knob; power supply printed circuit board; ac line cord and strain relief; fuse holder; 15-contact socket; solid and stranded hookup wire; machine hardware; spacers; solder; etc.
Note—The following items are available from Southwest Technical Products Corp., Box 16297, San Antonio, TX 78216: power supply circuit board No. 170-Pb for $2.85; complete power supply kit, including board, No. 170-C for $14.55 plus postage on 4 lb; complete main frame kit, including chassis and cowling, display time control, reset switch, etc., but minus readout assembly, No. 170-CP for $19.55 plus postage on 8 lb; "Utilogic" display-counter kit No. MNX-1 for $49.50.

transistor-transistor-logic (TTL) integrated circuits and other modern design techniques to provide maximum accuracy and reliability. The readout system consists of decoders, drivers, and Nixie® neon-glow tubes to provide $3\frac{1}{2}$ decades and, thus, 3-place accuracy.

The cost of the parts for the main frame is estimated at less than $75; while the Frequency Counter module is about $42.

The Main Frame. The Digital Measurements Lab can be built around almost any type of decimal counting system capable of responding to 20 MHz or more. For example, you can use either of the two decoder/driver systems that have previously appeared in POPULAR ELECTRONICS (see "Build Numeric Glow Tube DCU," Feb. 1970 and "Assembling The Popular Electronics Mini DVM," Sept.

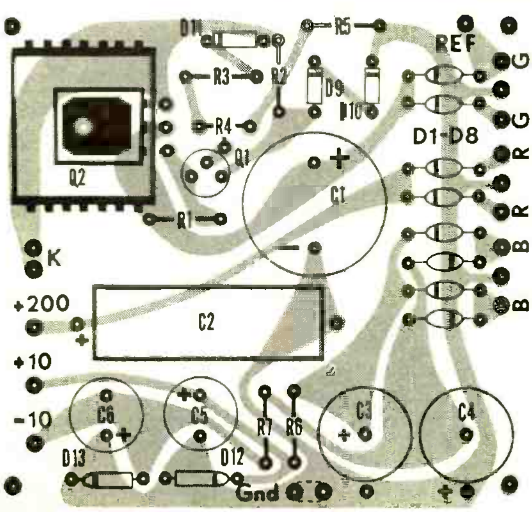


Fig. 2. Actual size etching guide for power supply printed circuit board is provided above. At left is components location and orientation diagram. Carefully follow color coding when secondary leads of T1 are connected to circuit board (holes at near left).

replacing components. You need to really know the fundamentals.

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

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

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

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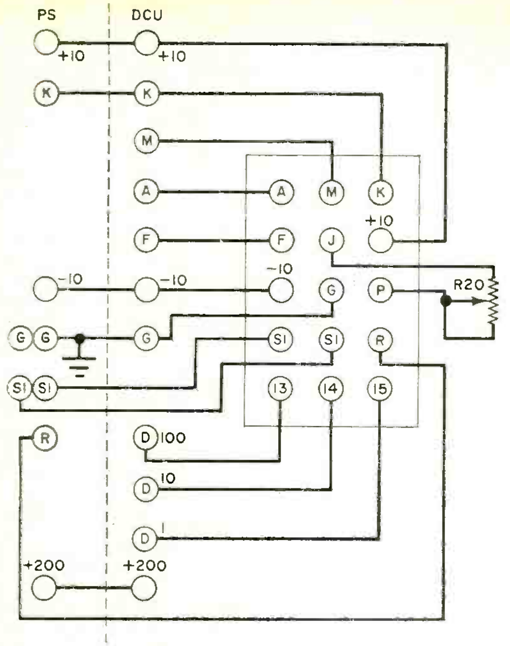


Fig. 3. Power supply (PS) and readout (DCU) boards and 15-contact connector are wired together as shown. Potentiometer R20 is display time control.

1970). However, since the "Utilogic" three-and-a-half-digit display and counter assembly was designed specifically for the Lab's main frame, its use is recommended (see Main Frame Parts List).

The first step in putting together the main frame is to assemble the readout system from the plans provided in a previous issue or with the "Utilogic" kit. Next, assemble the power supply circuit, the schematic diagram for which is shown in Fig. 1, on its printed circuit board. In the event you plan to etch and drill your own circuit board, an actual size etching guide and components location and orientation diagram are given in Fig. 2. When assembling the power supply circuit board, pay close attention to the orientations of the diodes, transistors, and electrolytic capacitors. Use bare #22 hookup wire for the three jumpers.

Once the boards are assembled, they must be wired to each other and to a 15-contact connector. The connector provides a means for routing the signal and power lines to and from the plug-in modules. The wiring procedure is greatly simplified by the fact that all wiring holes in the circuit boards are assigned a letter-code designation. This code is set up so that like letters mate with each other and with the coding on the connector as shown in Fig. 3. Between the boards, you can use solid hookup wire, but between the boards and connector, it is recommended that you use stranded wire.

After the wiring is completed, bolt the readout circuit board to the chassis with machine hardware and 3/8" spacers. Then use #6 hardware to bolt the power transformer (*T1*) to the floor of the main frame's chassis (see Fig. 4) and temporarily set the power supply board in its appropriate location. Measure the secondary leads from *T1* to their respective holes in the power supply board. Add about an inch to each measurement and trim away any excess lead lengths. Strip away 1/4" of insulation from each lead, push the leads through the holes in the power supply board, and solder them to the foil pattern.

Mount the RATE control and the RESET

THEORY OF POWER SUPPLY DESIGN

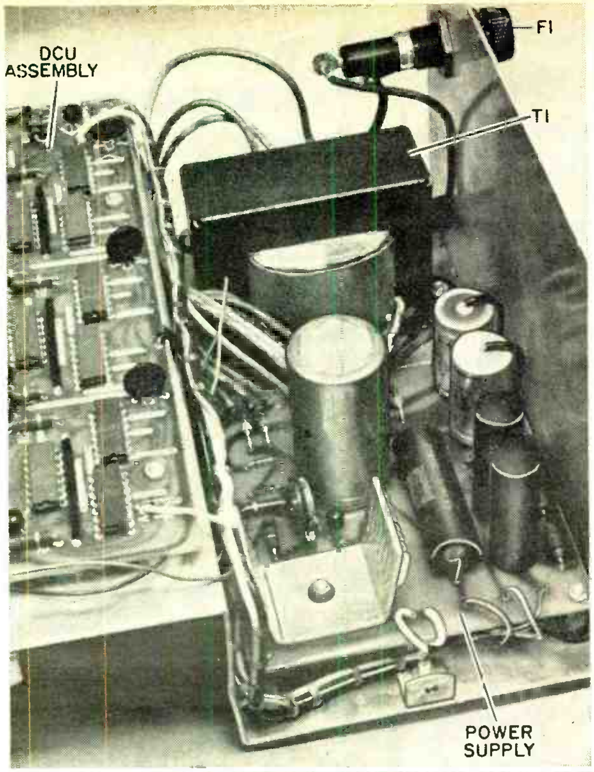
The power supply used in the Digital Measurements Lab and shown schematically in Fig. 1 is designed to provide all of the voltages required by the circuits that make up the Lab. The +200-volt output is used for firing the readout tubes and neon lamps in the multi-decade readout assembly. This output is not critical and is, therefore, unregulated.

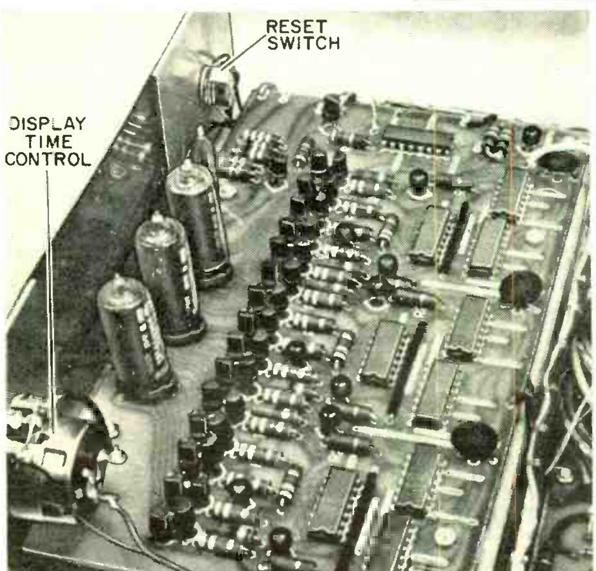
The various transistor circuits in the Lab are powered by the +10- and −10-volt outputs which are voltage regulated by zener diodes *D12* and *D13*. For the more critical demands of the IC's, the +5-volt output is derived from a special regulator circuit that maintains the output voltage within 5% of the 5-volt level at point K. The regulator circuit consists of series-pass transistor *Q2* and error amplifier transistor *Q1*. In operation, a sample of the output voltage is applied to the base of *Q1* by the wiper of voltage level control *R4*. If any loading condition attempts to force the output voltage to increase, the base voltage of *Q1* will also increase slightly and cause *Q1* to draw more collector current. The increase in collector current then causes a decrease in the base voltage of *Q2* of sufficient magnitude to maintain the output voltage at its original +5-volt level. If, on the other hand, loading conditions attempt to decrease the output voltage level below 5 volts at point K, the opposite action will occur.

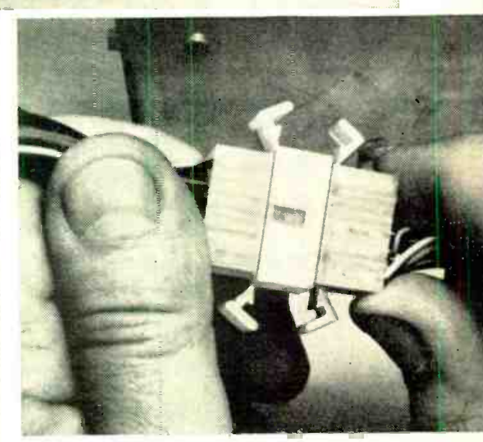
The positive and negative 10-volt outputs are obtained from the bridge rectifier assembly made up of diodes *D3-D6* and filter capacitors *C4-C6*. The +200-volt output is obtained from a separate *T1* secondary winding, diodes *D1* and *D2*, and filter capacitor *C2*.

The +5-volt output is obtained from a third secondary winding, *D7* and *D8*, and *C1*. Potentiometer *R4* is a voltage level control, capable of varying the output voltage between approximately 4 and 6 volts. This control would normally be set to provide a 5-volt output.

Locations of power supply (right) and 3½-digit decoder/driver assembly, reset switch, and display time control (below) are shown mounted on respective sections of main frame chassis.







A 15-contact Molex connector is recommended for use in Digital Measurements Lab for positive electrical contact.

switch on the front panel of the main frame. Then, on the rear apron, mount the fuse holder and pass through its entry hole the ac line cord and fasten it in place with a strain relief. Then finish wiring the power supply primary circuit, referring back to Fig. 1 and Fig. 3 for details.

Solder one end of a length of hookup wire to one of the lugs on the RESET switch; the other end goes to hole M on the DCU board. Cut a length of stranded hookup wire to size, and connect and solder its ends to the same lug on the RESET switch and contact M on the connector. Then connect and solder a final

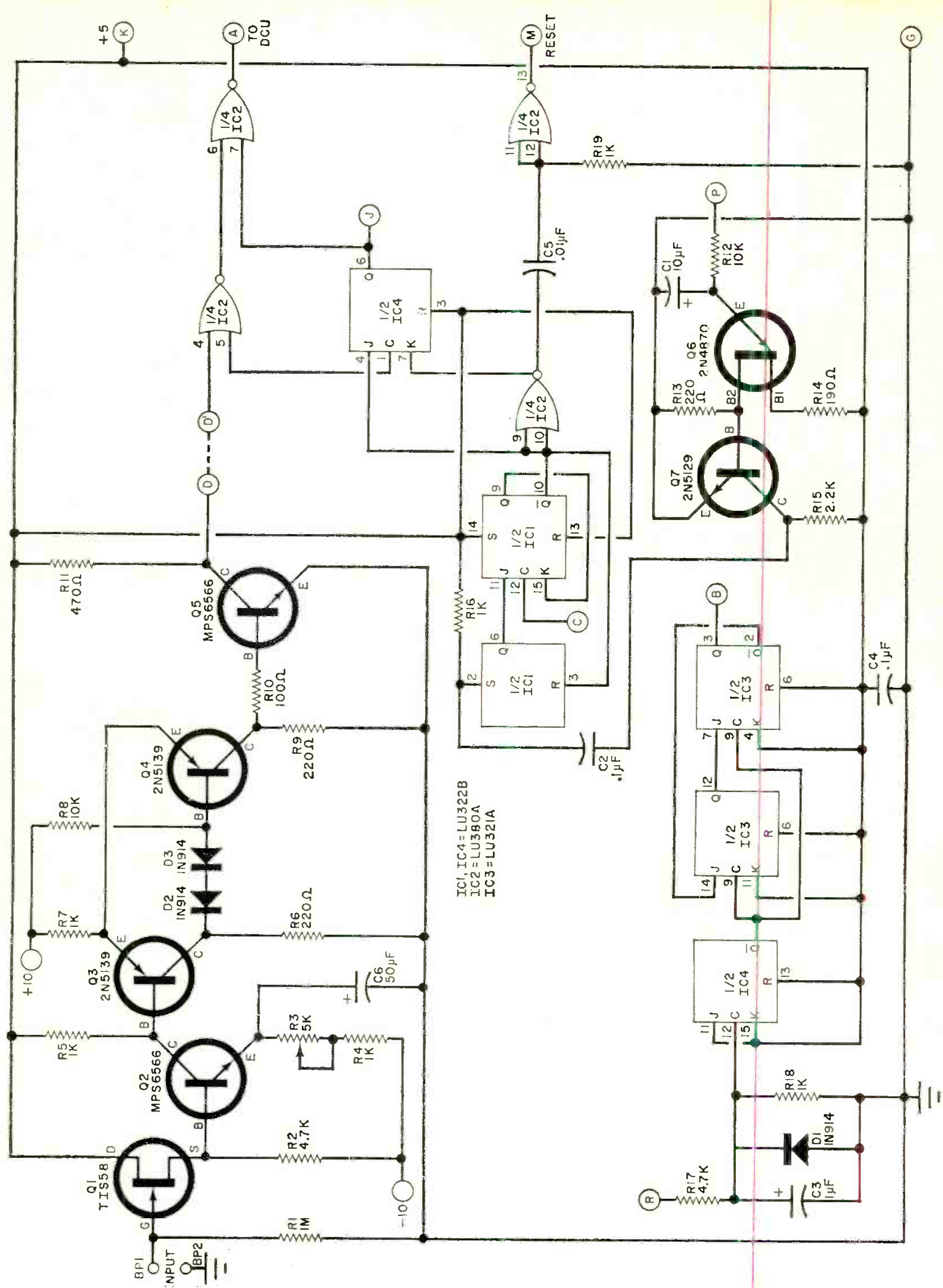


Fig. 5. By connecting D to D' and B to C, basic Time Base circuit shown can provide single 2000-Hz range. To obtain full 20-MHz, five-range capability, Scaler/switching arrangement would be connected to these points.

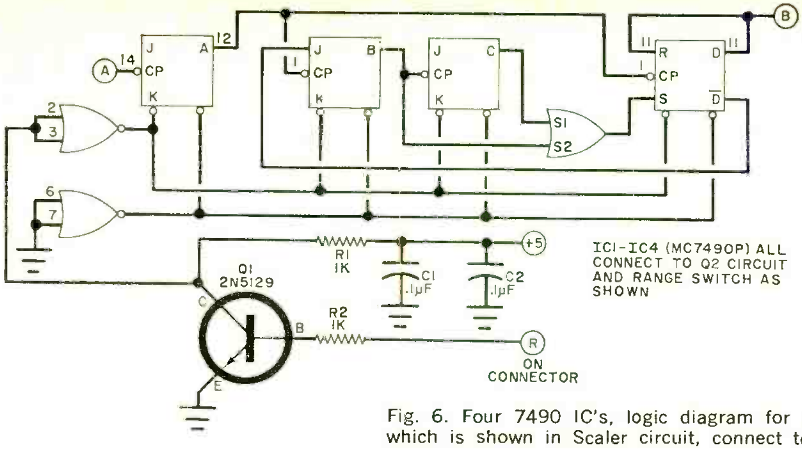


Fig. 6. Four 7490 IC's, logic diagram for only one of which is shown in Scaler circuit, connect to Q1 stage.

length of wire between the free lug of the switch and chassis ground.

