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VOLUME 5 NUMBER 2 FEBRUARY 1974

Popular Electronics

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FEATURE ARTICLES

CONSTRUCTION STORIES

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THE SCENES

PRODUCT TEST REPORTS

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Editorial

By Milton S. Snitzer, Editor

LOOKING OVER THE ISSUE

Putting together an issue of POPULAR ELECTRONICS is not just a matter of pounding typewriters and yelling for the "copy boy" to rush things to the printer. We always find something of personal or professional interest in each article; and sometimes we go all out on a project, generating so much enthusiasm that editors of our sister publications come around to see what's going on.

That's what happened this month in preparing our cover story—as we assembled and tested the model car and radio control system. There was a lot of excitement around the office and we discovered what a really fascinating hobby it is—and easy to get into. An article in a future issue will dig into the innards of radio control circuits, detailing the various techniques that are used by the hobbyist.

Another article of special interest this month is the story on light beam communications, which lays the groundwork for a subsequent construction article on the first light beam communicator project we've seen that uses a single infrared light-emitting diode as both source and detector. This area of communications is close to our hearts, and we have been in the forefront of publishing articles on it for many years. In 1970, for example, we described a build-it-yourself helium-neon laser voice communications system that was later exhibited at the Smithsonian Institution. We'll have a more refined one to present soon. Watch for it!

Then there's our story on vhf/uhf scanning monitors, a roundup discussion of this exciting hobby. Monitoring the vhf and uhf Public Safety bands is a recent outgrowth of the hobby of shortwave listening. On these bands, you can hear your local police, fire, business radio, tow trucks, taxi operations, computer repair services, newspaper reporters, and continuous weather broadcasts. Since most of these transmissions are intermittent, scanning monitor receivers (which automatically tune from one channel to another, stopping on an active channel) have grown in popularity. The article includes a directory covering more than 70 different models from 15 manufacturers.

And, of course, we have a group of truly unique construction projects—an ultra-sensitive gas/smoke detector with meter readout, a home experimenter's miniature environmental test chamber, a fast-acting resettable electronic fuse, and a single-IC direct-reading capacitance meter, among others.

All-in-all, it adds up to an issue we think you will find interesting to read—stimulating both thought and action.

Letters

ELECTRONIC MUSIC MANUFACTURERS

Your October issue, on page 36, lists the manufacturers of electronic music equipment. The third company listed was CBS Laboratories, 1300 East Valencia, Fullerton, Calif. 92631.

We wish to advise that our company purchased the complete inventory of the CBS system, both as to parts and completed units, approximately one year ago. We are now the sole distributor of these synthesizers and synthesizer parts.

GREGORY KRAMER, Pres.
Electron Farm
2 Ketch St. Suite 201
Marina Del Rey, CA 90291

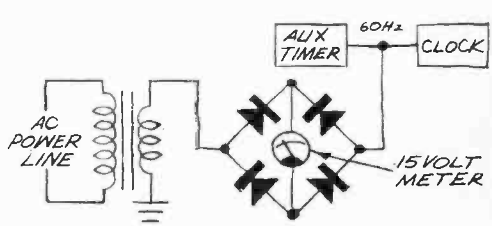
I wish to add to your list of electronic music manufacturers the name of Chalice Organ Co. which has been producing kit organs and synthesizers since 1970.

Chalice manufactures a large line of very sophisticated organs and synthesizers which use the latest digital multiplexing techniques, along with digital wave shaping. We make instruments which use either full digital tone generation, independent oscillators for tone generation, or frequency division for tone generation.

PAUL J. ISHAM, Pres.
Chalice Organ Co.
P.O. Box 209
Santee, CA 92071

FAIL-SAFE DIGITAL CLOCK

The phase detector circuit shown in my article "Make Your Digital Clock 'Fail-Safe'" (December 1973 issue) is in error. The correct configuration for the circuit shown in Fig. 4



is shown in the drawing. Sorry, I should have caught the error during proofreading.

CALVIN DILLER
Bluffton, Ohio

SCOPES VS PROBES

I must take exception to Leslie Solomon's statement in the November "Test Equipment Scene" to the effect that a scope is not as reliable as a logic probe. This may be true for inexpensive scopes used by hobbyists and experimenters, but professionals in the field of digital logic realize that a logic probe falls far short of a good quality oscilloscope.

Some logic probes cannot distinguish between an open input to a gate and a high level on that gate. It is virtually impossible with a logic probe to determine whether you have a high dc level or a pulse with a high rep rate. A logic probe will also not reveal illegal OR-tied gates which are usually visible on a scope.

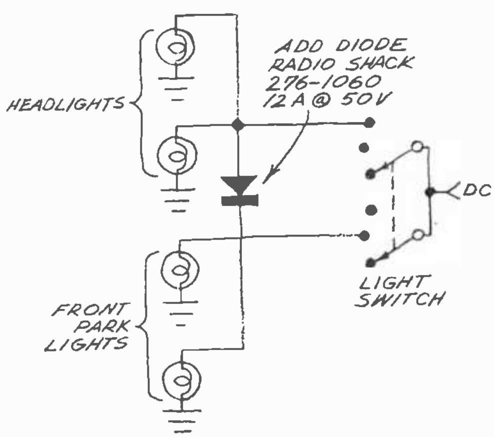
I'm not knocking probes; they have their place. But to say that they are better than a scope is stretching things a little.

GARTH FISHER
Grand Terrace, Calif.

It is true that there are times when a probe is not the best instrument to use. However, Les's discussion was aimed at the hobbyists and experimenters who do not have lab-grade scopes. He was trying to show that, in this case, a logic probe has discrete 1 and 0 switching levels while a scope just displays signals.

FOUR-WAY FLASHER ADDITION

I was quite interested in your brief item on a "Four-Way Flasher" in your December 1973 issue. Here's an additional item of safety.



On older cars whenever the headlights are turned on, the front parking lights are turned off. If one headlight goes out, one side of the front of the car will be unlighted. By adding one more diode as suggested on the schematic, the parking lights will be turned on whenever the light switch is on. The operation of the headlights will remain unchanged.

ROBERT SERGENT
St. Charles, Mo.

Stereo Scene

By Ralph Hodges

Cassette Recording Levels

THE cassette is finally overcoming its tendency to wow, flutter, and (occasionally) snarl itself up in the innards of even the better cassette-deck mechanisms. It's about time. Of the remaining performance problems that face it, I can see only one looming large enough to be of serious concern: distortion caused by tape overload. Many recordists—particularly those who tape live music—are finding that working with cassettes can be a game of blindman's buff with high-frequency distortion that makes easy losers of the unwary. The game is blind because the recording-level meters, your hedge against distortion-producing levels, are not always to be trusted; dB numbers that are "safe" in one situation can lead you astray in another.

While tape overload (magnetic saturation) is the bane of tape recording in all its forms, it is nowhere so prevalent as with the cassette. All the parameters of the cassette medium—thin tape, narrow recorded tracks, very slow tape speed—add up to very little magnetic-oxide material per inch of tape, and very little material per unit of time. To skimp on oxide is to invite magnetic saturation, and this is likely to occur most often at high frequencies, because of the treble boost the recording circuits apply to offset inevitable high-frequency losses and to fight the hiss that is rampant with cassettes. The combinaion record-playback head of most cassette decks is an additional complication. A head that is ideal for playback is itself prone to overload when *recording* high-level signals.

Meters That Lie. Assuming you agree to put up with the cassette's limitations, why can't you at least have recording-level meters that do their job (let you know when you're exceeding the capabilities of the medium)? Apparently, the answer is that the development of suitable cassette record-level indicators has lagged behind the progress made by the rest of the technology. Too many of the meters have response characteristics approximating those of VU devices, and while this may sound admirably rigorous and "professional," this type of meter is not really appropriate for cassette recording.

True VU meters conform to a well-defined standard of ballistic damping. As a result, they respond to the recording signal in a kind of lagging, lingering manner. This is good, because it makes the meters readable. An undamped meter, responding to every brief spike of the musical waveform, would wiggle, shudder, and overshoot its way across the dial in a blur of movement. However, it's also bad because a VU meter is incapable of registering momentary peaks that might be just long and strong enough to cause audible trouble. This is very much a matter of degree.