Locate the 15-contact connector and pass it through the cutout in the center wall of the main frame's chassis so that it is easily accessible through the plug-in compartment. Then neatly lace together the wiring.

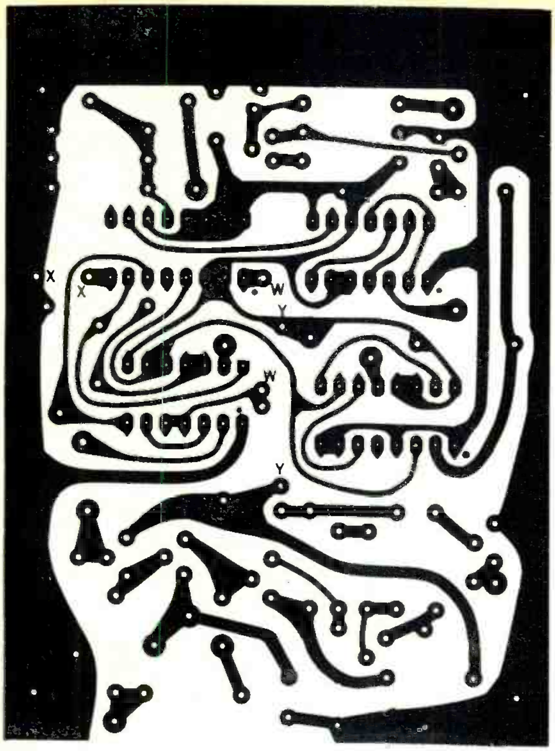
Testing the Main Frame. Temporarily connect a jumper wire between the two **S1** contacts on the connector (see Fig. 3). Plug the line cord into a convenient 117-volt, 60-Hz ac outlet. Use a voltmeter to check the +10-volt, —10-volt and +200-volt outputs from the power supply. Your readings should be within 10% of these values. Then connect the meter to point **K** in the power supply and chassis ground and adjust *R4* for an exact 5-volt reading.

Now, check the front panel of the main

PARTS LIST FREQUENCY COUNTER

Time Base:
BP1,BP2—Five-way binding post (one black, one red)
C1—10-µF, 15-volt electrolytic capacitor
C2,C4—0.1-µF, 12-volt disc capacitor
C3—1-µF, 15-volt electrolytic capacitor
C5—0.01-µF, 12-volt disc capacitor
C6—50-µF, 15-volt electrolytic capacitor
D1-D3—1N914 diode
IC1,IC4—LU322B integrated circuit (Signetics)
IC2—LU380A integrated circuit (Signetics)
IC3—LU321A integrated circuit (Signetics)
Q1—TIS58 transistor (Texas Instruments)
Q2,Q5—MPS6566 transistor (Motorola)
Q3,Q4—2N5139 transistor (Fairchild)
Q6—2N4870 or 2N4871 unijunction transistor
Q7—2N5129 transistor (Fairchild)
R1—1-Megohm
R2—4700-ohm
R4,R5,R7,R16, R18,R19—1000-ohm
R6,R9,R13—220-ohm
R8,R12—10,000-ohm
R10—100-ohm
R11—470-ohm
R14—190-ohm
R15—2200-ohm
R17—4700-ohm
(All resistors ½-watt, 10% tolerance)
R3—5000-ohm linear-taper potentiometer
S1—10-position, 4-deck non-shorting rotary switch with spst switch attachment for S1 in power supply

Scaler:
C1,C2—0.1-µF, 10-volt disc capacitor
IC1-IC4—MC7490P integrated circuit (Motorola)
Q1—2N5129 transistor (National Semiconductor or Fairchild)
R1,R2—1000-ohm, ⅛-watt, 10% tolerance resistor
Misc.—Time Base and Scaler printed circuit boards; 33,000-ohm, ½-watt, 10% tolerance resistor (see text); control knobs (2); L bracket chassis; 15-contact plug to match SO1 in main frame; 4-40 machine hardware; ¼"-long spacers (8); solid and stranded hookup wire; solder; etc.
Note—The following items are available from Southwest Technical Products Corp., Box 16297, San Antonio, TX 78216: complete Time Base kit, including circuit board, No. TB-2, for $17.50; Complete Scaler kit, including circuit board, No. S-410 for $14.95, both kits plus chassis and 15-contact plug, No. FC-2 for $34.95 plus postage on 3 lb.



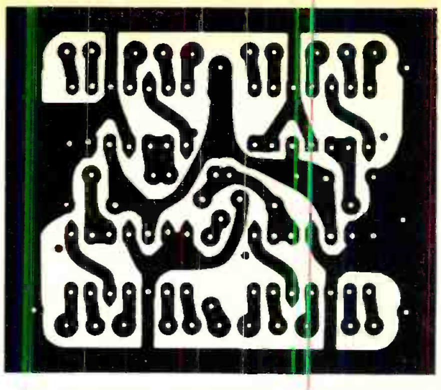
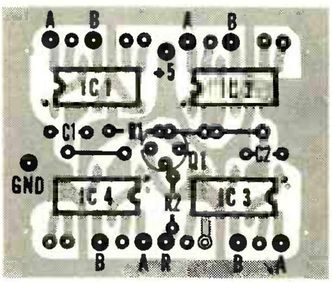


Fig. 7. Actual size etching guides for Time Base and Scaler printed circuit boards are shown at left and above, respectively. Use etching guides to check for solder bridges between closely spaced conductors after all components are soldered to circuit boards.



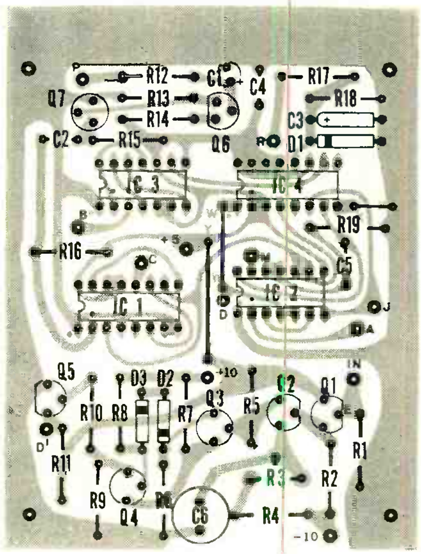


Fig. 8. When mounting electrolytic capacitors, diodes, IC's, and transistors on circuit boards carefully orient them exactly as shown here.

frame; with power applied, the readout tubes and neon lamps should glow. If so, depress and release the RESET switch. If the main frame is operating properly, all tubes should immediately reset to "0". Then set the main frame aside.

Frequency Counter Module. As mentioned earlier, the first in the series of integrated plug-in construction plans is a 20-MHz Frequency Counter. The module, employing TTL integrated circuits, consists of two basic circuit assemblies: one is the Time Base and the other is the Scaler, shown schematically in Fig. 5 and Fig. 6, respectively. For minimum loading on the circuit under test, the counter module is equipped with a high-impedance source-follower field effect transistor input circuit.

The Frequency Counter module has full-scale ranges of 1000 Hz, 10 kHz, 100 kHz, 1 MHz, and 10 MHz with a 100 percent overrange capability. This means that it will count pulses up to a frequency of 19.99 MHz direct-

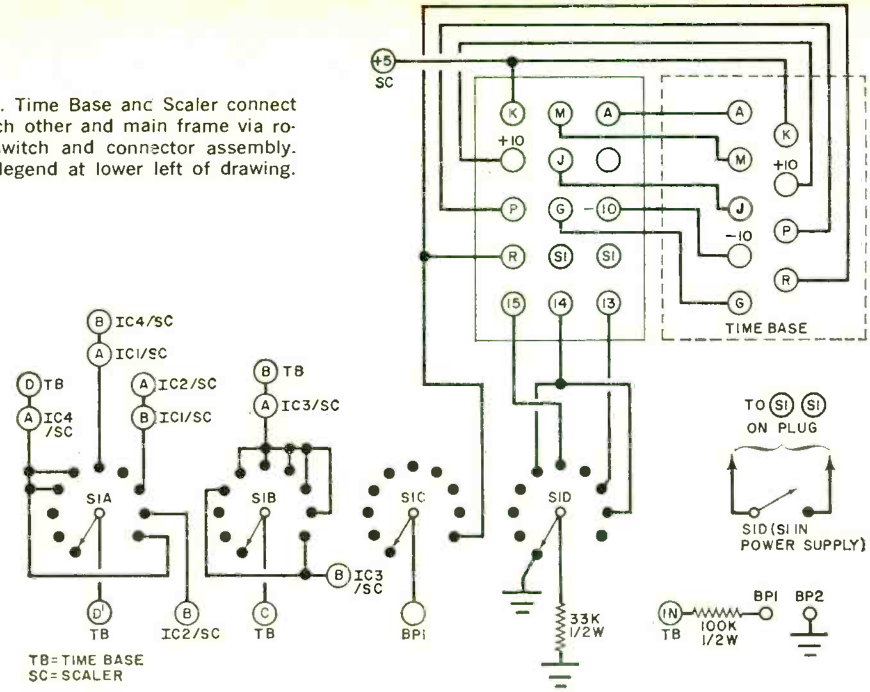


Fig. 9. Time Base and Scaler connect to each other and main frame via rotary switch and connector assembly. Note legend at lower left of drawing.

ly when the module is used with the main frame. Also, the counter has a built-in TEST circuit to which you can switch at any time to check the operational status of the Lab.

Assembling the Module. The use of integrated circuits in the Time Base and Scaler subassemblies makes it necessary that the cir-

(*Continued on page* 96)

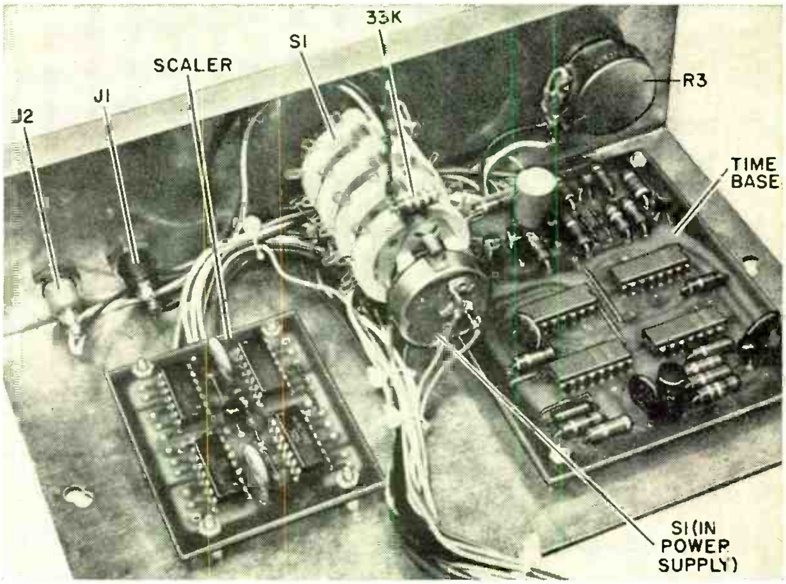


Fig. 10. Time Base and Scaler circuit boards fasten to chassis with 4-40 machine hardware and spacers. A 33,000-ohm resistor (1/2-watt) is used to limit current through decimal point in readouts. Wires connect to foil sides of boards.

THE NUMBERS GAME

IF FOUR IS BETTER THAN TWO, IS SIXTEEN BETTER THAN EIGHT?

In 1961, POPULAR ELECTRONICS turned loose an avalanche and has lived through a storm of brickbats and bouquets. At that time, the "Sweet Sixteen" represented a hi-fi system that many readers wanted to build and find out first hand if the multiple-speaker idea would work. Sometimes it did, many times it didn't. In this article, our specialist on speaker systems tells why.

TO THOSE SYMPTOMS of national madness, such as the tulipmania craze in the 1600's, most knowledgeable audio enthusiasts usually add the multiple-cheap speaker epidemic of the early 1960's. POPULAR ELECTRONICS[1,2] instigated the construction of thousands of speaker systems, each containing 16, or more, small 5" permanent magnet speakers. Although the heyday of the craze has abated, hundreds of these systems are still being constructed—usually for the wrong reasons.

According to the builders of the multiple speaker systems, the obvious advantages could be summarized as follows:

A. The system produces noticeably

BY DAVID B. WEEMS

lower distortion because the amplifier power is divided between many speakers.

B. The use of multiple speakers extends the bass range since mutual coupling permits all speaker cones to work together in unison at the lower frequencies.

C. The dips and peaks in the response of individual speakers are averaged out and the overall frequency response of the system is very smooth.

D. The use of small cones in the multiple speaker system insures the generation of a good treble response.

E. The multiple small speaker system does not require a crossover network and thus eliminates phase shift effects.

F. There is a noticeably "bigger" sound due to the expanded area of the source.

G. The multiple small speaker system can be built for a very low dollar figure.

All of the above qualities represent worthy goals. The reasons supporting each goal seem clear and logical. Yet, the manufacturers of high fidelity speaker systems have failed to exploit the use of multiple cheap speakers. It is natural to ask why. A hard look at the various concepts and the advantages claimed for them may disclose the answer.

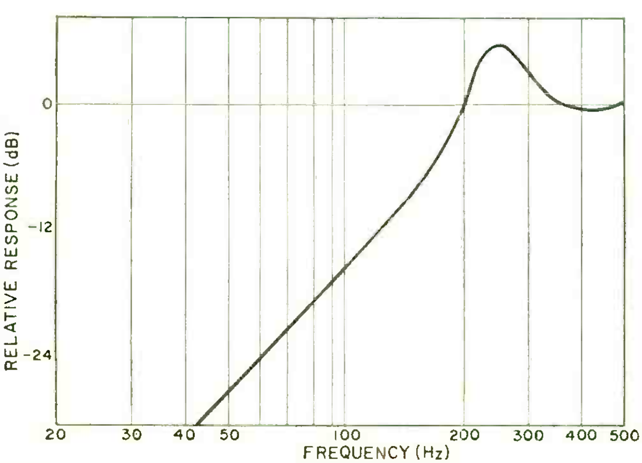
Distortion. The sound output from a loudspeaker is usually not a true representation of the electrical signal input. The production of harmonic and intermodulation distortion are mentioned most often in considering loudspeaker system performance.

Harmonic distortion, frequency doubling, tripling, etc., can be produced in a speaker by either a nonlinear cone suspension or a nonuniform magnetic field surrounding the voice coil. Most speaker cone suspensions exert an increasing force on the cone as the cone moves away from its rest position. By intentional design, the suspension of a high-quality speaker tends to exert the same restoring force on the cone throughout its normal movement range. The magnet and voice coil structure of a good speaker is usually deep enough to always keep the voice coil operating in a field of uniform flux density.

Cheap speakers are made for applications where the normal power handling requirement can be measured in a fraction of a watt. At such sound intensity levels the cone movement—and distortion—is kept within tolerable limits. Since an array divides the power between all speakers, harmonic distortion should not be a major problem in normal use. At the very least, harmonic distortion will generally be lower than if one cheap speaker were used in the system.

However, if the speaker array is used to generate a high level of sound intensity at low frequencies, the cone movement can become excessive—producing distortion. In this case, the nonlinear suspension can be relieved of part of its distortion producing effects by installing the speaker array in a sealed enclosure. The captive air in the enclosure acts as a restoring force and tends to limit cone movement. Unfortunately, the creation of this "pressure box" treatment causes another problem that is discussed later on in this article.

Intermodulation distortion is the mod-



Generalized response curve of a cheap speaker in a sealed box has a resonance peak at 245 Hz. Amplitude of peak would depend upon speaker and enclosure properties.

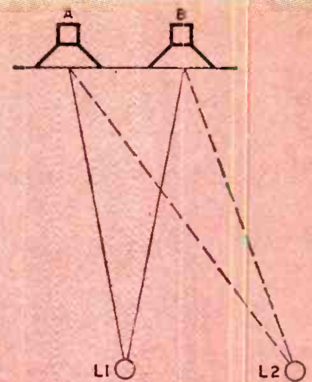
ulation of one audio frequency by another audio frequency. Low frequencies can modulate high frequencies when both are being produced by the same speaker. High quality speaker systems reduce intermodulation distortion through the separation of bass and treble ranges. Thus, these two-way or three-way systems are also not as severely limited in their power handling capacity through a limitation of cone movement. Excessive cone movement aggravates and increases intermodulation distortion.