At one time the VU meter was admired for its tendency to stolidly ignore a little bit of "blasting," since the ear is tolerant of very short bursts of distortion, and to distract the recording engineer with split-second overloads that no one would ever hear seemed self-defeating. But mind you, these rules applied only to the finest recording equipment of that time. And even so, a good deal of practical experience was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Neil Diamond is an artist who creates scenes with music. So when he decided that state-of-the-art sound systems be used during press premières to reproduce his original music score for the film JONATHAN LIVINGSTON SEAGULL,* realism in terms of spectral balance, spatial character, and lifelike sound-power levels were mandatory requirements.
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For information on the 901 SERIES II, complimentary copies of the reviews, and a report on the theatre sound system competition, circle your reader service card or write Dept. K1
*Original motion picture soundtrack recording available on Columbia records and tapes.
†This research is presented in the article "Sound Recording and Reproduction" published in TECHNOLOGY REVIEW (MIT), Vol. 75, No. 7, June '73. Reprints are available from BOSE for fifty cents a copy.
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necessary to interpret a VU's readings accurately and safely in every situation.

With cassettes, and particularly in live recording situations, a VU meter is definitely not the level indicator of preference. The cassette has a hair-trigger readiness to overload not shared by studio recording equipment. Signal peaks of very short duration must be taken into account; they can produce very audible distortion. And large peaks come along frequently in live recording.

When you dub a disc, FM broadcast, or any kind of second-hand program source onto a cassette, you are dealing with material that has been "pre-limited"—all the severe peaks have been chopped off (not audibly, one hopes). This stands to reason when you consider that a full-scale live performance may have a dynamic range well exceeding 80 dB, whereas a disc or tape recording with a 60-dB dynamic range is really pushing the state of the art.

Most cassette decks have been designed with copying chores in mind; and in this application, brief meter excursions up to 0 dB and a little above usually create no problem. But the live cassette recordist quickly finds that, to keep the meter needle from going berserk on fortissimos, he must choose levels that have it resting on its bottom peg, barely moving, for distressingly long periods. And even if he doesn't succumb to the temptation to inch the level controls up gradually (sheer disaster when a climax takes him by surprise), he may *still* not be entirely safe if the meters aren't fast enough.

Meters That Level with you. Of late the recording industry has been taking peak levels very seriously, and many of the newer consoles and mixing desks are festooned with light displays that register and hold peaks, and even "remember," for later reference, the maximum levels achieved during a recording session. Some of these devices have already begun filtering down to the consumer sphere, where they exist—in a simpler, modified form—in a few recently introduced cassette decks. Among these devices are:

Peak-Reading Indicator Lights. These are warning flashers that supplement the meters (usually more-or-less conventional VU-type level indicators) by flickering on in the presence of sharp, potentially troublesome transients that the meters are too slow to register. Logically enough, LED's (light-emitting diodes), with their virtually instantaneous response, are becoming rather popular in this application. The levels that trigger these indicators, and the time constants they follow, are discretionary with the manufacturer, who has presumably taken the trouble to find out what types of signal are likeliest to cause audible distortion with his machine.

Peak-reading meters. As noted earlier, an unaided meter fast enough to respond accurately to brief musical transients would have to be so underdamped that it would whip all over the dial in an undecipherable fandango. But if a conventional meter is driven by its own little amplifier, the time constants of the meter's response to the recording signal can be controlled electrically for whatever result is desired. The combination of a meter and a driving amplifier with a fast attack time and slow release time (the electronics hold onto the transient somewhat longer than it actually lasts) produces a reasonably valid peak-reading indicator. (Fig 1.) One manufacturer's device

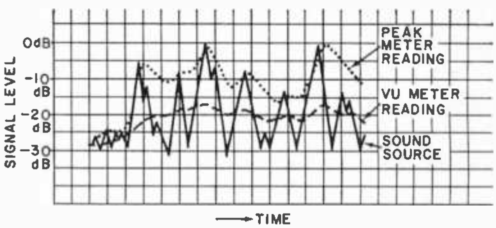


Fig. 1. Response of two meters to dynamic profile of typical music signal (solid line). The VU meter (dashed line) roughly indicates average level. Because of fast attack and slow release, the peak-reading meter (dotted line) follows contour of the peak levels.

of this type gets to within 2 dB of actual value for a signal lasting only 50 milliseconds. (Compare this with a VU meter's attack time, which is somewhere around 2 to 4 *tenths* of a second.) Another manufacturer advertises an attack time of 20 *microseconds* (and release time of 70 milliseconds) for his meters' amplifiers.

Because of their slow release times, peak-reading meters tend to display a somewhat compressed picture of the actual signal dynamics. This tends to make them fairly readable. At the same time, since they ride along the peaks of the musical waveform, ample indication of excessive levels is given.

Equalized meters. A conventional record-

ing-level meter reads the "flat" signal as it comes from the inputs of the tape recorder. The signal applied to the tape, however, has received a strong high-frequency boost to offset hiss and treble losses. This means that the tape can easily get into trouble with excessive high-frequency levels that the meters know nothing about. The obvious remedy is to have the meters monitor levels *after* the recording-equalization stage—in other words, equalized meters. As a rule, this requires separate driving amplifiers for the meters, which may or may not have peak-reading time constants. Also, the meter movements should be able to tolerate substantial amounts of high-frequency energy without burning out.

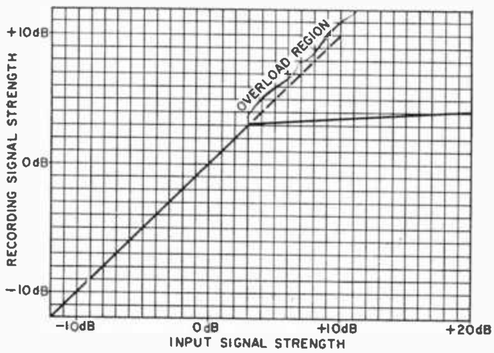


Fig. 2. In ideal limiting circuit, instead of following high-level signals into overload region (dashed lines), the amplifiers are gain-controlled to permit little or no signal increase above a certain threshold.

Peak limiters. A limiting circuit controls the gain of the recording amplifiers, typically acting only when a preset threshold level (usually a level that produces 1 to 3 percent distortion) is reached. A good limiter just won't let the signal going onto the tape get any stronger than that, no matter what the level at the inputs. (Fig. 2.) All the worrisome transient peaks are thereby simply eliminated.

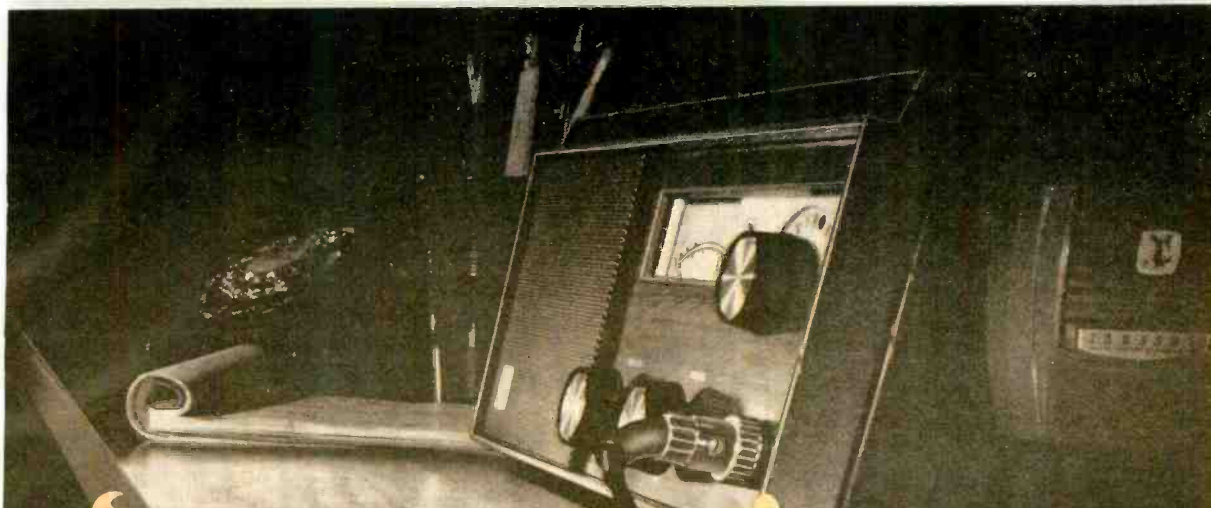
An audibly unobtrusive limiting circuit has to be designed with a rather fast attack time and a *very* slow release time—several seconds or so. Otherwise the decaying tails of cymbal crashes and similar abrupt, loud sounds would disconcertingly "bob up" in level. Therefore, any limiter which is working (in many live-recording situations, it will work quite a lot) is going to introduce considerable compression in the recorded signal. And since no limiter found in consumer equipment is likely to be sophisticated enough to be inaudible under every circumstance, there should be a switch to take it out of the circuit when it's not wanted.

But how does the ear react to being deprived of the high-level musical transients we tend to associate with excitement and "realism" in reproduced sound? Up to a point, the ear is forgiving. The action of a limiter will be heard if it is allowed to affect the average levels of the program. But if the recordist chooses levels that result in only the briefest clipping of peaks, the limiter may very well go unnoticed in the final recording.

What Won't Help. All over the recording world, the perils of high-level transients have been a little slow in receiving acknowledgment. In fact, none of the developments that made the cassette a high-fidelity medium have any direct bearing on the tape-overload situation. The B-Type Dolby noise reduction system is a help only because it permits lower recording levels *overall* while still retaining a good signal-to-noise ratio. Chromium-dioxide tape is somewhat more resistant to overload distortion than iron oxide, but it's clear from the proposed standards for CrO_2 playback equalization that its potential is generally being exploited in another way—to *increase* the recorded levels of high frequencies and thereby further improve the S/N. This is probably the correct priority to follow for most cassette users. However, it eases the plight of the overload-prone cassette medium hardly at all.

If the new meters, overload indicators, and limiters can't do anything to counter the cassette's real limitations, at least they can give a more complete representation of where the problems are, as well as prevent some of the grosser consequences of overload from taking place.

Of course, the benefits these devices can provide depend entirely on their being used properly. Meters in particular communicate in a language you have to learn pretty thoroughly for best results, and complete mastery in every situation probably won't come until you've had a chance to assess what went wrong with a number of previous recordings. Which is another way of saying that there's no substitute for experience in tape recording, as seasoned recordists are already aware. ◈



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News Highlights

First Quadraphonic Juke Box

Wurlitzer, which brought out the first coin-operated music box in 1896, has now introduced the first quadraphonic juke box. The unit, on which marketing has just begun, will incorporate full-logic SQ™ circuits. The announcement came just weeks after Columbia Records released the first quadraphonic single disc to be distributed in the U.S.—Art Garfunkel's "All I Know."

Sony Trading Sells Heathkit in Japan

Sony Trading Corp., a Tokyo subsidiary of Sony Corp., has been named exclusive representative for the Heath Co.'s electronic kits in Japan. Sony will sell a line of Heath stereo, amateur-radio, test-equipment and general products. All will operate on 50 or 60 Hz ac. The equipment sold in Japan will contain translated construction manuals. This marks the first time in Heath's history that a major foreign corporation has been appointed to sell their products overseas. Heath sells through its own facilities in the U.S., Canada, England and Europe. The company, the world's largest manufacturer of electronic kits, had sales in 1972 of over $66 million.

Sylvania Acquires RCA Institutes Schools

An agreement has been announced whereby GTE Sylvania Inc. acquires four schools of RCA Institutes. Involved are the schools in Cherry Hill, N.J. and Upper Darby, Pa., as well as the Home Study School and TV Studio School in New York City. The RCA Resident School in New York City is not included in the acquisition. It's reported that there will be no interruption in any of the courses currently underway at the facilities. (About 10,000 students, American and foreign, are currently enrolled in the schools.)

Troubles With Liquid Crystal Watch Displays

Some buyers of the new digital electronic watches with dynamic scatter liquid crystal displays have experienced difficulties in reading the displays. The watches do have to be tilted at an angle in order to see the display clearly and users must recognize this limitation. There are some other reasons for possible lack of legibility. If the display is not hermetically sealed properly, moisture may get inside and contaminate the liquid display; and if watches are baking in direct sunlight in the jeweler's window or if direct sunlight is allowed to beat down on the user's arm while riding in an open car, temperatures may rise to well over 100 degrees F, causing the display to be temporarily transparent. Finally, if the MOS interface circuit is improperly designed so that residual dc offset is not minimized, the display will be degraded.

FTC Revises Proposed Rule on Audio Sound Power Rating

The Federal Trade Commission has revised its proposed rule on what power must be promoted and disclosed by manufacturers of

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audio equipment. First, they have deleted the incorrect term "rms power" and have substituted the proper term "average power" or more completely "sine wave continuous average power." Although rms output voltage is properly used in calculating the output power, this value of power is *not* an rms power. Second, a new section has been added covering "standard test conditions" under which power measurements are to be made. The section states that the line voltage shall be 117 volts (the IHF specifies 120 volts); the frequency shall be 60 Hz; the amplifier shall be preconditioned by operating it at one-third rated output power for one hour; and rated power and distortion are to be obtained with test signal applied for not less than five minutes at the amplifier's auxiliary input. It has not yet been decided when the ruling will go into effect.

Color Pictures Recorded on Audio Tape Cassettes

A new cassette picture system that records stereo sound as well as still color pictures for reproduction on a TV set has been demonstrated by Hitachi in Japan. Slide films, opaque cards or still frames of a TV picture can be recorded and reproduced for any length of time over 12 seconds. About 240 still pictures can be recorded on a C-120 tape cassette. The recorder is expected to be available on the market in October. The price has not been announced, though it is said to be less than that of present VTR systems.

Pocket TV from England

A pocket-size black-and-white television set is expected to be introduced by England's Sinclair Radionics Ltd. around the middle of the year. The receiver may sell for under $100. Distribution in the U.S. is to be by Sinclair Radionics, N.Y.

Automotive Electronics Market Approaches $1 Billion

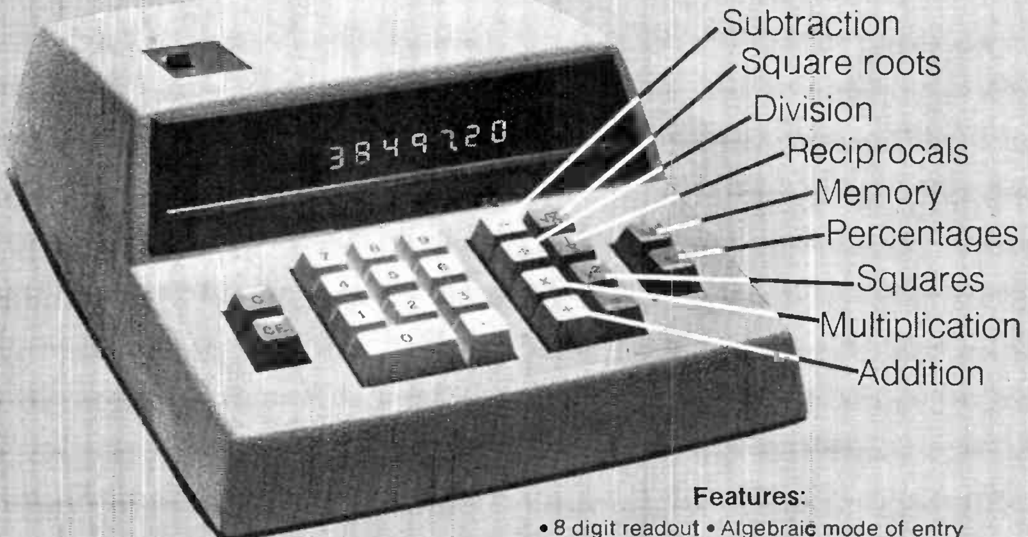
By 1977 the automotive electronics market is expected to reach nearly $1 billion, climbing from less than $600 million in 1973, according to a study by a West Coast market research company, Creative Strategies, Inc. Entertainment products, primarily radios, form the largest segment of the market at this time, though this segment is not expected to show significant change. The engine control electronics market, consisting of electronic ignition, carburetion and transmission controls, is expected to reach $200 million in 1977. The market for electronic test equipment for cars will probably expand substantially due to more complex engines, emission testing, and the need to test and repair electronic devices.