Bass Response. The bass response of any speaker falls off below the frequency of the fundamental cone resonance. The frequency of cone resonance is lowered as the compliance and mass of the cone are increased. The simplest and most obvious method of obtaining extended bass response has always been to choose a speaker with a low fundamental cone resonance frequency.

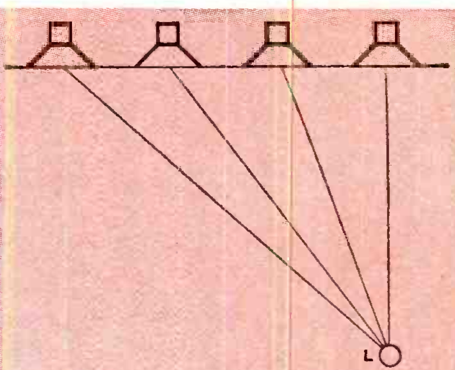
The idea of using a number of speakers to generate low audio frequencies at very high power levels was suggested as early as 1931.[3] Because of this suggestion, there have been claims that mutual coupling extends the bass response to a degree that is limited only by the number of speakers used. However, subsequent to the publication by POPULAR ELECTRONICS of the "Sweet Sixteen" system, James F. Novak[4] presented a mathematical analysis showing that coupling occurs at certain bands of frequencies and that these bands are determined by the separation between individual speakers. For example, when the center-to-center spacing between speakers is less than ⅛ wavelength, the air mass offers a reactance to the sound output. For the usual separation—about 6" to 8"—this puts a lower limit of about 200 Hz on the coupling range of an array of small speakers. To lower this frequency, the speakers should be moved farther apart; but confusing the issue, to make the coupling more effective, speakers must be close together.

Besides contending with the problem of spacing between speakers, the builder must also decide whether the enclosure holding the speaker array is to have an open back or be built as a sealed enclosure. Since mutual coupling increases the air load, the effective mass of the speaker cones is increased tending to lower the resonant frequency of the array below that of a single speaker. However, when the array of speakers is mounted in an airtight enclosure, the fundamental resonance of the speaker system is raised. In this trade-off, if the enclosure is small enough to add some restoring force to the cones and reduce distortion, it will also have the effect of raising the array resonance probably far above the original frequency of an individual speaker. Theoretically, a cheap speaker in a sealed enclosure should have its amplitude of peak resonance vary inversely with the damping on the speaker (see illustration). Cheap speakers are notoriously poorly damped, both electrically and mechanically. Of course, the point of resonance can be lowered by omitting the enclosure back, but the distortion increases and the frequency response curve of the speaker system becomes dependent on the shape of the open-backed box.

A large, shallow open-backed box pro-



Effect of changing listener position from L1, on-axis with two speakers, to L2, off-axis. Difference in sound path lengths at L2 makes phase shift. Cancellation occurs if difference is ½ wavelength (phase shift of 180°).



Off-axis listener to multiple speaker system is at different path lengths from various speakers. Differences change as he moves from location to location. (Drawing not to scale.)

duces less peak amplitudes and more extended response than a small, deep open-backed box. Unless distortion becomes a major problem, the back should always be removed from the enclosure of a multiple cheap speaker system to improve the bass response.

Synthetic Bass. Distortion, especially that caused by driving the speakers to the limits of their suspensions or magnetic fields, may produce the illusion of more bass frequency response. Griffiths[5] experimented with electronically induced distortion and seems to have confirmed the existence of this illusion.

In the Griffiths experiment, clipping and distortion, similar to that produced by overdriven cheap speakers, was purposely designed into an audio system with a 200-Hz low-end cutoff. The percentage of distortion was controlled by the listener until the bass was thought to be "equal" to that produced by a low-distortion full-range audio system. Experimental results indicated that most listeners heard more "bass" when the distortion in the filtered system was increased to certain arbitrary values.

Another kind of synthetic bass occurs in speaker systems that have a prominent resonance. A resonant frequency in the upper bass range—say about 250 Hz—may make the system sound full and bassy, although music played through it has a distinct one-note quality. The earliest vacuum-tube amplifier juke boxes were noted for their generous bass response—most of it at one frequency.

Listeners can also be deceived into hearing bass frequency response that isn't there in the first place! A land line telephone system doesn't reproduce the fundamentals of a known voice, but the harmonic structure is recognized by the listener and the ear and brain supply the missing information. This tendency to hear the missing fundamental notes often leads the owner of a miniature transistor radio receiver with a 2" speaker to compliment the product on its "fine tone."

Some types of synthetic bass may sound satisfactory—even impressive—at first hearing. But if the listener becomes accustomed to hearing true fundamental bass response, he won't be happy with synthetic bass again.

Smooth Response vs Phase Shift. One of the qualities attributed to the multiple speaker system is that of a smoothed response—considered to be an absolute requirement for high-fidelity sound reproduction. However, many authorities claim that a medium-range system with a smooth response is preferable to a wide-range system that has numerous peaks and dips in the audio response curve. And, peaks are worse than dips.

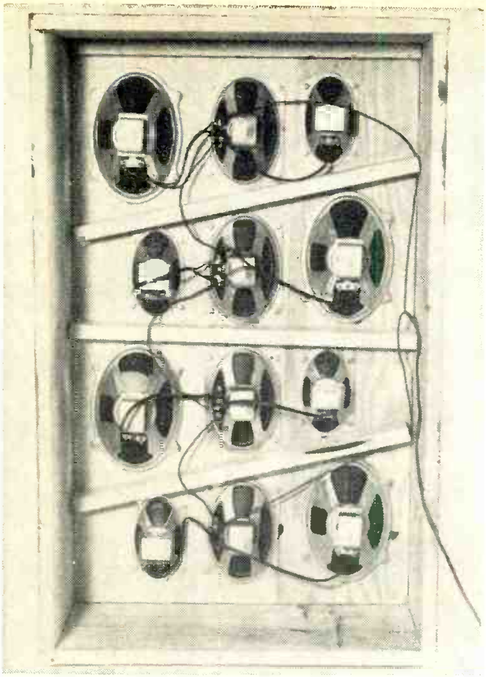
It is now well accepted that a speaker's response curve is always smoother when the speaker is operated at a reduced volume level.[6] For example, a 10" full-range speaker may have a high-level response curve embracing the spectrum between 40-20,000 Hz at ±12.5 dB. When the input is reduced by 75%, the response curve is within ±5.0 dB. Presumably, operating a number of speakers at low volume should flatten the overall response curve. Unfortunately, what sounds good in theory does not produce acceptable results in practice.

The audio enthusiast who has built several multiple-speaker systems soon realizes that the results are fairly unpredictable. A system using only four speakers may sound pretty good, although the builder has a feeling that the sound could be improved. The number of speakers is doubled, but the sound is still not right. The number is doubled again and the system sounds terrible. The faults are numerous, but they are difficult to identify—except for some obvious peaks in the midrange.

The mid-range peaks are due to mutual coupling between speakers. The maximum coupling and boost is at the sound frequency corresponding to a separation of one-quarter wave length. In a multiple-speaker system with center-to-center spacing of 7" to 8", the coupling peak is at about 500 Hz. This peak is insidious and even if not immediately noticeable, makes the system sound "loud" even at low volume levels and eventually proves quite tiring to the listener.

The problem is amplified when speakers are mounted so that there are many identical center-to-center distances and for this reason the square pattern of mounting multiple-speakers is one of the worst possible arrangements. This also helps explain why larger numbers of smaller speakers sometimes sound much worse than a similar system with only four to six speakers.

In addition to the boost in the mid-range by the multiple-speaker system, the same arrangement produces sharply defined peaks and dips at the higher frequencies. These upper-range deviations are noticeable to the listener who is sitting off axis of the system. They occur at frequencies where the sound waves from adjacent speakers reach the listener at various phase angles (see illustrations). Researcher Joel Julie[7] calculated that



Speakers of different sizes permit unequal spacing between speakers and staggered resonances, alleviating two of worst faults of multiple speaker systems. But problem of restricted fundamental bass response and high-frequency dispersion remains.

for a listener 10° off axis of two speakers separated by center-to-center distance of only 8″, the 180° phase shift occurs at 4200 Hz. As the listener moves farther off center, the frequency of cancellation decreases and at 30° it is down to 1650 Hz.

For the two listening positions cited above, the listener would also receive in-phase sound boosting at 8400 Hz and 3300 Hz, respectively. At frequencies other than those specified, the sound waves mix with varying degrees of phase shift and the result is sound-wave phase distortion.

Since the broad results represent what happens with only two speakers, the reader can imagine that the phase interference situation becomes incredibly complex in a multiple-speaker situation.

Phase interference can occur in an ordinary two-speaker woofer-tweeter arrangement, but only at frequencies near the crossover point where both the woofer and tweeter are producing the same tones. Phase shift in crossover networks may be more of a problem than generally recognized, but it could hardly produce the nightmare that is generated from multiple speakers mounted on a single baffle.

The Big Sound. The feeling of spaciousness from a sound source depends, in part at least, upon good dispersion. Large speakers are notoriously directional devices at the higher audio frequencies. At frequencies above that at which the wavelength of the sound is equal to the diameter of the speaker cone, the dispersion is poor. Thus, when several speakers are mounted on a square baffle and all of them reproduce the high audio frequencies, the source is spread over the baffle, and dispersion suffers.

Cost. Since the introduction of the "Sweet Sixteen" in the early 1960's, the cost of building such a system now mitigates against its construction. Numerous manufacturers now offer a variety of woofers with resonant frequencies and prices far under comparable models available 10 years ago. Meanwhile, the cost of plywood and other lumber has skyrocketed and when this material cost is added to the price of obtaining 16 speakers, the multiple-speaker array is no longer cheap.

To make such an investment in an essentially cheap speaker system defeats one of the main purposes of assembling a multiple-speaker system.

It would be unfair not to mention in this article that there are useful purposes to be served by multiple speaker systems. Several good-quality woofers in a multiple system will handle far more power with much lower distortion than a single woofer. The use of multiple speakers in a line radiator provides good horizontal dispersion and the omnidirectional speaker system can frequently be used to definite advantage.

The ordinary multiple-speaker system has seen its day. It was a good idea—but, the facts of life are catching up with it. —30—

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Third in a Monthly Series by J. Gordon Holt

FOUR-CHANNEL STEREO is here. Whether it is here to stay is questionable; but one thing certain is that, the less it costs the consumer, the better are its chances of survival.

Ideally, four-channel stereo should be reproduced using a four-channel tape play-back machine, a four-channel preamplifier, two stereo amplifiers, and four loudspeakers. This will be expensive, even if you are prepared to swap four medium-fi channels for two hi-fi channels. It will also mean a permanent commitment to tape, which is persistently costlier than discs and makes your disc collection obsolete if for no other reason than that you just won't buy anymore discs.

The high cost of four separate channels is not likely to dismay the home equipment manufacturers. But if recording studios and broadcasters have to scrap some of their present equipment and duplicate the rest of it in order to switch to four channels, they will drag their feet; and that, plus consumer resistance, could quash quadrasonics before it ever gets off the ground. Under the circumstances, it is hardly surprising that there is considerable interest in the possibility of going four-channel without having to go all the way.

A number of people are working on ways of reproducing four channels via two channels; and at the time this was written there had been demonstrations of two such systems: one developed by Peter Scheiber and the other promoted by David Hafler of Dynaco—who points out that he did not invent it. (The "Hafler system" and some interesting variations thereof have been in use in some European countries for at least four years.) There will be others demonstrated in the future: and the industry will take careful note of each because one of them may determine the future (or lack of it) of four-channel sound.

The problem facing these designers is that there is simply no way, at any "state of the art," of making two channels carry as much information as four channels. The thing that offers some hope of success is the fact that, most of the time, the two channels of a stereo pair are not fully "occupied" by program material; and when they are, there is usually a substantial duplication of material in both channels. Thus, the hope is to use the "gaps" between unduplicated signals to carry information for the other two channels or to find a way of preventing material from wasting space.

Both the Scheiber and Hafler systems are based on the latter approach, using matrixing to suppress duplicated material in such a way that a later "comparison" between the channels from which it was removed allows it to be reconstituted. Matrixing, by the way, simply refers to a process whereby differences in the intensity and electrical polarity of two or more signals are used to cancel out unwanted material and strengthen the desired material.

In the Groove. The easiest way to visualize how matrixing works in the Scheiber and Hafler systems is in terms of stylus motion in a disc groove. The solid arrows in Fig. 1 show the direction in which the stylus tip vibrates in a conventional two-channel recording, as viewed from the front of the pickup. Modulations in the left and right channels are at a

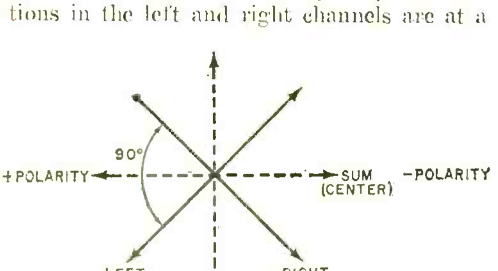


Fig. 1. Stylus motions in two-channel disc groove. Dotted arrows are resultants of left/right axes.

45-degree angle to the horizontal and at right angles to each other. The right-angle relationship is important as it permits the stylus to move along one axis without changing its position along the other axis, to provide theoretically perfect channel separation.

The dotted horizontal arrow in Fig. 1 represents the direction of stylus motion when both stereo channels carry identical in-phase information (that is, both move simultaneously at 45 degrees to left or right). The *average* motion then is horizontal, at 45 degrees to each axis, separation is only 50% and each main channel reproduces half of the resulting signal in-phase. This condition causes the sound to "appear" midway between the side speakers, directly in front of the listener. Normally, it is a "phantom" center, since it seems to be coming from a loudspeaker where there *is* no loudspeaker, but if a third speaker is connected so as to receive the combined signals from the left and right channels, the resulting "matrixed" signal will appear from that speaker twice as loud as from either side speaker. This effectively derives a third channel from the original two.

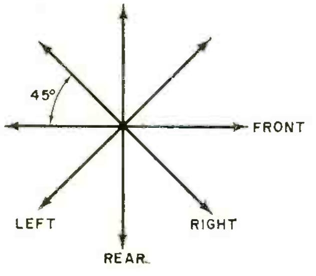


Fig. 2. Hafler system derives signals from sum/difference axes to drive front and rear speakers.

The difference information in a stereo groove comes through as *vertical* modulations (dotted vertical arrow). If a signal is equal in both channels but out of phase, difference (vertical) information will be at a maximum, the front-center adding channel will "see" equal plus and minus polarities, and complete cancellation of the signal will occur. The center speaker will be dead, while the side speakers will each reproduce half of the total signal out of phase.

Now, suppose we add a fourth loudspeaker, connected so as to respond only to difference signals. Equal out-of-phase signals will then be reproduced through that speaker, twice as loud as through the side speakers, while the front center speaker will remain "dead." This is how the Hafler four-channel system works.

Figure 2 shows how these four channels are represented by groove modulations. Note that the front and rear modulations are at right angles to one another (providing 100% potential stereo separation) but adjacent channels are 45 degrees apart so separation between these cannot be better than 50%. Thus, while it is possible for a perfectly balanced signal to cut one channel off completely, the other three channels will continue to be active, and the center one of those will be twice as loud (+3 dB) as the flanking channels. This is enough "separation" to provide a strong impression that the sound is coming from that center speaker, as long as you sit roughly in the middle of a four-speaker rectangle. A closer seat to any one of the three active speakers will make it predominate even when one of the others is 3 dB louder.

But Is It Compatible? Mr. Hafler claims that his system is "completely compatible with normal two-channel stereophonic reproduction," which is almost but not quite true. On a two-channel system, a point-source rear signal would emerge out-of-phase from the side speakers, producing the vague kind of imaging normally expected from out-of-phase speakers. This is hardly compatibility. Monophonic playback would be even less satisfactory, since the mixing of the out-of-phase rear signals would cancel them out, neatly eliminating from the music any instruments that were located at the rear of the listener.

There are some definite advantages to the Hafler system, not the least of which is its extreme simplicity. The playback dematrixing of the four channels from two can be done without electronic hardware. All it takes is four (preferably identical) loudspeakers connected as shown in Fig. 3. You can in fact dispense with the front center speaker if the side speakers are able to produce a firm and definite "phantom center" by themselves. The fact that the consumer will not have to buy decoding devices may, however, account for some of the industry's current lack of enthusiasm.