Heath Introduces New Digital Color TV

Heath has just announced a unique solid-state 25-in. color TV kit that uses digital design techniques to silently change vhf or uhf channels at a touch. What's more it displays the channel numbers on the screen along with the time digits using an optional digital clock assembly. The silent, all-electronic touch tuning requires no knobs to turn, no humming motors and no mechanical contacts to clean. Channels can be intermixed in any combination. Even the sound is controlled digitally, changing levels in small increments at the touch of a button. Also there is a new fixed-tuned LC filter with an IC i-f amplifier—a first in the TV industry. There are no traps to go out of adjustment either. Although the set uses 19 IC's, 71 transistors, 20 glass-epoxy circuits boards and 12 cables, the assembly operations are said to be greatly simplified.

MITS Presents

The new 908DM, Desk-Top Calculator.



Features:

• 8 digit readout • Algebraic mode of entry • Fixed or floating decimal • Leading and trailing zero suppression • Chain and mixed operations

* Plus the option of programmability.

***Prices: 908DM**

Kit . . **$129.95** Assembled . . . **$149.95**

Size: 8-1/2" x 12" x 3-1/4"

Full Operation Memory

Memory may be used as:

1. A constant
2. A temporary storage register
3. An accumulator

Indicators:

• True credit balance sign • Overflow

*Programmer

To be used with the MITS 816, 1440, or the new 908DM, desk calculators.

1. Provides 256 programming steps. (With option of expandability to 512 steps.)
2. Stores up to 64 separate programs.

Size: 8-1/2" x 12" x 3-1/4"

Instructions:

A. "If Neg," B. "Go To," C. "Return," D. "Remember," E. 2 Run modes of operation

*Programmer Kit . . . . . **$199.95** Assembled **$299.95**

*Combination 908DM and Programmer Kit . . . . . **$299.95** Assembled **$399.95**

Warranty: Kit: 90 days on parts. Assembled: 2 years on parts and labor.

*Prices subject to change without notice. Available from your local Olson Electronics Dealer

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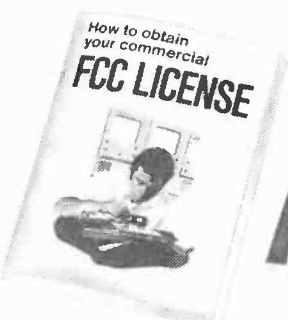


Gives information on getting a Federal Communications license, and provides typical FCC exam questions and answers. *Yours free.*

Tells about opportunities in electronics, what you need to know, how LaSalle prepares you at home to start a career. *Yours free.*

MAIL ATTACHED CARD, NO OBLIGATION

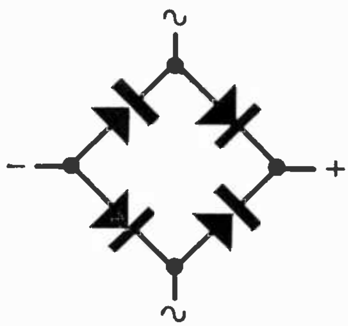
CIRCLE NO. 20 ON READER SERVICE CARD

Hobby Scene

Rectifier Bridge Leads

Q. *I bought a package of semiconductors, and among the unmarked ones, is a device that appears to be a rectifier bridge, but it has no markings on it. How can I identify which lead is which?*

A. Using the high-resistance range of your ohmmeter, check all combinations of the four leads until you find a pair that has infinite resistance. This is the ac input.



(We are assuming that all four diodes are good.) The other two leads are then the dc output. If you know the polarity of your ohmmeter (red usually positive), you can easily determine which is the positive output. That is, when the positive lead is on the upper ac input, there will be conduction through the upper right diode, making this the cathode or positive end.

Does "Instant On" Wear Out Tubes?

Q. *I have a TV receiver with an "instant on" feature. Do the tubes "wear out" faster since they always have a slight heater current flowing, and should I disconnect the receiver from the power (when not using it) to save the tubes?*

A. Tests have shown that tube life is not shortened by continuous application of heater current. In fact, there is more damage done when turning a tube set on and off due to heater thermal shock. Some manufacturers even claim a longer tube life with "instant on" due to constant heater temperature.

Why Won't a Diode Work?

Q. *I have an old crystal-detector radio that used a "cat's whisker" and a piece of galena. Recently, I lost the galena so I decided to replace it with a modern diode. Although the receiver still works, all I can get are the very strong stations. When I had the galena crystal, I received quite a number of stations. The circuit is still the same. What is going on?*

A. Although a modern diode can run rings around the old galena-cat's whisker combination in most cases, this is one area where the old way is better. The galena-cat's whisker diode started to conduct at almost zero voltage, while the germanium diode starts its conduction at about 200 mV and silicon types start at about half a volt. So you see why you are getting only the strong stations. If you are building a crystal set, germanium diodes are recommended.

What Is DIN?

Q. *I keep seeing the word (or letters) DIN on more and more audio equipment. What does it mean?*

A. DIN stands for Deutsche Industrie Normenausschus, a West German institute which sets certain industrial standards. The largest contact we have with them is in the audio field, where various plugs and sockets having DIN geometry and connections are used.

Have a problem or question on circuitry, components, parts availability, etc.? Send it to the Hobby Scene Editor, POPULAR ELECTRONICS, One Park Ave., New York, NY 10016. Though all letters can't be answered individually, those with wide interest will be published.

For the world of STEREO— XV-15/1200E

Designed for use with all stereo and four-channel derived compatible systems.

"PRECISION" is the one word that best characterizes the extraordinary quality of the new Pickering XV-15/1200E cartridge. We sincerely feel that the 1200E is the furthest advance achievable today—and perhaps in the foreseeable future—in stereo cartridge design and performance. Its exceptional ability to pick up *all* the material recorded at the lightest possible tracking forces make it totally unique and superior.

And all of Pickering's exhaustive testing shows that the 1200E is superior in the flatness of its frequency response and channel separation in comparison to competitive cartridges.

SPECIFICATIONS:

Frequency Response:	10 Hz to 30 kHz
Channel Separation, Nominal	35 dB
Tracking Force:	¾ gram, + ½ gram, − ¼ gram.
Nominal Output:	4.4 mv
Stylus Tip:	0.0002" x 0.0007"

For the world of DISCRETE 4-CHANNEL— UV-15/2400-Q

Designed and engineered specifically for playback of discrete recordings.

QUADRAHEDRAL™

The discrete 4-channel system requires a completely new cartridge that could not only faithfully reproduce the 20 Hz to 20 kHz AM signals, but also the 30 kHz FM modulated signals. The result is the Pickering UV-15/2400-Q. It consists of a completely redesigned cartridge and a new high performance stylus assembly, the Quadrahedral™, specially developed for this application. The UV-15/2400-Q performs in a superior manner by every test, and is capable of satisfying all technical and aesthetic requirements for playback of both discrete and stereo disks. Moreover, its stylus is designed to reduce record wear.

SPECIFICATIONS:

Frequency Response[1]:	10-50,000 Hz
Channel Separation:	35 dB
Tracking Force[1]:	1-3 grams
Output[3]:	3.6 mv ± 2 dB
Stylus:	Quadrahedral

Notes: 1 Recommended by manufacturer for optimum performance 2 When the cartridge is terminated in the recommended load of 100K ohms and 100 PF 3. Output with reference to 5.5 cm/sec record velocity.

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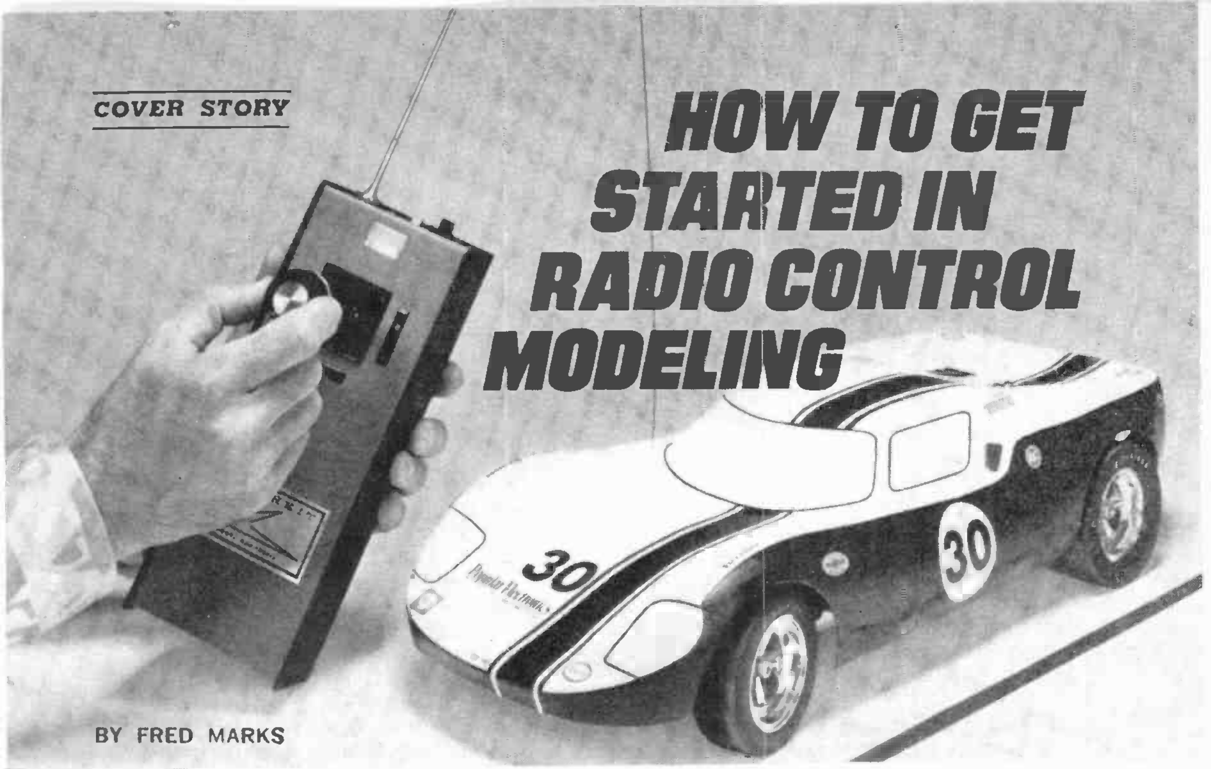
For further information write Pickering & Co., Inc., Dept. E, 101 Sunnyside Boulevard, Plainview, New York 11803

CIRCLE NO. 25 ON READER SERVICE CARD

COVER STORY

HOW TO GET STARTED IN RADIO CONTROL MODELING



BY FRED MARKS

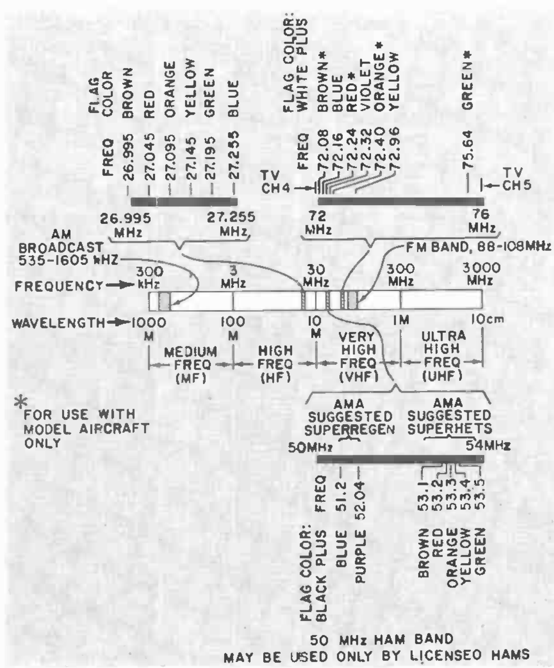
Solid-state designs spur growth of exciting hobby

IT IS almost impossible to convey the full excitement of radio control (R/C) modeling to anyone who has never been at the controls. While some of the glamour and excitement of the hobby are almost certain to rub off on the "audience" at a modeling meet, the ultimate thrill is reserved for the hobbyist at the transmitter controls as he maneuvers his model airplane, racing car, or boat over an intricate course.

Operating a model by radio control is similar to—yet vastly different from—operating a full-size vehicle. The major difference, of course, is that the model under your control is always at a distance from you. Even so, you can almost feel the G forces acting on it.

R/C modeling is one hobby that lets you exercise maximum creativity, manual dexterity, and competitive spirit. And you will learn a great deal about electronics, mechanics, and physics while having fun.

How It Started. Radio control for modelers dates back to the 1930's. By today's standards, the electronic gear that the pioneers of the hobby used was primitive and massive. Back then, you needed a ham license to operate R/C equipment, which



Three bands of frequencies have been allotted for use by hobbyists in radio control. Flag colors designate channel being used.

HOW WE TESTED HEATH'S

TO PRESENT a full report on R/C modeling, the staff of POPULAR ELECTRONICS built and tested its own car and control system. We used kits made by the Heath Company, which included a Model GDA-1057-1 3-channel transmitter, Model GDA-1057-2 receiver, Model GDA-405-3 receiver battery, and two Model GDA-405-44 miniature servos. (These items have a special system price of $150, though, if purchased separately, the total cost would be $170.) For future use, we added an optional Model GDA-1057-4 fourth channel ($20) and two more miniature servos ($25 each).

To use with our radio control system, we decided on a model racing car, which is probably the easiest thing to control and can be operated under less favorable circumstances than a boat or a plane. We used the now discontinued Heath "Spectre" racing car in which we installed a locally obtained $25 glow-plug engine.

The R/C System. The transmitter is basically a three-channel digital-proportional unit that supplies 500 milliwats to the input of the power amplifier. A joy stick controls the encoding for channels 1 and 2 (left and right turning on channel 1 with nothing on channel 2, or, for a model plane, elevator and rudder), both of which are equipped with secondary trim-pot tabs. The channel-3 control (throttle) is a similar trim-pot tab located on the right side of the transmitter case, which is the size of a walkie-talkie. The stick is spring-loaded on both channels so that it returns to its center (neutral) position. The throttle control stays where it is set. When converting to a four-channel system for model planes, the control for channel 4 (rudder, with channel 2 becoming aileron) goes on top of the stick.

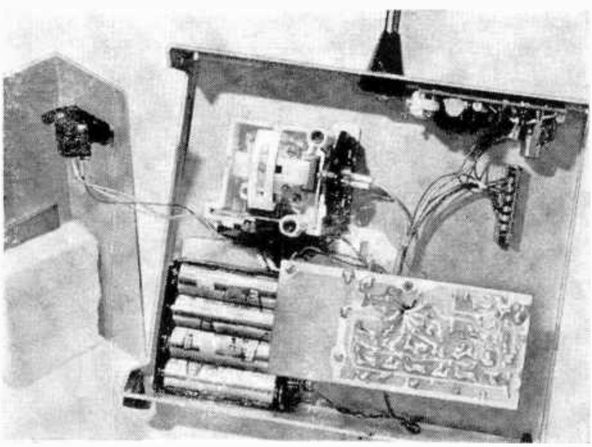
The only other external control is the power switch located on top of the case near the telescoping whip antenna. The switch is equipped with a lock-off tab that slips into place to prevent accidental turn-on. The state of the battery charge is indicated by a small meter on the front of the case just above the stick assembly.

The transmitter (and receiver) operates on one frequency, which can be any one of 17 in the 27-, 50-, and 72-MHz bands. We chose our transmitter to operate on 26.995 MHz.

The receiver measures $2\frac{17}{64}$" by $1\frac{3}{16}$" by $1\frac{5}{32}$" and weighs 2.5 oz, exclusive of the battery pack. Its i-f is 453 kHz, while its sensitivity is 5 microvolts or better. Operating from its 4.8-volt nickel-cadmium battery pack while driving two miniature servos, the current drain is roughly 6 mA, providing four hours of service from a full charge. Three ceramic filters are used in the i-f section.

Each of the miniature servos measures $2\frac{17}{32}$" by $1\frac{5}{8}$" by $\frac{7}{8}$" and weighs 1.75 oz. They will accept a pulse 1 to 2 ms wide at 4 volts peak-to-peak. Thrust is 4 lb, minimum; travel time is 0.6 second; linear output travel is $\frac{1}{2}$" end to end; and rotary output travel is 90°. The mechanical outputs include one rotary arm, one wheel, and two linear racks.

Assembling the transmitter was a



A typical 3-channel transmitter using conventional cells rather than rechargeable.

limited the number of hobbyists to a relative few.

In 1952, the FCC established the Citizens Radio Service, permitting almost anyone who wanted one to obtain a radio operator's (CB) license. No code or written test was required for the new license, and many people who did not feel it was worth it to study code and theory for ham licensing exams clamored for the new CB license. Some wanted it for voice communication; prospective R/C hobbyists wanted it to get into modeling.