Another nice thing about the Hafler system, at least as far as the consumer is concerned, is that it can be used with some existing two-channel recordings to derive a legitimate rear-ambience signal. The theory here is that any natural ambience, having been reflected several times from the walls and ceiling of the recording hall (upholstered seats minimize floor reflections), has random phasing, of which roughly half at any given moment is out-of-phase energy that will be reproduced

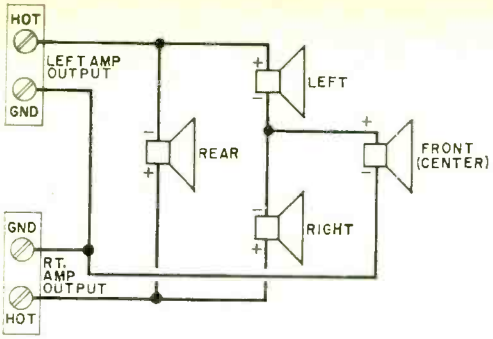


Fig. 3. Dynaco's recommended loudspeaker hookup for Hafler four-channel playback. All speakers should be identical, and the two stereo channels should be modified to provide 6 dB of separation (unless a separate summing amplifier is used to drive the front center loudspeaker).

by the rear loudspeaker. Because of the limited separation between the rear speaker and the side speakers, some side-channel information comes through the rear speaker along with the ambience, but there is enough pure ambience in many recordings to add an impressive sense of spaciousness to the sound, and to make two-channel reproduction sound disturbingly "flat" by comparison.

As Dave Hafler points out, the effect could be greatly heightened if the recording companies actually added extra out-of-phase ambience to their two-channel recordings, instead of depending on random-phase pickup from their present mike setups. His suggestion has not been met with overt enthusiasm from the major American recording companies, but industry scuttlebutt has it that some European companies are already doing this, and four-channel playback of some recordings (a la Hafler) would seem to confirm this rumor. I have not heard of any disc manufacturer who is making—or even contemplating—four channel ping-pong recordings for Hafler playback, although this would be possible with the separation and compatibility limitations mentioned previously.

Peter Scheiber has not, to my knowledge, made any claims for the compatibility of his system. In fact it is less compatible than the Hafler proposal. The Scheiber system uses exactly the same matrixing procedures as Hafler, but with two significant differences. One of these is shown in Fig. 4, where it will be noted that the stylus axes for the four channels lie midway *between* the axes used by the Hafler system. It is as though the whole arrangement had been rotated 22½ degrees. This initial phase rotation or "encoding" takes place in a circuit that is a masterpiece of simplicity, involving only a handful of resistors.

Something Extra. The dematrixing decoder for the Scheiber system playback does exactly the same thing in reverse, but because the axes of adjacent channels are at 45° angles to each other, the adjacent-channel separation is no better than from the Hafler system. Scheiber carried things a bit further, though, by adding to the basic decoder circuit a pair of variable-gain control amplifiers and sensing circuits. Now, when a signal is supposed to appear in one channel only, the device senses the very large separation between that channel and the opposite one and automatically shuts off the two adjacent channels where crosstalk is appearing. At the same time, the levels of both the "speaking" channel and its opposite (which has unlimited separation) are increased to overcome the 3-dB dematrixing loss. The control action is almost instantaneous so it can operate selectively within the structural details of a complex signal, "picking out" each cycle and routing it to the proper speaker.

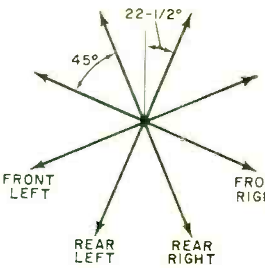
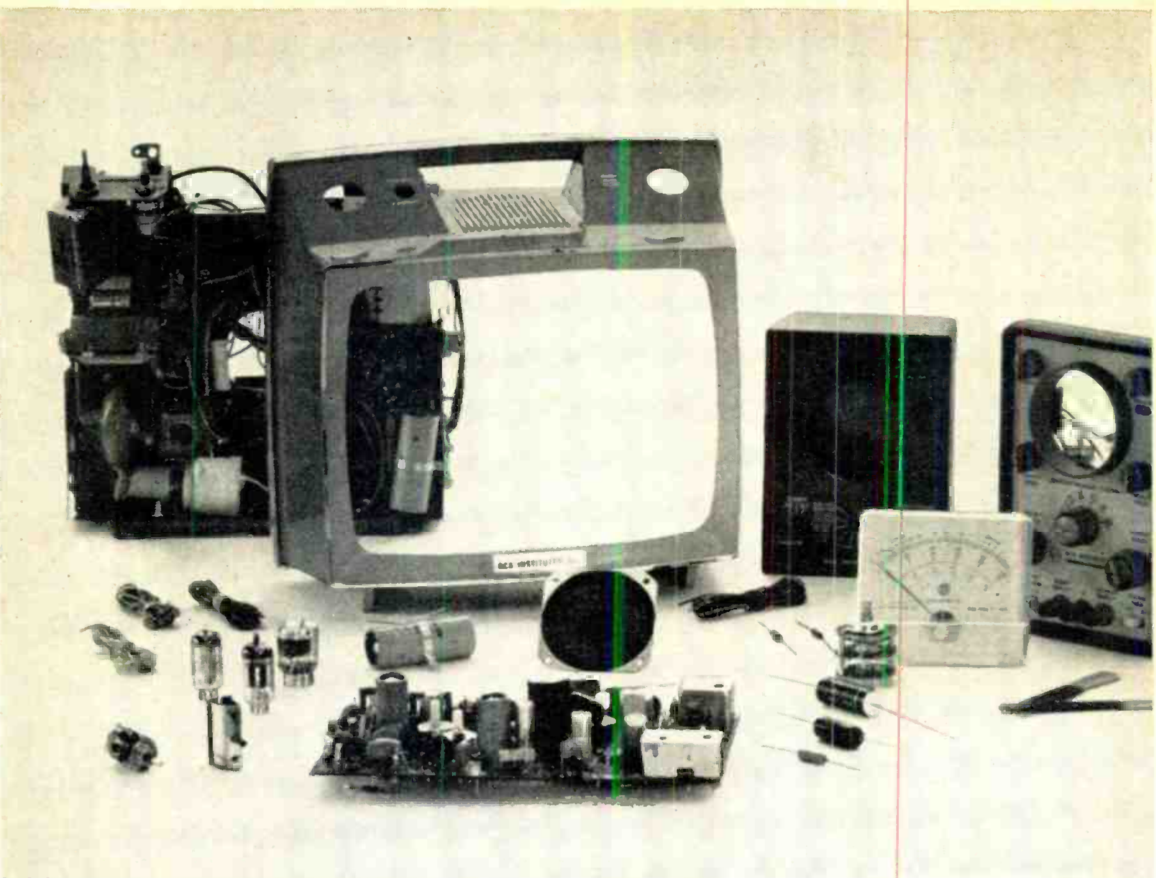


Fig. 4. Scheiber system produces modulation axes 22½° rotated from those used in Hafler's system.

Unlike the Hafler system, the Scheiber *can* reproduce four-channel ping-pong effects, and this is in fact its strong point. At the demonstration I attended, I was not able to tell any difference whatsoever between a four-channel tape of ping-pong-times-two material and the Scheiber playback, but I wasn't so sure about how it behaved with more complicated program material. Perhaps complex signals such

(*Continued on page* 100)



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THE PRODUCT GALLERY

Third in a Monthly Series by "The Reviewer"

AS A GENERAL RULE I would prefer not to discuss a couple of allied products in the same column, but the summer months provided the opportunity to take a close look at CB (Citizens Radio Service). As a result, I am devoting much of this column to a CB antenna that has been around for several years and a 5-watt input mobile CB transceiver that apparently typlifies current trends in circuit design and performance.

The Avanti "Astro-Plane." There is no textbook explanation or analysis of the unusual physical configuration of the Astro-Plane. It is a CB antenna totally unlike every other base station antenna. To a minor extent the Astro-Plane might be thought of as an inverted colinear with vastly shortened radials and a trombone matching section. But even this supposition is not entirely correct, although maximum signal radiation appears to come from the 4′ "clear" section beneath the capacity-hat or top-loading radials.

Power to the Astro-Plane is introduced to one leg, is divided at the bottom of the antenna and passes to the other leg going up to the "grounded" side of the coaxial line (gamma matching?) and is balanced in the top-loaded section against the lower section of the antenna. The manufacturer claims a vertically polarized 4.4-dB gain over an isotropic dipole and an SWR of less than 1.4:1.

Installation. The Astro-Plane is shipped disassembled in 15 pieces sans supporting mast. The supporting mast section should be at least 12′ long in order to provide a 4′ clearance between the bottom of the Astro-Plane and all other surrounding objects (metallic tower, other antennas, etc.). A coaxial cable feedline must be provided by the user and should be 52-ohm cable. The manufacturer recommends the use of RG-8/U cable for runs longer than 30-35′. The smaller diameter cable—RG-58/U—may be used for short runs.

Assembly time will vary according to what provisions you have available for mounting the supporting mast section. Bolting together the Astro-Plane itself will require under one hour and should be done in an open area where supports can be provided to keep the bottom closed loop and the top-loading radials off the ground.

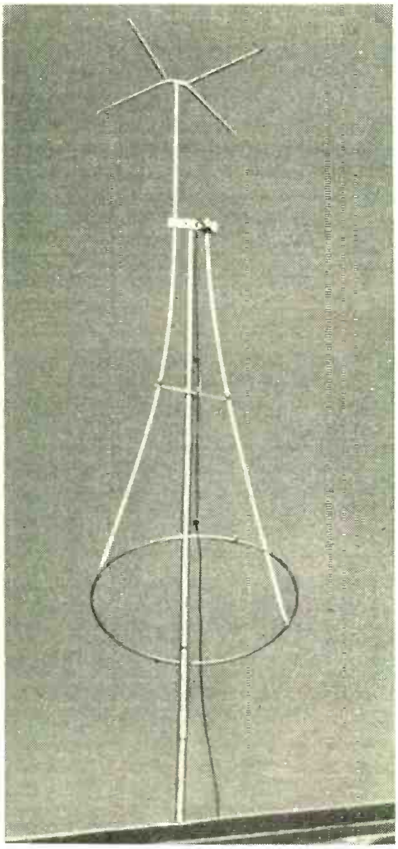
The antenna itself is lightweight (3½ lb) and is physically well-balanced around the supporting mast. Although it doesn't look it, wind loading is minimal and no bending or distortion has been observed at wind gusts up to 40 mi/h.

On the Air. Switching over to the Astro-Plane from a colinear produced several immediate surprises. The background noise level took a nose dive, long range (1000-plus miles) skip signals were stronger and close-in skip (400-500 miles) was weaker. The decrease in background noise level was admittedly disturbing and a check was made on the SWR with the following favorable results:

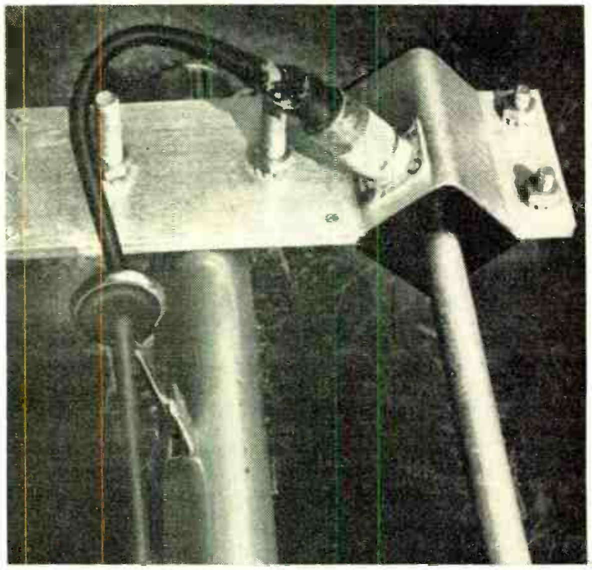
Channel Number	SWR
1	1.5:1
4	1.4:1
7	1.4:1
10	1.35:1
13	1.3:1
16	1.3:1
19	1.25:1
22	1.2:1

Candidly, the exact reason for the reduction in background noise level has not been determined at this writing and may be due to a variety of contributory causes. However, the skip effects appear at first view to verify the manufacturer's claim of greater signal concentration (lower angle of radiation) close to the horizon. The Astro-Plane is strongly polarized vertically and in comparison with other CB antennas seems to attenuate horizontally polarized signals on the order of 24 to 26 dB.

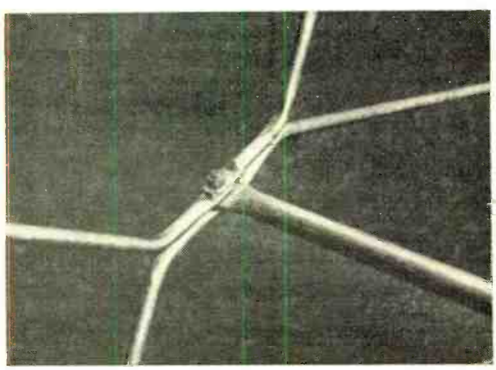
Mounted at the legal height for CB antennas, signals have been heard on ground wave out to 45 to 50 miles. Sky wave signals (both double-hop sporadic-E and F2 layer) have been heard at distances exceeding 2000 miles. As far as can be determined, the horizontal pattern of the Astro-Plane is omnidirectional and the SWR does not change radically when operating the CB base station in a rain shower. After eight weeks of use, I am still pleased with the results and will report further on this antenna during the summer of 1971 after it has been subjected to a winter in the northeastern states.



The Avanti Astro-Plane may be thought of as inverted colinear with short radials (top, above) and a trombone matching section below. Shortened top-loading radials are made of pre-bent seamless aluminum tubing. Liberal use of lock washers (see photo at right) practically eliminates the possibility of wind or ice loading bending the radials.



Don't forget to caulk coax cable plug when it is attached to the Astro-Plane input connector. The liberal use of caulking prohibits moisture from corroding the silver plating on the connector and keeps it from entering the coaxial cable.



(More Product Gallery overleaf)

The B & K Cobra 24. This CB transceiver (5 watts input) can be operated on any one of the assigned 23 channels. The unit is designed for mobile operation (positive or negative ground—up to 14 volts dc input) and a 117-volt ac power supply is available as an optional extra for $32.95. The receiver circuit is dual-conversion with a first i-f of 10.595-10.635 MHz and a second i-f of 455 kHz. A ceramic mechanical filter to provide adequate adjacent channel rejection is used in the first 455-kHz i-f stage and an integrated circuit is used in the second stage. The first mixer is a FET, but the r-f stage is a bi-polar transistor.

A full-time series-gate noise limiter is included in the receiver circuit and the squelch is adjustable (see below). The receiver circuit makes use of amplified agc and bootstrap secondary agc to minimize breakup and overloading when in the immediate vicinity of a very strong signal. The transmitter and receiver are fed from a 14-crystal frequency synthesizer with tolerances exceeding FCC requirements. The modulation is hi-level with audio filtering and speech compression—called "Dyna Boost." The output is rated at 3.5 watts into 50 ohms. Antenna loading may be optimized by adjusting one section of the output network (rear panel insulated screwdriver adjustment).

A switch on the front panel disables the transmitter and feeds the modulator audio output to an external PA speaker. The PA volume is adjustable using panel volume control.

Laboratory Tests. The Cobra 24 tested by POPULAR ELECTRONICS was equal to or better in terms of sensitivity, selectivity and rejection than the manufacturer's published specifications. Absolute AM sensitivity was 0.5 μV for 10-dB (S+N)/N and the squelch threshold operated at the same level. The squelch range is limited (tight) and will not cut off signals exceeding 200 μV input.

Selectivity was measured at just under 7 kHz wide at 6 dB down and 18 kHz wide at 60 dB down. On the test model the second i-f had ended up on 452 kHz instead of 455 kHz which resulted in a lopsided adjacent channel rejection equalling the manufacturer's claimed 50-dB rejection on the high-frequency side and over 70-dB rejection on the low frequency side. Rejection of interference possibly breaking through on the first i-f exceeded 90 dB.