With the opening of the Citizens Band, R/C modeling started to grow. By 1958, in fact, there were as many as 50 modelers who met at flying fields or boat sites

During this period, the equipment remained relatively unchanged. Furthermore, straightforward job, simplified by the fact that the transmitter section comes fully assembled and pre-aligned to the frequency specified. Assembly time was about nine hours.

The receiver and servos employ very small PC boards, the former containing two closely packed assemblies that require careful component mounting and lead soldering. In neither case was assembly particularly difficult, and the servos went together quickly because most of the electronic functions are performed by a single IC in each. Assembly time for the receiver (including installation of fourth-channel option) was about 5½ hours, while only 1½ hours are required for each of the servos. (Note: the battery charger was assembled with the transmitter. It simultaneously charges the nickel-cadmium batteries for both the transmitter and receiver.)

How It Performed. The combination of Heath car, engine and R/C system proved to be an excellent choice for us. After tuning the system for the proper responses at maximum range, we were ready for our first run. We found an immediate snag; the new battery we had bought the day before must have stood too long on the shelf because it would not start the engine. But once it was replaced by a fresh unit, the engine turned over with a roar and spewed out billows of bluish smoke (normal for a glow-plug engine).

At first we operated the controls timidly. For example, we opened the throttle just enough for the racing car to move at about a normal walking pace while controlling left-right steering in a slalom-like pattern. A few minutes of this, and we were ready for more speed. But owing to our lead fist, we advanced the throttle to almost wide open. There was an immediate increase in decibels as the engine wound out and the car almost flew away from us. Just a touch on the steering was enough to send it spinning out. Then when we attempted to throttle down and apply the brake a second snag appeared: the car slowed too gradually for proper operation. An inspection revealed that the brake had torn loose from its lever.

The next weekend, after soldering the brake back onto its lever, the car and R/C system performed flawlessly. Another mishap occurred when we forgot to lubricate the axle between runs; the axle seized in its bushings. Fortunately, after it cooled and was lubricated, we found that no permanent damage was done. We now remember to obey the lubrication caution noted in the Heath manual.

Owing to the car's mass, low center of gravity, and fast steering response, the Spectre stayed glued to the racing course at speed. Getting used to the light touch required on the steering at speed and to switch perspectives as the car is coming toward us took only about a half hour. Now that we have many hours of operation behind us, we feel confident enough to entertain the idea of entering some races. ◈

all modelers had to share primarily 27.255 MHz, a frequency also used by voice-communicating CB'ers, taxicabs, and traffic departments for controlling signal lights. The modeler's maximum transmitter power was limited to an input of 5 watts, but other services on the same frequency were permitted up to several hundred watts.

Through the efforts of the Academy of Model Aeronautics (AMA), the national association of model aviation, hobbyists were permitted, commencing September 11, 1958, to operate on five new Class C frequencies: 26.995, 27.045, 27.095, 27.145, and 27.195 MHz. The new frequencies and the development of more selective receivers bought interference problems to a temporary halt.

Operating on the new frequencies offered

Simple projects like a converted Baja Bug are fine first projects for learning basics.

R/C EQUIPMENT MANUFACTURERS

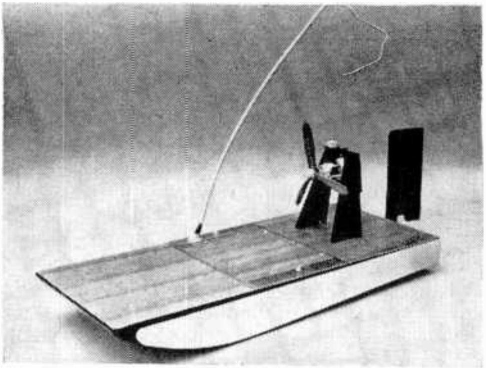
Ace Radio Control, 203 W. 19 St., Higginsville, MO 64037
Citizenship Radio Co., P. O. Box 297, Westfield, IN 46074
EK Products, Inc., 3233 W. Euless Blvd., Hurst, TX 76053
Futaba, 1124 E. Amo Blvd., Carson, CA 90746
Heath Co., Benton Harbor, MI 49022
Model Rectifier Corp., 2500 Woodbridge Ave., Edison, NJ 08817
Orbit Electronics, 312 Gillette St., Santa Ana, CA 92705
Pro-Line Electronics, Inc., 1213 E. Glendale Ave., Phoenix, AZ 85011
Royal Electronics Corp., 2119 S. Hudson St., Denver, CO 80222
RS Systems, 2407 S. Broadway, Santa Ana, CA 90707
World Engines, Inc., 8960 Rossash Ave., Cincinnatti, OH 45326

a greater advantage. Selectivity made the new receivers immune to transmitters on other frequencies. Hence, as many as six models could be controlled simultaneously. At large meets, flight lines actually formed for each frequency.

Meanwhile, the introduction of the transistor in the mid-1950's gave a tremendous boost to R/C modeling. Small and lightweight, the transistor considerably reduced the demands placed on battery supplies in both transmitters and receivers, which in turn, reduced the size and weight of the batteries themselves. As transistors replaced tubes, R/C equipment became miniaturized to the point where transmitters were, for the first time, small enough to be hand-held. And transistor circuits proved to be much more reliable than tube-circuit counterparts.

An Era of Change. By 1963, interference had again become a serious problem to R/C modelers. Class D CB'ers had crowded the airwaves, and there were now more modelers than there was spectrum space to meet their needs. It was common at many flying fields for a strong signal from a passing mobile CB rig to completely disrupt operations.

An organized effort, begun in 1963 and led by officers of the AMA, culminated in 1966 with the FCC's approving five new frequencies for R/C operation: 72.08, 72.24, 72.40, 72.96, and 75.64 MHz. In 1971, 72.16 and 72.32 MHz were added to the list.



Another simple first project is an airboat. It is ideal for use on local city park ponds.

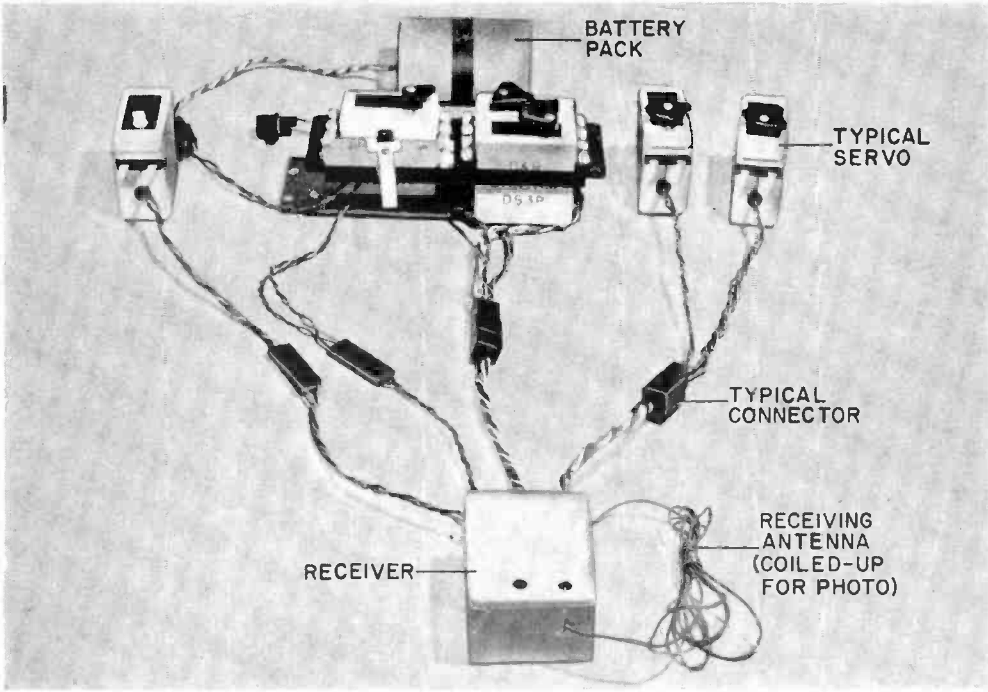
The present frequencies on which R/C modeling is permitted are shown in the frequency spectrum diagram. Six frequencies are available in the 27-MHz CB band, seven in the 72-76-MHz band (four for model aircraft use only), and seven in the 50-54-MHz 6-meter ham band. If all available frequencies were in simultaneous use at a given site, as many as 20 models could be active.