The agc characteristic for a variation of r-f input of 80 dB was about 8 dB. This is within the specifications supplied by the manufacturer who estimates the variation to be ±5 dB (?) with an input change of 5 μV to 0.5 V.

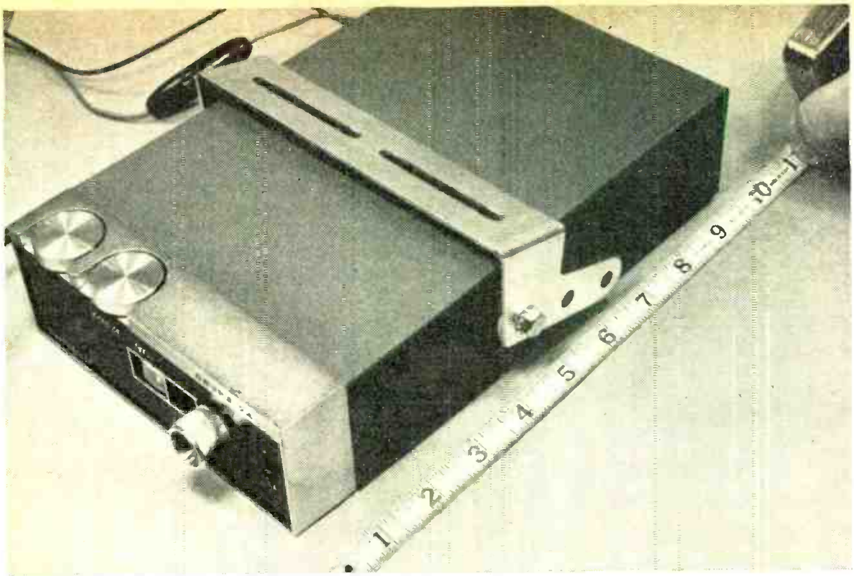
The measured power output (carrier only, unmodulated) with 13.6 volts dc input was 3.25 watts. Modulation is 100% with absence of clipping and distortion although the built-in compression circuit limits only positive peaks.

On the Air. The Cobra 24 was air-tested for several weeks as a mobile unit and performed better than average (if there can be such a thing) CB transceiver. Base-to-mobile transmissions were regularly carried out to distances of 15-plus miles using the Avanti Astro Plane antenna (see above) and the Antenna Specialists M-125 mobile antenna. Modulation from the Cobra 24 as received at the base station was crisp and even a woman's voice appeared to modulate the carrier to 90-100%. The noise limiter in the mobile unit was effective.

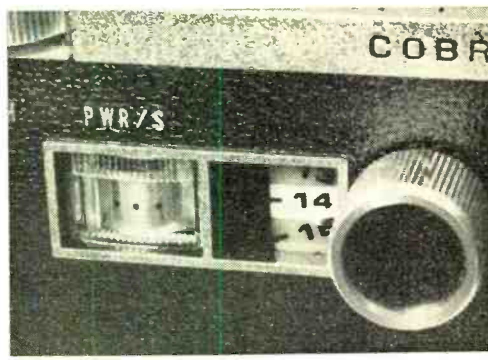
Electronically, the Cobra 24 is an example of the circuit refinements now seen in many Japanese top-quality imports. Personally I would have liked to see the addition of delta tuning to clear up reception of the CB'ers operating slightly off frequency. The thumb wheels on the squelch and volume controls are sufficiently unusual to be a little awkward to handle. Inside the Cobra 24 all parts appear to be well-mounted and presumably the transceiver can withstand road shock for a long time to come.

Work in Progress. Quite a few unusual products are scheduled for review in the next few issues. They include the new Heathkit solid-state color TV, an Ungar IC de-soldering kit, various pieces of test equipment and several audio/stereo items. In addition, I am making up a column of smaller product reviews that will include a couple of things that just barely stay on the right side of the line from being fraudulently advertised. I have been fascinated by ludicrous products and frequently wonder if people really buy things that just couldn't possibly live up to their advertised claims. As much as I detest the idea of giving some people free publicity, I nevertheless feel that it is the purpose of this column to bring some of the phonies to your attention. It'll make interesting reading.

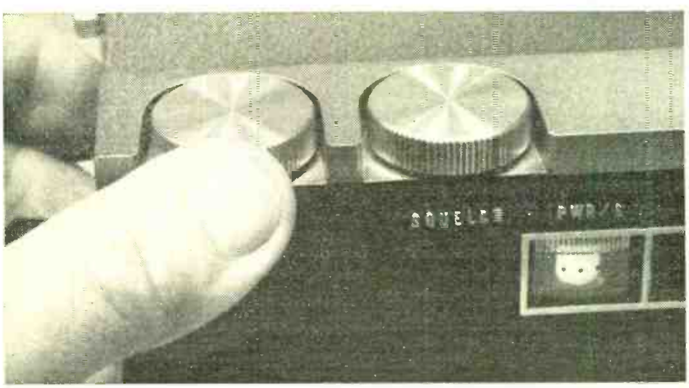
My personal thanks to the many readers who wrote suggestions and constructive criticisms. Your letters were answered and your thoughts appreciated.



The Cobra 24 is one of the slightly deeper mobile CB transceivers. This may present a mounting problem in some automobiles. To be on safe side, allow a minimum of 12" (including the coax cable connector) if you don't want a transceiver that projects too far out from under the dashboard of your car.



Meter indicating incoming signal strength and relative power output is small and uncalibrated. This is of minor importance in mobile operation where visibility is limited and a rough indication is all that is required. However, as a base station, a true, accurate S-meter might be more desirable.



Your reviewer had some mixed feelings about the thumb wheels on the volume and squelch controls. They are unmarked, cannot be reset and require more than a little "getting used to."

FOR MORE INFORMATION
Astro Plane—Circle No. 86 on Reader Service Page 15.
Cobra 24—Circle No. 87 on Reader Service Page 15.

COMMUNICATIONS

SHORTWAVE LISTENING

WWV Time Booklet Available—The 1970 edition of "NBS Frequency and Time Broadcast Services, Radio Stations WWV, WWVH, WWVB, and WWVL" is now available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for 25¢. This 16-page booklet contains detailed information on all the major services provided by the National Bureau of Standards through the WWV chain of stations. Catalog coding for this Special Publication 236 is SD Catalog No. C13.11:236. A copy is invaluable for interpreting the propagation forecast and geophysical alerts.

CITIZENS RADIO (CB)

German CB—Citizens Radio in the Federal German Republic is a farce, according to a first-hand report by Dave Dunwoodie, KDM3144, published in the "7-11 Monitor," Spokane, Washington. Dave says that there are two classes of CB license—one limited to 2 watts input and a second limited to 30 watts input. Licenses are good for one month (!) and you get no callsign, but pay a minimum of $10 depending on the number of mobile units. All outdoor antennas are illegal and operation on channel 17 is frowned upon since it is supposedly used by the ambulance services. Working skip is legal and you can yak your heart (and pocketbook) away.

TELEVISION

TV Channels Go Land Mobile—*The Federal Communications Commission has finalized a new plan to permit sharing of TV channels 14, 15, 16, 17, 18 and 20 with public safety (police/fire), land transportation, industrial and domestic public radio services. Restricted to certain cities (urban areas) the plan permits land mobile operation in the spectrum occupied by TV channels 14 and 15 in New York/northern New Jersey; 14 and 20 in Los Angeles; 15 and 16 in Detroit; 16 and 17 in San Francisco/Oakland; 14 and 16 in Boston; 17 and 18 in Washington; 14 and 18 in Pittsburgh; and 14 and 15 in Cleveland. Allocations for Chicago and Philadelphia are to be made in a few months. TV viewers will now be treated to a hash of public safety signals—as an entertainment bonus.*

SHORTWAVE LISTENING

Changes at BBC?—The External Service of the BBC is in for a rough time according to a press report in the London Sunday Telegraph (August 16). International shortwave broadcasting costs about $28,500,000 per year and the Foreign Office is unhappy about spending that much money without having a bigger say of how it is to be spent and how the External Service is run. Should the Foreign Office put the External Service under its Central Office of Information, the "image" of the BBC's objective news coverage will be lost forever. Shades of Radio Moscow!

CITIZENS RADIO (CB)

And in New Zealand—The information is confusing; but, in response to inquiries about weak phone signals: yes, there is a Citizens Band in New Zealand! The maximum power input is 1 watt and the channels (in numerical order) are: 26,425; 26,450; 26,475; 26,500; 26,525; 26,550; and 26,575 kHz. Sample location prefixes are: AK, Auckland; CH, Christchurch; IN, Invercargill; DN, Dunedin; and WN, Wellington. More specific information about licensing and equipment would be appreciated by the Editors.

AMATEUR RADIO

Hamfest Directory—A Directory of 1971 Hamfests is being prepared by Art Collatz, K9JZM. Distribution will be nationwide. Amateur radio clubs are urged to appoint a representative to notify Art about their hamfest plans by Dec. 1, 1970. Address: Art Collatz, K9JZM, 2127 Market St., Blue Island, IL 60406.

TELEVISION

One More Try For Phonevision—*In late August, the Federal Communications Commission granted Zenith Radio Corporation approval to proceed with its Phonevision system. Zenith Radio and Phonevision (now a misnomer) have been advocating a form of subscription television since 1947. The system was tested over the air via station WHCT (TV), Hartford, Conn. from July 1962 to February 1969. Phonevision is a means of scrambling a TV picture and sound so that it cannot be received via a non-customer's receiver. Subscribers rent a special decoder to unscramble the signal and pay only for those programs that they want to watch—in contrast to cable TV. Zenith radio has given options to RKO General, Teco, Kaiser, and Field Enterprises to use the Phonevision system in selected cities. Subscription-type Phonevision is expected to start in late 1971.*

SHORTWAVE LISTENING

Radio Free Europe and Radio Liberty—There is a strong possibility that both Radio Free Europe and Radio Liberty will discontinue part of their services to eastern Europe within the next few months. The West German government has reportedly made informal inquiries to the United States about cessation of broadcasts until after the 1972 Olympic Games. RFE has cut back on its New York City staff (probably an uncorrelated action) and there are indications that Radio Liberty may reduce its hours of operation. If true, the excessive Soviet block jamming would cease—but heaven help the Communist Chinese when all that surplus jamming equipment is transferred to Siberia.

BROADCAST BAND

King David—*A new pirate AM broadcasting station went on the air at 6:00 a.m. (GMT), September 1. Calling itself "Capital Radio," this pirate is operating several miles off the Netherlands coastline aboard the trawler "King David." The operating frequency is 1115 kHz with 10-kW output power and a daily schedule from 6:00 a.m. to 2:00 p.m. Instead of the top-heavy mast used by many pirate broadcasters—to their grief (see "Radio Hauraki," September issue)—Capital Radio uses a ring-type antenna that is claimed to radiate no sky wave! NRC and IRCA DX'ers take note!*

RESEARCH

It Looks Like a Boo-Boo—Broadcasters—both AM and FM—have begun a campaign to force General Motors (Delco Radio Division)

(*Continued on page* 102)

SOLID STATE

One Hundred Seventy-Fourth in a Monthly Series by Lou Garner

WITH ROCK-AND-ROLL enthusiasts demanding multi-hundred-watt amplifiers, industrial engineers needing multi-kilowatt power controls, and communications specialists seeking higher and higher powers at ever-increasing frequencies, it is not surprising that nearly all semiconductors manufacturers are devoting major efforts to creating more powerful solid-state devices. But, it may come as a mild shock that most of these same manufacturers have smaller, but equally devoted, engineering groups assigned to developing devices with minute power requirements.

Actually, absolute power levels are relatively unimportant in most signal-handling, signal-processing, instrumentation, logic and computational applications, except where physical work must be performed. Electromechanical devices such as solenoids, loudspeakers, and motors require substantial power, naturally, as do induction and dielectric heaters, microwave ovens, and ultrasonic cleaners and machine tools. And, of course, relatively high powers may be required for long-distance data transmission and communication to compensate for fairly large line and radiation losses, but information handling circuits do not, in themselves, require much power. After all, one of the most effective of all information processing and control systems, the human brain, is a relatively low-power device.

The development of effective low-power circuits and equipment designs, then, offers a fertile and challenging field for the serious hobbyist wishing to push the state-of-the-art to its lower limits. A *powerless* functioning circuit, while a theoretical ideal, would be a virtual impossibility, but circuits with power requirements measured in the microwatt range are not only theoretically possible, but within practical reach.

An advanced experimenter tackling micropower projects for the first time should find the following guidelines of value:

- Use only low-leakage active and passive devices—i.e., high-quality silicon rather than germanium transistors, and ceramic or mica capacitors instead of electrolytics.
- Where possible, avoid the use of power-robbing bleeder networks.
- Series diode chains rather than resistive voltage dividers are preferred for stage biasing.
- Design for the minimum bandwidth compatible with application requirements.
- Employ series and/or complementary circuits where feasible, and Darlingtons where high gain is needed.
- Use high-value load resistors to achieve maximum gain per stage.
- If practicable, use class B or class C amplifier stages in preference to class A designs.
- Optimize the circuit stage-by-stage.
- Seek the *minimum* output voltage swing consistent with reliable operation in the intended application—that is, don't "overdesign."

On the commercial level, at least two major firms are now offering microwatt IC amplifiers as off-the-shelf products—Fairchild Semiconductor (313 Fairchild Drive, Mountain view, CA 94040) and Solitron Devices, Inc. (Semiconductor Division, 8808 Balboa Ave., San Diego, CA 92123).

A monolithic operational amplifier requiring only 100 μW standby power when operated on a $\pm$3 volt dc supply, Fairchild's μA735 utilizes a direct-coupled, three-stage circuit featuring twenty-one transistors and sixteen thin-film silicon-chromium resistors. Six of its transistors are diode-connected. The device furnishes an output voltage swing of only $\pm$1.2 volts when powered by a low-voltage source, but can supply swings of $\pm$12 volts when a $\pm$15 volt power source is used. At the higher supply voltage the μA735's standby power is raised to 6 mW. The device's large-signal voltage gain ranges from 20.000 with a low-voltage supply to over 40,000 when higher source voltages are used. As is typical of operational amplifiers, its frequency response is dependent on the type(s) of compensation network used, but a suitable choice of external feedback components will extend the response to over 100 kHz.

Solitron's UC4250 is a general-purpose

operational amplifier designed for use with power supplies of from ±1 to ±18 volts. With a ±1 volt dc source and its quiescent current adjusted to 10 μA the device has a standby power requirement of *only 20 μW*. The UC4250 can furnish a gain of 100,000 into a 10,000-ohm load when operated on a ±6 volt supply, with its quiescent current adjusted to 30 μA.

In tests at Solitron, two miniature electronic watch batteries were used to power a square wave oscillator using the UC4250. The circuit's load current checked out at a mere 100 pA, thus indicating that the oscillator should be able to run continuously for 30 months on one set of batteries. Unfortunately, the actual operational battery life is somewhat less, for these small cells have a rated shelf life of only a little over 15 months. The circuit's power drain is so small, then, that its power supply batteries would fail chemically long before they are exhausted electrically. How about that for low power?

Micropower circuits are particularly useful in medical electronics, biological and geophysical telemetry, portable instrumentation, long-term monitoring, and miniature computers. A recent development in another field may make such circuits of even greater value in medical appliances.

Working with selective catalysts, Drs. J. H. Fishman and J. F. Henry at Leesona Corporation's Moos Laboratories Division (Great Neck, N.Y.) have developed experimental fuel cells using human blood as a source of both fuel and oxygen: In practice, two electrodes are immersed directly into the blood stream, one of which reacts with glucose and similar organic materials, the other with oxygen, to produce electric power. The experimental units tested to date yield approximately 5 μW for each square centimeter of electrode area. Although this power yield may be improved considerably as techniques are refined, it is already sufficient to operate circuits comparable to Solitron's UC4250.

Looking to the future, one day we may see implantable solid-state heart pacers and similar aids which are powered by the patient's own blood stream.

Your editors would be interested in hearing of any micropower circuits developed by our readers. If of general interest, we may find a place for it here.

Reader's Circuit. A practicing engineer as well as an enthusiastic experimenter, reader Eugene Richardson (310 East Mason Ave., Alexandria, VA 22301) feels that the programmable unijunction transistor, or PUT, has not received the attention it deserves and, therefore, is not as widely used by most hobbyists as are such familiar devices as transistors, SCR's, diodes and conventional unijunctions. As he points out, the PUT is an exceptionally versatile device.

Essentially an anode-gate thyristor, the PUT is functionally equivalent to standard unijunction devices, but has a number of superior features. Its stand-by and holding currents are much lower, its *on* resistance considerably lower, and its peak current rating much higher. Further, its firing threshold can be either programmed or made variable and, in addition, its inherent regenerative action gives it a fast-acting characteristic.

As evidence of the PUT's versatility, Eugene has submitted the sweep/frequency divider circuit illustrated in Fig. 1 for consideration and possible use by other experimenters. Capable of delivering either sawtooth or pulse waveforms, its output can be

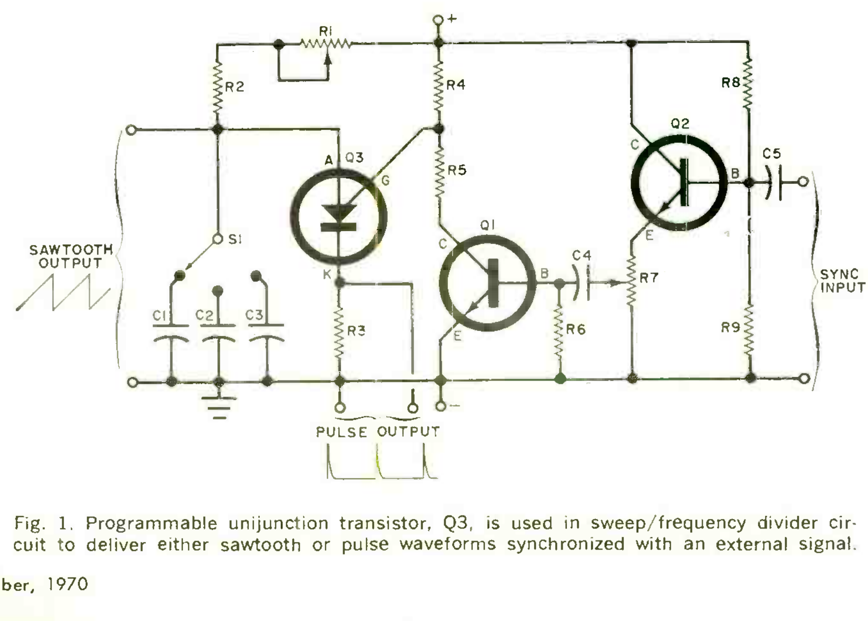


Fig. 1. Programmable unijunction transistor, Q3, is used in sweep/frequency divider circuit to deliver either sawtooth or pulse waveforms synchronized with an external signal.

synchronized with an external signal. He suggests that the circuit can be used as a general purpose waveform or pulse generator or, if preferred, incorporated into other equipment, such as an oscilloscope as a linear sweep, or in a counter as a pulse frequency divider.

In the circuit, the PUT, *Q3*, is used as a modified relaxation oscillator, with *Q1* serving as a bias control device and emitter-follower *Q2* as a sync amplifier/buffer. In operation, *Q3*'s anode-cathode capacitor (*C1*, *C2*, or *C3*.) is slowly charged toward source voltage through a series resistor (*R1* and *R2*), forming the leading ramp of a sawtooth waveform. During this period, *Q3*'s gate is maintained essentially at source voltage, because *Q1*, (part of the gate bias voltage-divider consisting of *R4*, *R5* and *Q1*'s emitter-collector resistance), is operated without base bias and acts as an open circuit. Under these conditions, the PUT cannot "fire" (i.e., switch to a conducting state).

If, at this time, a positive-going sync pulse is applied to *Q1*'s base, the transistor starts conducting, dropping the PUT's gate voltage below its anode voltage and causing it to fire, discharging the anode-cathode capacitor through cathode resistor *R3* and developing a sharp output pulse. With the capacitor discharged, *Q3*'s anode voltage drops and the device switches back to a non-conducting state, permitting the cycle to repeat.

For optimum operation, the sync pulse rate should be at a frequency comparable to *or higher than* the relaxation oscillator's "natural" frequency, as determined by the supply voltage and its anode-cathode RC time constant (*R1-R2* and *C1*, *C2* or *C3*). In fact, the sync pulse rate may be several times higher than the circuit's natural frequency, for the PUT will not fire until its anode voltage reaches a pre-established peak value. Since the output pulse rate (across *R3*) can be an integral fraction of the sync frequency, the circuit may be used as an effective frequency divider.

In practice, *S1* serves as a frequency range control, selecting various capacitor values and thus changing the relaxation oscillator's RC time constant. Similarly, variable resistor *R1* acts as a "fine frequency" control. Potentiometer *R7* provides an adjustment of sync amplitude.

Eugene has not specified component values for his circuit, indicating that these will be determined by the individual devices used, by the dc supply voltage, by the desired

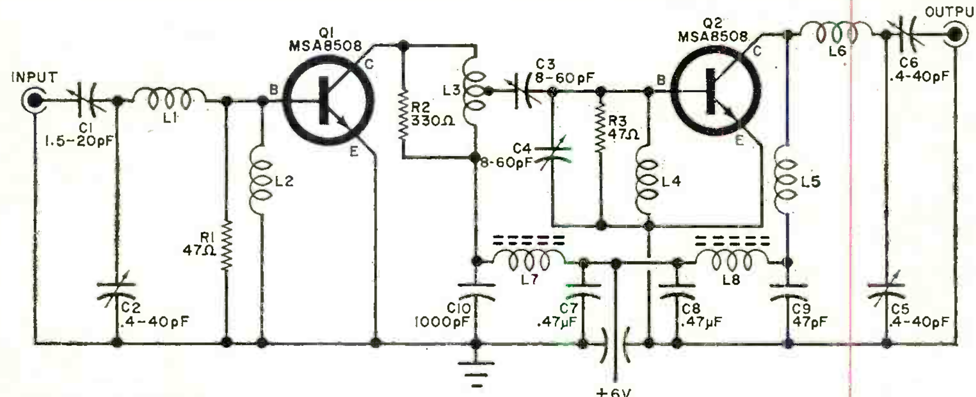


Fig. 2. R-f power amplifier employing npn VHF silicon power transistors can be used in either hand-held, base station, or mobile applications. Operating frequency can be changed by varying LC values.

repetition rate(s) (frequency), and similar factors. However, he has suggested that the PUT can be GE types D13T1 or D13T2, or Motorola types MPU131 to MPU133. The other transistors (*Q1*, *Q2*) should be low-leakage, general purpose npn silicon devices. A relatively low value (under 50 ohms) resistor should be used for *R3* to insure a sharp output pulse and short discharge time.

Manufacturer's Circuit. Originally designed for operation in the Land Mobile Communications band, the r-f power amplifier circuit in Fig. 2 was abstracted from a brochure published by Fairchild Semiconductor to illustrate the use of their MSA8506-08 series of npn VHF silicon power transistors. Hams should find the circuit of particular interest, for it can be used in either hand-held, base station, or mobile applications. A complete transmitter may be assembled by adding a suitable crystal-controlled FM oscillator/buffer, an antenna, and a dc power supply to the basic amplifier. The circuit's center operating frequency (175 MHz) may be shifted to other bands simply by changing its LC component values, although the transistors specified in the design are characterized for optimum performance at from 150 to 175 MHz.

The circuit is a straightforward arrangement with two cascaded npn common-emitter stages, *Q1* and *Q2*. Broadband coupling is used throughout to insure satisfactory operation with FM signals. Adjustable input (*C1-C2*, *L1-L2*) and output (*C5-C6*, *L5-L6*) networks are included to provide efficient coupling to the driver and antenna, respectively, while a tapped coil, *L3*, insures a match of interstage impedances.

Referring to Fig. 2, *Q1* and *Q2* are Fairchild type MSA8508. Capacitor *C1* is a 1.5-20 pF Arco type 402; *C2*, *C5*, and *C6* are 0.4-40 pF Arco type 403; *C3* and *C4* are 8-60 pF Arco type 405; *C7* and *C8* are 0.47 μF ceramic discs; *C9* a 47 pF mica capacitor; and *C10* and *C11* are 1000 pF feedthrough types. Resistors *R1* and *R3* are 47-ohm, ¼-watt, 5% resistors; while *R2* is a 330-ohm, ¼-watt, 5% unit.

Both hand-wound and commercial coils are used in the amplifier. *L1*, *L5* and *L6* each consist of 2 turns of #18 wire, ¼" diameter; *L3* consists of 3 turns, #18, ¼" diameter, with a tap at 1½ turns; *L2* and *L4* are 33 μH chokes; while *L7* and *L8* are small ferrite chokes (Ferroxcube #200-10-3B).

In common with most VHF projects, layout and lead dress are reasonably critical. Good r-f wiring practice must be observed

SOLID STATE

(*Continued from page* 85)

when duplicating the circuit, with signal leads kept short and direct and common ground points used in each stage.

According to Fairchild, the basic circuit will deliver 5 watts r-f output when driven by a 200 mW signal and operated on a 6-volt dc source. The design is not critical with respect to either drive or supply voltage, however, and, within reasonable limits, both higher and lower drives as well as dc voltages may be used without changing component values. With a 12-volt power supply and 400 mW drive, for example, the amplifier should deliver over 8 watts.

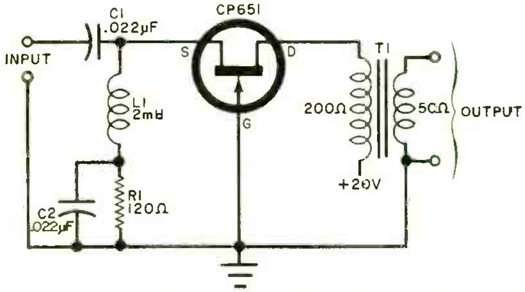
R.F. Preamp. We discovered the schematic illustrated in Fig. 3 in the back of a catalog recently issued by Teledyne Crystalonics (147 Sherman St., Cambridge, Massachusetts 02140). Although relatively simple, the design should have numerous potential applications in r-f instrumentation and communications as a general purpose preamplifier.

Featuring a type CP651 *n*-channel JFET in a grounded-gate configuration, the preamp could be duplicated easily in a single evening by any hobbyist with average skills. Standard components are used throughout, with *C1* and *C2* small ceramic capacitors, *R1* a half-watt resistor, and *L1* a 2 mH. r-f choke. Inductor *T1* is a 200:50-ohm untuned impedance matching r-f transformer. A 20-volt dc power supply is required, with the unit drawing 30 mA.

Crystalonics indicates that the preamp has a bandwidth extending from 500 kHz to 40 MHz and can furnish 10-dB voltage gain with a dynamic range of 140 dB. It will accept input signals of up to 3 volts p-p and has a noise figure of only 2.5 dB. Its cross-modulation characteristics are quite good. With 1-volt, 3-MHz and 5-MHz test signals, the 3rd order product is down 44 dB, while 0.25-volt signals reduce the 3rd order product to a low −80 dB.

Device News. Two new MODEM IC's, the MC1488L and MC1489L, have been announced by Motorola Semiconductor Products, Inc. (P.O. Box 20912, Phoenix, AZ 85036). Supplied in 14-pin dual in-line ceramic packages, both devices are DTL/TTL compatible monolithic integrated circuits designed to provide systems interfacing between communication networks and data terminal equipment. According to the manufacturer, these two new units are the forerunners of a planned line of MODEM system circuits.

The MC1488L is a quad line driver consisting of four NAND gates: three two-input gates and a single input gate. Its output current is limited to 10 mA to comply with an applicable EIA standard.

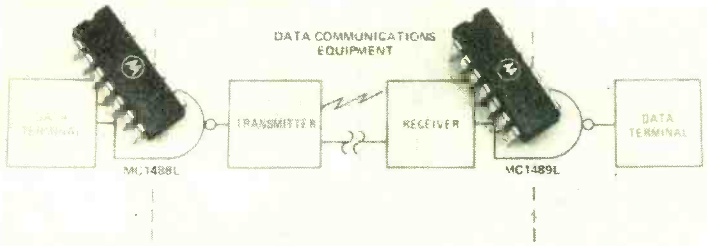


The MC1489L is a quad line receiver including four special two-input NAND gates, with each containing three inverting stages. One input of each gate can be used as a response control node, and feedback is provided from the second to the first stage of each. With the response control input open,

(*Continued on page* 94)

Fig. 3. An n-channel JFET in grounded-gate configuration (left) has applications in r-f instrumentation as a general purpose preamp.

New MODEM IC's from Motorola include a quad line driver containing four NAND gates (below left) and a quad line receiver which contains four two-input NAND gates. Both are DTL/TTL.

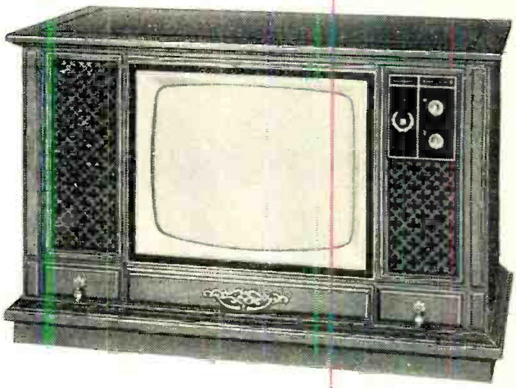


New from Heath...in time

New Heathkit® solid-state modular color TV

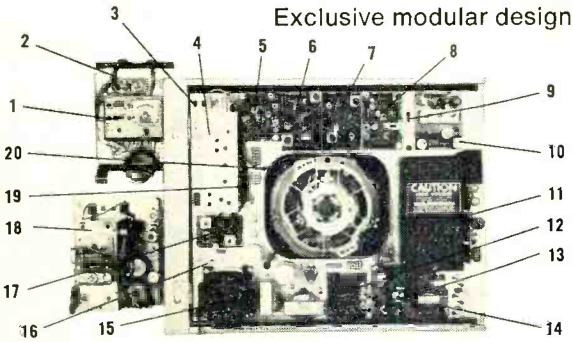
The result of over five years in research and development, these sets represent one of today's greatest color TV values. Here's why: a total of 45 transistors, 55 diodes, 2 silicon controlled rectifiers, 4 IC's containing another 46 transistors and 21 diodes plus 2 tubes (picture and high voltage rectifier) combine to deliver performance and reliability unequalled by any conventional tube set. Other features include: MOSFET VHF tuner; high-gain 3-stage solid-state IF; emitter-follower output; automatic fine tuning; VHF power tuning; built-in degaussing plus manual degaussing coil; automatic chroma control; adjustable noise limiting and gated AGC; "instant-on"... sound instantly, picture in seconds; bonded-face, etched glass picture tubes; adjustable tone control; exclusive hi-fi outputs; and 48-hour factory service facility for modules. The sets are designed to be owner-serviced ... the only sets on the market with this exclusive feature. A built-in dot generator, volt-ohm meter, and modular snap-out epoxy circuit boards make routine adjustments and service a snap... virtually eliminating service calls and offering significant savings over the life of the set. It all adds up to the color TV buy of a lifetime in the GR-270 and GR-370 ... ready now for Christmas giving!

Kit **GR-270,** 227" 20V tube, 114 lbs. **$489.95***
Kit **GR-370,** 295" 23V tube, 127 lbs. **$559.95***
Kit **GR-370MX, GR-370** with RCA matrix tube, 127 lbs. **$569.95***



- Modular plug-in circuit board construction
- MOSFET VHF tuner and 3-stage IF
- Pushbutton channel advance
- Hi-fi sound outputs — for amplifier
- Designed for owner-servicing

Exclusive modular design

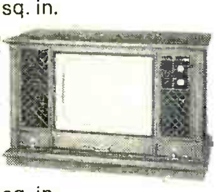


1 Exclusive check-out meter
2 Tilt-out convergence/secondary control panel
3 Gun shorting switches
4 3-stage IF assembly
5 Plug-in AGC/Sync circuit board
6 Plug-in 3.58 MHz oscillator circuit board
7 Plug-in Chroma circuit board
8 Plug-in Luminance circuit board
9 Service and Dots switches
10 Plug-in Video Output circuit board
11 High voltage power supply
12 Plug-in Vertical Oscillator circuit board
13 Plug-in Horizontal Oscillator circuit board
14 Plug-in Pincushion circuit board
15 Conservatively-rated power supply components
16 Circuit breaker protection
17 Plug-in Sound circuit board
18 Master control panel
19 Hi-fi sound output
20 Plug-in wiring harnesses and connectors for faster assembly

Choice of factory-assembled cabinets

3 models in 295 sq. in.