On the 27-MHz band, excluding 27.255 MHz, a maximum of 3 watts input to the final amplifier in the transmitter is permitted, and crystals must be ground to a 0.01-percent tolerance. On 27.255 MHz, 3 to 5 watts input, also 30 watts, is permitted, provided that the crystal is ground to a tolerance of 0.005 percent. The 27.255-MHz frequency, however, is seldom used by modelers because of the severity of the interference often encountered.

A 3-watt input for R/C transmitters is rather high. For practical purposes, a 1-watt input would be typical, while 0.5 watt is quite acceptable. Some transmitters are rated at 100 mW or less input. They require no station license, but are subject to the same tolerance and modulation requirements of the higher-powered transmitters.

Requirements for Operating R/C. Operating R/C equipment is a privilege granted the operator by the citizens of this country in that (a) one must properly share the radio spectrum and (b) be familiar with and observe the applicable regulations. Transmitters rated at over 100 mW may be operated only by those who have secured an FCC license. Any citizen of the U.S. who is 12 years of age or older can qualify for this non-ham station license.

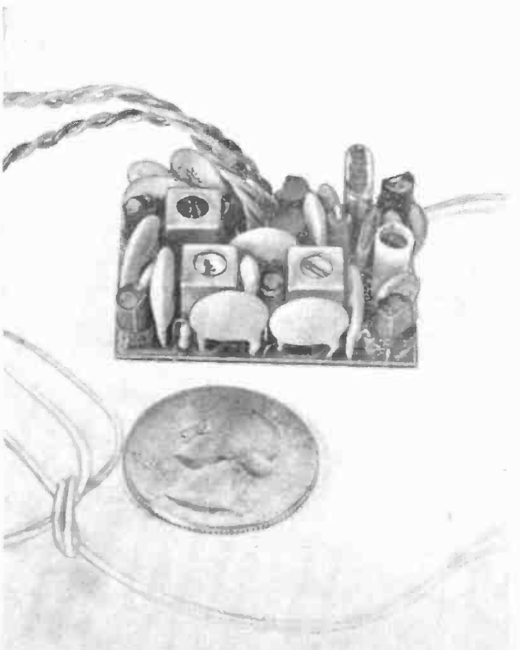
To obtain a license for the non-ham bands,



Airborne control package provides one to eight channels depending on transmitter used.

you must familiarize yourself with Volume VI, Part 95 of the FCC Rules and Regulations (obtainable from: Superintendent of Documents, Government Printing Office, Washington, DC 20402 for $1.25) pertaining to the Citizens Radio Service. Then fill out FCC Form 505 (get it from: Federal Communications Commission, Washington, DC 20544) and mail it with a check or money order for $20 to: Federal Communications Commission, Gettysburg, PA 17325. The $20 fee covers station licensing for five years. The station license covers all transmitters listed by you on Form 505 and bears your call letters.

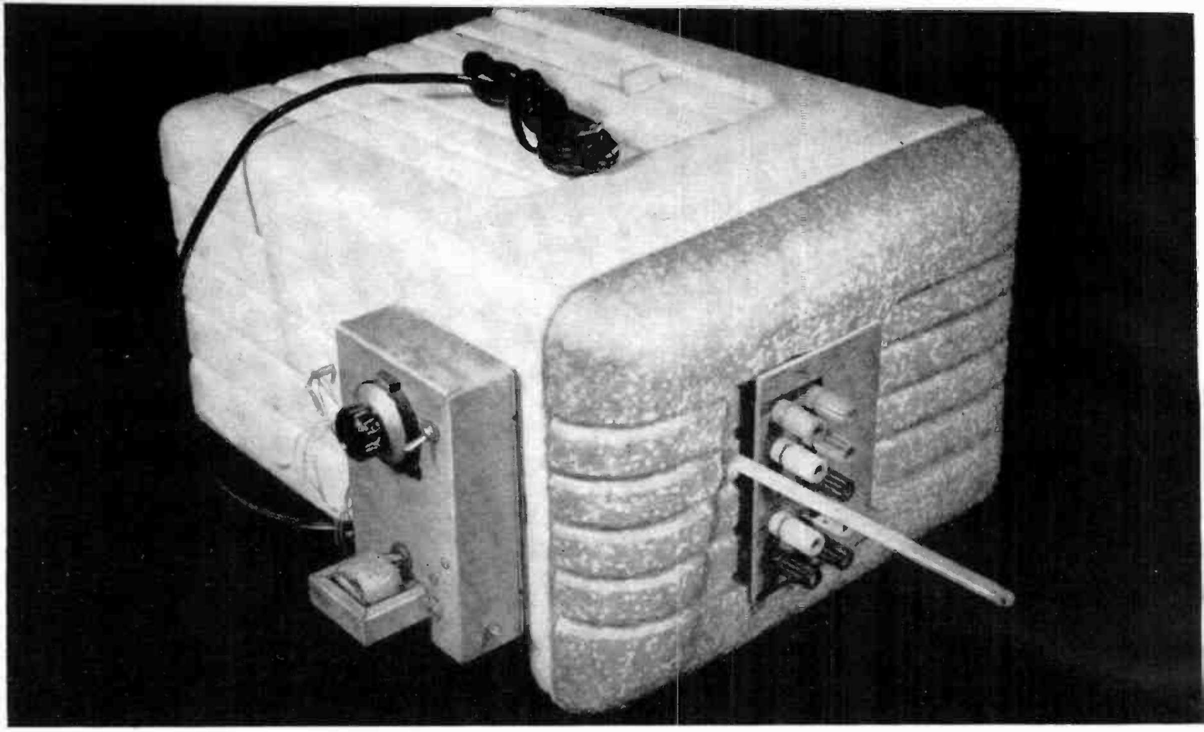
Tiny Ace R/C Microgem pulse receiver is not very much bigger than an ordinary quarter.



The ham license required for R/C operation on 50 to 54 MHz offers the advantage of being able to become active in other ham communications. You must pass a 5-wpm code test and a simple written test. Try to get your technician ticket at the outset. A novice ticket is good for only two years, after which you must pass the technician test to remain a ham.

Summing Up. Many hobby shops stock everything you need for R/C modeling. Your investment for electronic gear can be as low as $50 for the most basic single-channel pulse-type system to several hundred dollars for the most sophisticated multi-channel digital-proportional system. For more information about R/C gear, you might write to the companies listed in the accompanying table.

We are planning additional coverage of various R/C systems and how they work in a future issue. Watch for it. ◈



TEST BENCH

BUILD THE TORTURE BOX

MINIATURE ENVIRONMENTAL TEST CHAMBER CAN BE SET FROM 14°F TO 158°F WITH 1-DEGREE ACCURACY

BY RALPH TENNY

WE ALL know how strict the temperature tolerance specifications are on components and systems for military and space applications; but do we ever stop to think whether the projects we build in our workshops will operate satisfactorily "in the field"? A fire detector, for example, that works fine in the controlled conditions of the workshop can go haywire in an attic in the summer when the temperature can reach 140°F. A metal locator may operate quite differently in the coolness of the forest in the fall and in the heat of summer on the beach.

Maybe it's time to take the guesswork out of building for unusual temperature ranges and install your own temperature test chamber, simply by building the Torture Box described here. It can be used to test circuits at temperatures from below −10°C (14°F) to +70°C (158°F). Of course, this range is probably more than you will need since it exceeds the range of many commercial components.

The Torture Box is a low-cost project that provides a change of pace for experimenters. The electronic circuits are fairly simple, but the project uses a combination of materials and techniques that is a little different. The basic box is an ordinary molded plastic picnic-type cooler. All subassemblies in the Torture Box are fastened to thin pieces of plywood or wall-panel material, which are fastened to the plastic using either white furniture glue or aliphatic (fatty, acrylic) resin. Do not use an aromatic glue or cement!

The operating range of the Torture Box can be extended, but temperatures higher than 80°C (176°F) should not be attempted since they may soften the plastic. A large quantity of dry ice will lower the temperature below −28°C (−18°F), but the nonlinearity of the control thermistor may hamper control below about −10°C.

Construction. Select a picnic cooler of sufficient internal volume. The one shown in the photos of the prototype is 12″ by 9″ by 12″ and has an internal volume of about 700 cu in.