Luxurious Mediterranean Cabinet...factory assembled of fine furniture grade hardwoods and finished in a flawless Mediterranean pecan. Statuary bronze trim handle. 30-1/32" H x 47" W x 17¾" D.
Assembled GRA-304-23, 78 lbs. **$129.95***

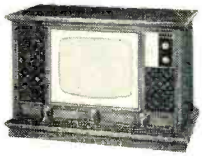


Deluxe Early American Cabinet...factory assembled of hardwoods & veneers and finished in classic Salem Maple. 29 21/32" H x 37¼" W x 19¾" D.
Assembled GRA-303-23, 73 lbs. **$114.95***

Contemporary Walnut Cabinet...factory assembled of fine veneers & solids with an oil-rubbed walnut finish. 29 17/32" H x 35 13/16" W x 19⅞" D.
Assembled GRA-301-23, 60 lbs. **$74.95***

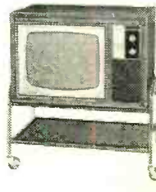
3 models in 227 sq. in.

Exciting Mediterranean Cabinet...assembled using fine furniture techniques and finished in stylish Mediterranean pecan. Accented with statuary bronze handle. 27 31/32" H x 41⅞" W x 19 9/16" D.
Assembled GRA-202-20, 85 lbs. **$114.95***



Contemporary Walnut Cabinet and Base Combination. Handsome walnut finished cabinet sits on a matching walnut base. Cabinet dimensions 20 31/32" H x 31 7/16" W x 18⅝" D. Base dimensions 7¾" H x 27¾" W x 18⅝" D.
Assembled GRA-203-20 Cabinet, 46 lbs. **$49.95***
GRS-203-6 above cab. w/matching base, 59 lbs. **$59.95***

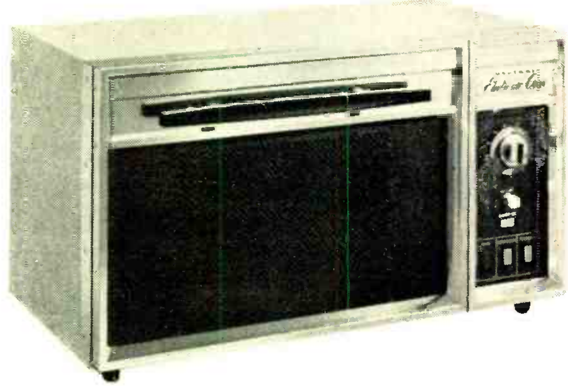
Handy Roll-Around Cart and Cabinet Combination. Features the GRA-203-20 walnut cabinet plus a walnut-trimmed wheeled cart with storage shelf.
Assembled GRA-203-20 Cabinet, 46 lbs. **$49.95***
GRA-204-20 Roll-Around Cart, 19 lbs. ..**$19.95***
GRS-203-5 Cart & Cabinet Combo, 65 lbs. **$59.95***



for Christmas giving

New Heathkit Electronic Oven

...only $399.95*



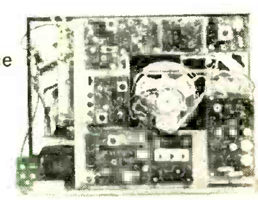
Now, through the miracle of microwave energy, a cooking revolution that frees you from conventional kitchen drudgery forever!

Imagine a baked potato in 4 minutes; baked beans in a little over 6 minutes; a five-pound roast in 45 minutes. This is the miracle of microwave cooking. And now Heath brings you this modern miracle for the first time in money-saving, easy-to-assemble kit form. For busy families on the go, meal preparation is a matter of minutes. You can cook on china, glass, or even paper dishes since only the food becomes hot. Your cooking dish can be your serving dish. Frozen foods can be defrosted in minutes for quick spur-of-the-moment frozen meals cooked right in their own containers. And there is not the slightest cause for concern about the safety of your Heathkit electronic oven. Exclusive door design prevents microwave leakage from the oven cavity. And with a SAFETY INTERLOCK SYSTEM UNIQUE IN THE INDUSTRY, not only does the oven stop cooking if the door is opened, but the door can't be opened unless the interlock is operating properly. A second independent door interlock is also provided for maximum protection. And all interlock mechanisms are tamperproof. Assembled in accordance with the manual, the GD-29 meets all the new federal standards for safety and radio interference. No special precautions are required when operating. The Heathkit electronic oven is as safe as your conventional oven! Quality components are used throughout: magnetron tube by Litton, the uncontested leader in the field; avalanche diode circuitry for longer tube life; simplified wiring harness with push-on quick-connectors for reliability and ease of assembly. GD-29 prototypes endured grueling "life-tests" equivalent to over 60 years of continuous service... further assurance of uncompromised reliability. Another feature is portability: the Heathkit electronic oven operates on regular household current. Plug it in anywhere... on a countertop, a wheeled cart, in the kitchen, on the patio, at the cottage... anyplace a grounded 120V AC power outlet is available. Make this a Christmas to remember by putting a Heathkit electronic oven under the tree. It's a gift your wife will thrill to... and a present the whole family will enjoy... meal after meal after meal.

Kit **GD-29**, 80 lbs. **$399.95***

New Heathkit portable solid-state color TV

- Big set performance, portable convenience
- MOSFET VHF tuner & 3-stage IF
- Modular, self-service design
- 102", 14 V picture tube



What do you do for an encore after you've created the solid-state GR-270 and GR-370 big-screen sets? Simple. Make them portable. That's virtually what's been done in the new Heathkit GR-169 solid-state portable color TV. Heath engineers took the same cool-running solid-state circuitry from the large screen chassis and packaged it in an easy-to-assemble compact chassis... with the same nine plug-in glass epoxy circuit board modules used in the big sets. In fact the only difference is the smaller preassembled horizontal deflection and high voltage power supply. The same MOSFET tuner and high gain 3-stage IF found in the big sets offer superlative color performance. And, as in the larger sets, complete owner-service features are provided by inclusion of built-in dot generator and degaussing along with an exclusive volt-ohm checkout meter. 48-hour factory service facilities for modules are also provided with the GR-169. Other features include: built-in antennas and connections for external antennas; instant picture and sound; complete secondary controls available behind the hinged door on the front panel; high resolution circuitry for sharp, crisp pictures; adjustable noise limiting to keep external interference to a minimum. If you're looking for big set color fidelity and performance with portable convenience... put the new Heathkit GR-169 on your Christmas shopping list now!

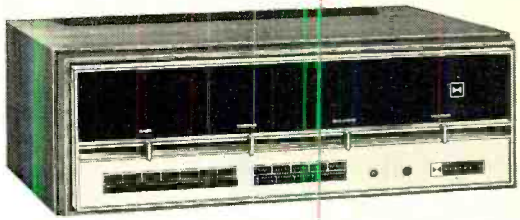
Kit **GR-169,** 48 lbs. **$349.95***

New Heath-gift ideas... for

New Heathkit® AJ-29 AM-FM-FM stereo tuner

This is the feature-packed tuner section of the famous Heathkit AR-29 stereo receiver . . . now available as a stereo "separate." The pre-assembled, factory-aligned FM tuner boasts 1.8 uV sensitivity for whopping station pulling power using FET design for superior overload characteristics. Three IC's in the IF section offer superior AM rejection, hard limiting, temperature stability, and outstanding reliability. Other features include a computer-designed 9-pole L-C filter for greater than 70 dB selectivity; new "blend" and "mute" functions; and a built-in AM rod antenna that swivels for best reception.

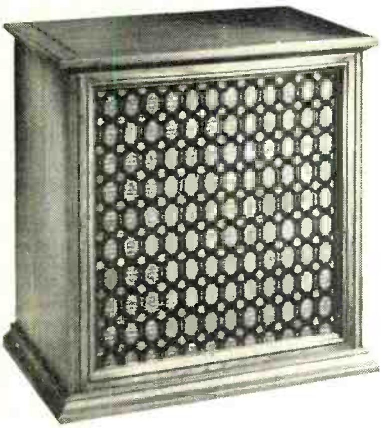
Kit **AJ-29,** 19 lbs., less cabinet **$169.95***
Assembled **AE-19,** oiled pecan cab., 9 lbs. **$19.95***



New Heathkit® AA-29 100-watt stereo amplifier

Power-packed amplifier section of the Heathkit AR-29, the AA-29 stereo "separate" marks another milestone in superior Heathkit amplifier design. Its 70-watts of continuous power is more than enough to drive even the most inefficient speaker systems. A massive, fully-regulated and filtered power supply, 4 conservatively heat sinked output transistors and the best IM and harmonic distortion specifications in the industry add up to sound fidelity you never expected to hear outside the theater. Modular plug-in circuit boards make assembly easier . . . snap out in seconds for future servicing.

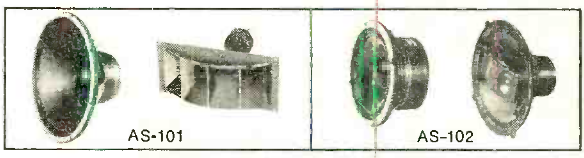
Kit **AA-29,** 27 lbs., less cabinet **$149.95***
Assembled **AE-19,** oiled pecan cab., 9 lbs. **$19.95***



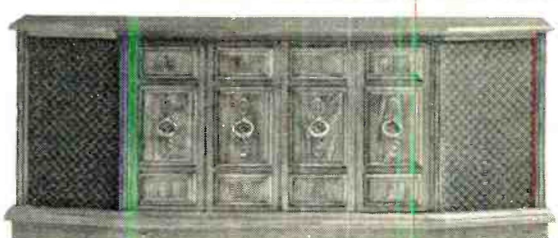
New Heathkit® floor model speaker systems

In the new Heathkit AS-101 and AS-102 speaker systems, Heath engineers have combined the best of both worlds of sound and beauty. The AS-101 Heath/Altec-Lansing 2-way system features a 15" woofer and sectoral horn delivering from 35 to 22,000 Hz with uncompromising accuracy. The AS-102 Heath/Bozak 3-way system uses a 12" woofer, 6" mid-range, and two 2½" tweeters in an infinite baffle design to produce clean natural reproduction from 40 to 20,000 Hz. Both systems are housed in assembled Mediterranean pecan cabinets, 29⅝" H x 27¾" W x 19⅞" D.

Kit **AS-101,** 53 lbs. **$259.95***
Kit **AS-102,** 39 lbs. **$259.95***



New Heath stereo equipment credenza



Romantic Mediterranean styling in wife-pleasing one-piece console design . . . yet with plenty of room for your favorite separate stereo components. Six-and-a-half feet of solid craftsmanship executed in North American Hickory veneers and solid oak trim, finished in oiled pecan. Completely assembled and finished, ready for installation of Heath or other components. Speaker enclosures are ducted port reflex design, pre-cut for 12" speakers. An adjustable shelf has room for stereo receiver, cartridge or cassette tape player or separate tuner and amplifier. Below the shelf is room for your turntable and record storage. Accessory matching drawers on ball bearing slides are available for turntable and tape player.

Model **AE-101,** 90 lbs. **$189.95***

home, shop and ham shack

New Heathkit® IC 15 MHz frequency counter...199.95*

A highly accurate, low cost frequency meter for anyone requiring accurate frequency measurements. Compare these features to counters selling for over twice this low price: accurate counting, 1 Hz to over 15 MHz; integrated circuitry; automatic trigger level for wide range input without adjustment; five digit readout with Hz/kHz ranges and overrange indicators for eight digit capability; high input impedance; storage circuitry for non-blinking, no-count-up readout; computer-type circuitry, no divider chain adjustment; temperature-compensated crystal time base oscillator; BNC input with cable; double-sided, plated-thru circuit board with sockets, three-wire, removable line cord; heavy-duty aluminum case handle/tilt stand and die cast zinc front panel; no special instruments required for accurate calibration.

Kit **IB-101**, 7 lbs. **$199.95***

IB-101 SPECIFICATIONS: Frequency Range: 1 Hz to greater than 15 MHz. **Accuracy:** ±1 count ± time base stability. **Gate Times:** 1 millisecond or 1 second with automatic reset. **Input Characteristics: Sensitivity:** 1 Hz to 1 MHz, less than 100 mV rms. 1 MHz to 15 MHz, less than 250 mV rms. After 30 minutes warmup. **Trigger Level:** Automatic. **Impedance:** 1 Meg ohm shunted by less than 20 pf. **Maximum Input:** 200 V rms, DC–1 kHz. Derate at 48 V per frequency decade. **TIME BASE: Frequency:** 1 MHz, crystal controlled. **Aging Rate:** Less than 1 PPM/month after 30 days. **Temperature:** Less than ±2 parts in 10^7/degree C. 20 to 35 degrees C after 30 minutes warmup. ±.002% from 0 to 50 degrees C. **GENERAL: Readout:** 5 digits plus overrange. **Temperature Range:** Storage: —55 to 80 degrees C. Operating: 0 to 50 degrees C. **Power Requirements:** 105-125 or 210-250 VAC, 50/60 Hz, 8 watts. **Cabinet Dimensions:** 8¼" W x 3⅞" H x 9" D not including handle. **Net Weight:** 4½ lbs.

See these and 300 other Heath-gift suggestions at one of the following Heathkit Electronic Centers:

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5444 Pearl Road

Dallas, Texas 75201
2715 Ross Avenue

Denver, Colorado 80212
5940 W. 38th Ave.

Detroit, Michigan 48219
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Houston, Texas 77027
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Los Angeles, Calif. 90007
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Hopkins, Minn. 55343
101 Shady Oak Road

New York, N.Y. 10036
35 W. 45th Street

Philadelphia, Pa. 19149
6318 Roosevelt Blvd.

Pittsburgh, Pa. 15235
3482 William Penn Highway

St. Louis, Mo. 63123
9296 Gravois Ave.

San Diego Area
LaMesa, Calif. 92041
8363 Center Drive

San Francisco Area
Redwood City, Calif. 94063
2001 Middlefield Road

Seattle, Wash. 98121
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Westbury, New York

Miami, Florida

San Francisco Area
El Cerrito, California

Cincinnati, Ohio

Los Angeles Area
Woodland Hills, California

Atlanta, Georgia

Prices listed are factory mail order.
Retail prices are slightly higher.

. . . or send for your FREE factory mail order catalog

New Heathkit® HW-101 SSB transceiver

The Hams at Heath have done it again . . . with an uprated version of the Heathkit HW-100, one of the most popular pieces of ham gear on the market! The HW-101 features improved receiver circuitry resulting in better than 0.35 uV sensitivity for 10 dB S+N/N. Image and IF rejection are better than 50 dB. Other improvements are a new 36-to-1 ball-bearing dial drive, new selectable SSB or CW filters and attractive new front-panel styling.

Kit **HW-101**, 23 lbs. **$249.95***

New Heathkit wattmeter/SWR bridge

Two switch-selected ranges allow measurement of RF output from 10-200 W and 100-2000 W. Built-in calibrator permits 10% accuracy throughout the 80-10 M ham bands.

Kit **HM-102**, 3 lbs. **$29.95***

HEATHKIT — a Schlumberger Company

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☐ Enclosed is $__________, plus shipping.

Please send model (s) __________

☐ Please send FREE Heathkit Catalog. ☐ Please send Credit Application.

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*Mail order prices; F.O.B. factory.
Prices & specifications subject to change without notice. CL-394R

CIRCLE NO. 16 ON READER SERVICE PAGE

SOLID STATE

(Continued from page 87)

the receiver has a typical turn-on threshold of 1.25 volts and a turn-off of 1.00 volts. Thus, a 250-mV hysteresis is provided to prevent possible oscillation from noise occurring during the rise and fall times of a slow input waveform.

Although MODEM circuits are used primarily in data transmission systems, the versatile characteristics of these new Motorola devices could be of real value to all serious experimenters working with digital projects.

A series of six new high-voltage npn transistors is being offered in plastic packages by Fairchild Semiconductor (313 Fairchild Drive, Mountain View, CA 94040). Featuring excellent beta linearity from 1.0 mA to 50 mA, these new units are registered as types 2N5964-65 and 2N5830-33. The first two are supplied in 700 mW dissipation TO-105 packages, the latter four in 310 mW TO-106 packages. All six are complements to the 2N4888-89 pnp types.

Both the input capacitances and the leakage currents of Fairchild's new devices are quite low—only 4 pF maximum capacitance, while leakages are but 10 nA for the 2N5833 and 50 nA for the others in the series. The 2N5833 and 2N5965 operate with an LV_{CEO} of 180 volts while their companion units range in sustaining voltage from 100 to 150 volts.

The TRW Semiconductor Division (14520 Aviation Blvd., Lawndale, CA 90260) has recently announced a number of new high-frequency transistors, including the 2N5773-76 series, the PT6738, and the PT6729. Of these, the 2N5773-76 series is a family of four broadband transistors for use in the 200- to 500-MHz range; power output levels range from 1.5 watts for the 2N5773 to 40 watts for the 2N5776.

A new SSB transistor furnishing 30 watts PEP across the 1.5-to-18-MHz band, the PT6738 has a power gain of 13 dB, with its intermodulation distortion guaranteed at −30 dB or better. Designed for operation on a 28-volt dc source, the unit is packaged in a TO-59 case.

The type PT6729 is claimed to be industry's most powerful 150-MHz communications transistor. Delivering 120 watts r-f power output with 6 dB gain when operated on a 28-volt dc power supply, this new device is packaged in a 4-lead diamond configuration case.

That concludes our Solid State story for November . . . until next month and the Holiday Season, keep cool. —*Lou*

INTERFACE

(*Continued from page* 10)

serious beginner with a limited budget.

C. JAROSZ
Baltimore, Md.

Congratulations on your "New Look." The upgrading is a welcome change and seems to signal increased confidence on your part in your readership.

R. BUNGER
Los Angeles, Ca.

It must have been coincidence that I picked up your "New Look" September issue and found it so interesting. Probably very few of your readers were aware of Olson's live orchestra/filter test and I was particularly happy to have this historical fill-in. The article on building small audio transformers was a bonus. However, the greatest satisfaction was the return of Gordon Holt to print. He and I had mutual friends in the 1950's and I found him very honest and fair.

I would be happy to swap information on disc recording which is a hobby of mine and not a profession.

A. R. JOURDAN
Meriden, Conn.

Whether they liked it or not, the Editors appreciated the time that several hundred readers took to write us about the "New Look." Some readers sorely missed the old monthly departments, but most were willing to wait and see what POPULAR ELECTRONICS *looked like in the months to come. The majority of letters and postcards (and telephone calls) were in favor of the changes and improvements.*

Boy, I sure hope they bring some more of these on their next trip up here!

MEASUREMENTS LAB

(*Continued from page* 63)

cuits be assembled on printed circuit boards. If you want to make your own boards, you can do so with the aid of the etching guides given in Fig. 7.

Mount the components on their respective circuit boards (see Fig. 8), paying careful attention to the orientations of the IC's, transistors, diodes, and electrolytic capacitors. When you finish soldering, examine the foil sides of the boards, comparing them against the guides in Fig. 7, to determine if any solder bridges exist between the closely spaced foil conductors. If you locate a solder bridge, reheat the connection adjacent to it and remove the excess solder.

Now, referring to Fig. 9, wire up range selector switch *S1*, and make all necessary connections between *S1*, the two circuit boards, and the 15-contact plug. (Note: Make absolutely certain that the wiring to the plug conforms with the wiring to the socket in the main frame. Use stranded hookup wire to and from the socket.) Then mount the circuit boards, TRIGGER LEVEL control, range switch, and input binding posts on the L bracket chassis as shown in Fig. 10. Before tightening the hex nut on *S1* (in the module) position it so that lugs 1 and 11 point upward; this way the index on the control knob will conform with the dial markings. Wire the TRIGGER LEVEL control and binding posts into the circuit. Then neatly lace together the wiring and put the control knobs on the shafts of the two controls.

Testing the Counter Module. Connect the plug on the module to the socket in the main frame and turn on the power by rotating the range switch to the 1000-Hz position. Rotate the DISPLAY RATE control on the main frame to its fully clockwise position and observe the readout display. With no input signal to the module, the readout tubes should reset to "0" as soon as the reset pulse occurs. Now, apply an input signal of 0.1 volt or more to the binding post input on the module and again observe the readout display. After a discrete interval, determined by the setting of the DISPLAY RATE control, the readout system

THEORY OF COUNTER DESIGN

The 20-MHz Frequency Counter Module is divided into two basic sections—the Time Base circuit shown in Fig. 5, and the Scaler circuit in Fig. 6. The Time Base circuit employs a high-impedance source-follower FET input stage (*Q1*) to minimize loading the circuit under test. The signal, fed first through *Q1*, is direct-coupled to *Q2* where it is amplified to a level sufficient to drive the *Q3-Q4* Schmitt trigger. The driving signal level to the *Q3-Q4* circuit is primarily a function of the TRIGGER LEVEL control *R3*.

The purpose of the Schmitt trigger is to condition the signal, giving it fast rise and fall times. This is necessary to prevent false counts on low-frequency signals. Although the TTL gates and flip-flops in *IC1*, *IC2*, and *IC4* will operate at almost any frequency, the gates can produce multiple counts if the signal passes through the trigger point too slowly. The Schmitt trigger, as a result of shaping the signal, eliminates the possibility of multiple counts.

Every time the input signal at the base of *Q3* fires the Schmitt trigger, the output at the collector of *Q4* changes state, producing a series of square waves. After this, the square-wave pulses are amplified by *Q5* and fed to the sync circuits.

To obtain a readout in Hertz, the signal must be gated into the counter for a specific period of time. This is accomplished with the time base made up of *IC3* and half of *IC4*. The time base network is a divide-by-six circuit that counts down from the 60-Hz power frequency (applied at point R and obtained from one side of the 12.6-volt secondary winding in the power supply) to provide at point **B** a series of pulses that occur every 0.1 second. Diode *D1* clips the negative alternations of the 6.3-volt input, and capacitor *C3* filters out any high-frequency noise that might be present on the ac line.

The output at point **B** can be directly coupled into the sync circuit at point **C** to provide a single counting range of 1000 Hz. Or, it can be coupled through the Scaler subassembly (see Fig. 6) through *S1* for further divisions to provide the 10-kHz, 100-kHz, 1-MHz, and 10-MHz ranges. The signal can now be applied to point **C** in the sync circuit.

In the sync circuit, the input and timing signals are synchronized in such a manner that the count always starts at the same point in the input cycle to avoid any "one count" ambiguities in the reading. The "one and only one" circuit formed by *IC1*, when armed with a pulse, allows only one timing cycle to occur.

The display time setting of *R20* determines the firing rate of unijunction transistor *Q6*. When *Q6* fires, a sharp pulse appears across *R13*. After amplification through *Q7*, this pulse is applied to the S input of the R-S flip-flop in *IC1*, causing the Q output to go to "high". The high signal is next applied to the J input of the JK flip-flop in *IC1*, setting the flip-flop to change state with the next clock pulse from the time base network.

The first clock pulse that occurs after the display time circuit is fired switches the JK flip-flop. The Q output goes to high and is fed into the K input of the same flip-flop. This will result in the flip-flop going back to its original state on next clock pulse. The not $\overline{Q}$ output goes to low (0 volt) on the first clock pulse, since it is the Q output's complement, and resets the S-R flip-flop and sets the sync switch of *IC4* to switch with the next clock pulse. The clocking pulse in this case is the input signal.

Now, the following occurs: On the first negative-going pulse that occurs in the input signal, *IC4* switches so that the Q output goes to low and opens the gate in *IC2* for signals to pass into the counter. The negative-going pulse that switched the flip-flop is inverted before being applied to the gate so that it becomes a positive-going pulse that does not pass through the gate to the counter.

The first count occurs on the next negative pulse of the input signal. When the "one and only one" circuit receives the second clock pulse from the time base, it switches back to its standby state to await another display generator pulse. This causes the sync switch to close on the first negative-going input pulse that occurs after the inputs change state. The leading edge of the pulse that opens the synchronizing circuit is applied to the inverter through *C5* to the reset buss in the counter, resetting the counter just before the next pulse train to be counted is applied to point **A**.

should display the frequency of the applied signal. Let the instrument reset itself several times and if the numerical indication remains the same for two of the three significant figures, this range is operating properly.

Test each of the remaining ranges individually as described, using an appropriate frequency signal to produce a readout display. Then, on any of the ranges, feed in a signal that exceeds the range capability by more than 100 percent and check to see that the overrange indicator lamp glows.

Finally, set the range switch to the TEST position and observe the readout display. You should obtain a 60-Hz reading every time the instrument automatically resets itself. If everything checks out, you can start using your frequency counter on the job. —30—

OPTICOM

(*Continued from page* 50)

the active elements at each other. Turn on the transmitter and measure the voltage across *R11*. Adjust *R9* until this voltage is ½ volt. With both units operating, depress the transmitter pushbutton *S1* and move the receiver slightly until a loud tone is heard in the earphone. If no tone is heard, test the receiver by aiming it at a 117-volt 60-Hz light. If the receiver is operating properly, you should hear a distinct 60- or 120-Hz hum. If you do not, troubleshoot the receiver. Once it is working, and you still get no signal from the transmitter, troubleshoot it.

With both units working, mount the lenses using a commercially available sealant. Mount them on the inside of the chassis so that they cover the holes and their centers are in line with the light-sensitive semiconductor elements on the PC boards.

Optical Alignment. Hold each unit in the beam path of a relatively distant light source. DON'T use the sun for this step—a common light bulb about 10 feet away will do. Align the chassis so that the light falls on the window of the active optical element. Move the PC board back and forth until the light comes to a sharp focus on the element window. Once this position has been located, lock the mount-

ing screws; and, though it is not necessary, place a spot of cement on the screws to insure permanence. Once both units have been aligned optically, check that the batteries are firmly mounted and assemble the chassis covers.

Range Testing. Place the transmitter on a level mount and point it along a path unimpeded by obstacles for at least several hundred feet. With the Test pushbutton (*S1*) either depressed or temporarily shorted, walk about 10 or 15 feet away from the front of the transmitter carrying the receiver. Turn on the receiver and point it toward the transmitter, varying the aim until you hear the tone. You will notice the extreme directionality of the system. This is what makes it so private—you must be on the beam to get the signal. In daylight, the range will not be as great, but it can be improved by switching the receiver Day-Night switch (*S2*) to the Night position. If you find the tight beam too constraining, you can de-focus the receiver by moving the PC board slightly in toward the lens. One side effect of doing this is a reduction in range.

Of course, if two systems have been built for two-way communication, do not exceed the range of the worst pair.

Operation. If you are using a pair of communicators as a network, the transmitter at one end should be aimed at the receiver of the other end and the transmitter Test button pushed to tone-modulate the transmitter. Both ends should be positioned until the tone at each end is heard loud and clear. Once the link has been established, the pushbutton is released and the microphone is used for speech communication. Manipulation of the receiver Day-Night switch (*S2*) will affect the range and volume.

Modifications. There are numerous modifications and variations that can be used with the Opticom. Telescopes or binoculars at either, or both, ends greatly increase the range. Even low-cost plastic Fresnel lenses may be used. Since the light collecting area of a circular lens is proportional to the square of the diameter, a small increase in diameter results in a significant increase in the effective area. For example, a lens three inches in diameter has more than twice the light collecting area of a two-inch lens.

Since a diverging beam of light follows an inverse square law and produces a light energy density dependent on the square of the distance from the light source, doubling the lens light area will, in theory, double the range of the Opticom. Of course, operation in daylight or over paths having varied thermal conditions will limit the range. Longest ranges can be obtained on clear, cool nights, with a telescope at each end.

The Opticom system may also be used as a short-distance rangefinder. Mount a bicycle reflector on the target and aim the tone-modulated transmitter at it. From a short distance away from the transmitter, aim the receiver at the reflector until the transmitter tone can be heard. The transmitter, target and receiver should form a triangle. Once the tone has been heard, simple geometry can be used to solve the triangle and calculate the distance.

Daylight range can be improved if the interior of the receiver chassis is painted flat black. Also, a long focal plane lens can be used to narrow the field of view and reduce background illumination. This tightens the beam and makes more accurate alignment necessary. Also consider the use of a black interior tube or shield protruding from the lens to reduce ambient light to the phototransistor. —30—

STEREO SCENE
(*Continued from page* 71)

as symphonic music, with a high degree of "sharing" between channels and a lot of random-phase content may confuse the decoder for I had the impression that the stereo localization of instruments between the front speakers was rather less definite from the Scheiber playback than from the original tape, and that the rear ambience, although definitely coming from behind, lacked some of the spaciousness of the four-channel original. If there are indeed some weaknesses in the Scheiber system, only time will tell whether they are inherent or can be "worked out."

As for compatibility, it is evident from Fig. 4 that the modulation axes for the rear-left and rear-right signals are not far removed from the vertical axis, which means those signals would virtually disappear in monophonic playback. A two-channel reproduction would place them out of phase at both side speakers, but because each axis is displaced from the vertical toward one side channel, its sound would be reproduced toward one side or the other, and the misphasing would not be conspicuous. More serious, though, is the loss of effective left-right separation, which would be reduced to a maximum of 75% (only 8 dB).

The cost to the consumer of a Scheiber decoder is something that seems rather indefinite at the moment. A spokesman for Advent Corporation, which is licensed to convert the basic Scheiber system into "marketable consumer products," said that the decoder could be "very inexpensive or quite costly," depending on its effectiveness! The intimation was that several versions would be made available; and, as far as performance was concerned, the buyer would get what he paid for. It seems reasonable to assume that the demonstration was conducted with the best version that could then be made and that cheaper versions would exhibit more or less the characteristics of a Hafler playback.

In view of the similarity between the two systems, it will be interesting to see how mutually compatible they are. Will a Scheiber-encoded recording play back on a Hafler "decoder" and vice versa, with the apparent sound sources appearing midway between the speakers? Could a Scheiber control amplifier allow the Hafler system to produce single-source ping-pong effects? I will have some of the answers at a later date. —30—

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COMMUNICATIONS

(*Continued from page* 81)

to take a hard, second look at its windshield radio antenna. Technically a fine-wire dipole imbedded in the windshield glass, the new antenna apparently has all of the advantages and drawbacks to be expected from an FM dipole—no gain and directionality. Although motorists acknowledge that the imbedded antenna curbs vandalism, both AM and FM reception are significantly deteriorated and broadcasters claim that the imbedded dipole cuts the FM reception area by two thirds! Some motorists claim that reception is worse during rain and snow storms whenever it becomes necessary to use the wipers; they say that signals bounce up and down in strength following the motion of the wipers.

AMATEUR RADIO

'Tain't Necessarily So—Contrary to a notice in a summer ARRL Director's Letter, the FCC has not altered its amateur radio Rules and Regulations—nor is there a disagreement between Chairman Burch and the FCC staff. With a little double-checking, interested parties would have discovered that someone is crying "wolf." Obviously, the FCC could not condone the "student takeover" or the solicitation of funds during spring upheavals at various universities. Nor could it grant ham licenses to fraternal organizations for the purposes of establishing communications networks. Both actions violate Part 95.39 of the Rules. There is no reason to suspect that the FCC was "clamping down" on voluntary communications for events such as parades, sports car rallies, the Eye Bank Network, and so forth.

OUT OF TUNE

"An Improved Four-Way Flasher" (August 1970). In the diagram on page 80 the unit specified for the flasher is a Tung-Sol type 535. This is a 3-terminal, 6-volt unit which will not work in this circuit. Instead, use Tung-Sol type 552, a heavy-duty 12-volt, two-terminal flasher.

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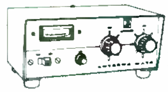

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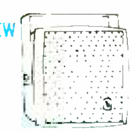

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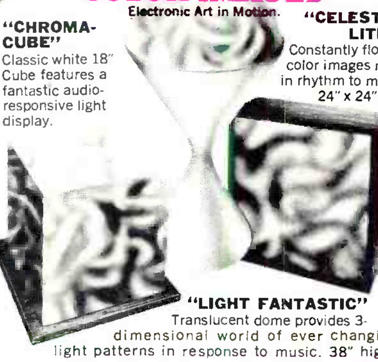

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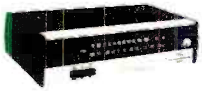

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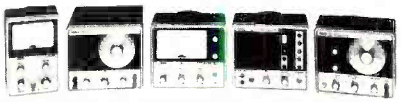

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