The assembly of the small mechanical units that are attached to the chamber is described in the following paragraphs. Plan the location of these units in your particular cooler so that the weight distribution will not cause the finished chamber to tip. (Remember that the basic cooler is very light compared to the weight of the mechanical subassemblies.) As shown in the photos, the cooler was placed on its wide side, and four small pieces of a similar plastic were glued to the bottom to serve as feet. Use a sharp instrument to make the required openings and holes. Keep the hot soldering iron away from the plastic. The cover should be tight fitting. If necessary, some type of locking device can be used.

Fan Motor. Any small motor is suitable. In the prototype, a shaded-pole motor/fan combination originally intended for elec-

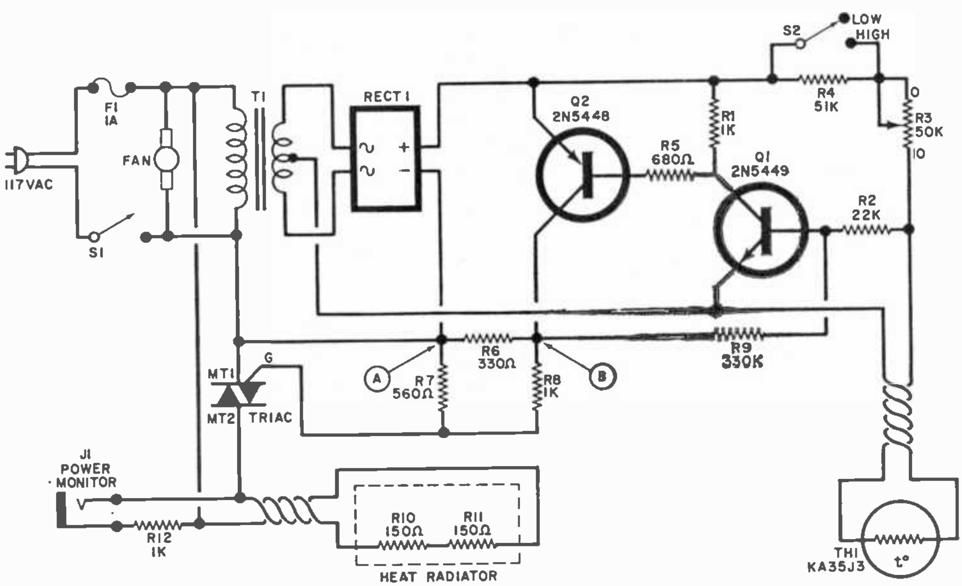


Fig. 1. Thermistor TH1 senses the heat radiated by power resistors R10 and R11.

PARTS LIST

F1—1-ampere fuse and holder
J1—Open-circuit jack (Calectro F2-842) or neon lamp (Radio Shack 272-1105)
Q1—2N5449 transistor
Q2—2N5448 transistor
R1,R8,R12—1000-ohm, ¼-watt resistor
R2—22,000-ohm, ¼-watt resistor
R3—50,000-ohm potentiometer
R4—51,000-ohm, ¼-watt resistor
R5—680-ohm, ¼-watt resistor
R6—330-ohm, ¼-watt resistor
R7—560-ohm, ¼-watt resistor
R9—330,000-ohm, ¼-watt resistor
R10,R11—150-ohm, 50-watt resistor (Dale RH-50 or similar, with heat-sink mounting)
RECT1—50-volt, 2-ampere rectifier (Radio Shack 276-1151)
S1,S2—Spst slide or toggle switch
T1—Transformer—12.6-VCT, 0.1-A secondary (Calectro D1-750)
TH1—Thermistor (Gulton 35TF1, Fenwal KA35J3, YSI44007)
TRIAC—RCA 40529
Misc.—Small shaded-pole motor and fan (see text), plastic container, white glue, ¼″ x ¼″ pine stock, 4″ brass tube, sheet metal, wire screen, thermometer, perf board, mounting clips, sockets, control dial (Radio Shack 274-605), five-way binding posts, plywood, mounting hardware, etc.

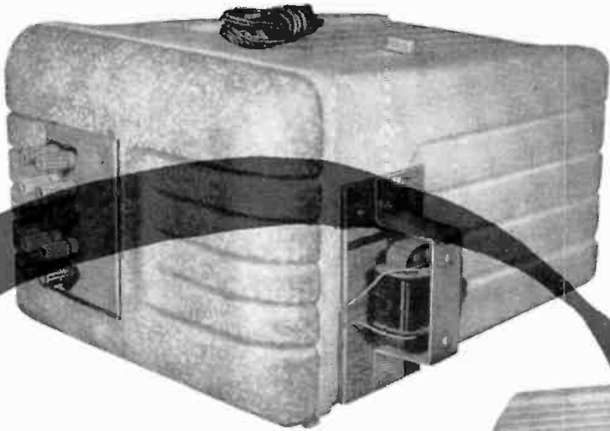


Fig. 2

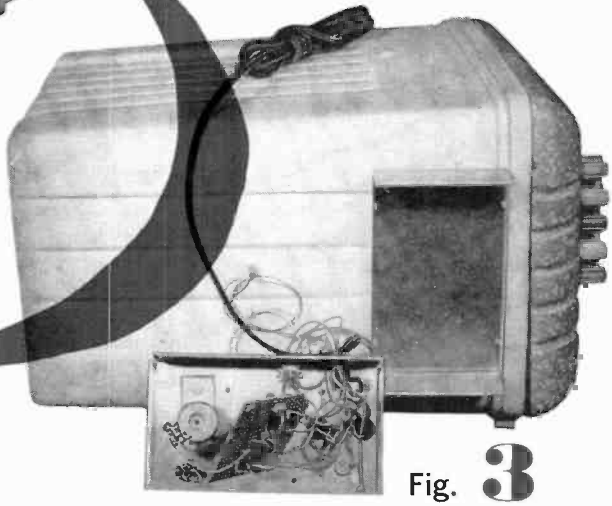


Fig. 3

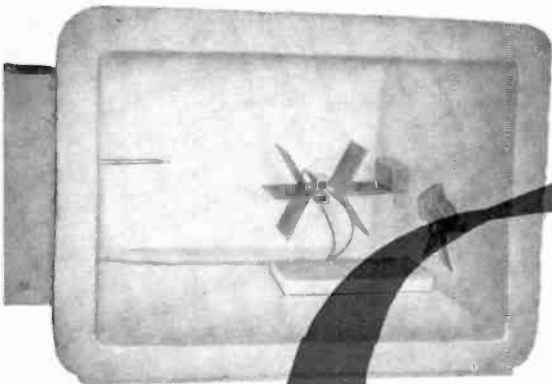


Fig. 4

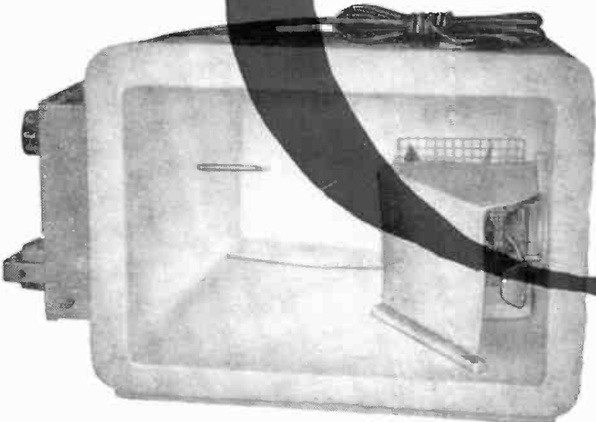
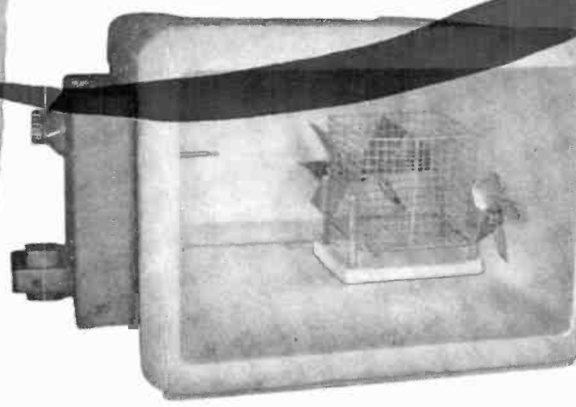


Fig. 5

Fig. 6



tronic chassis ventilation was used. After drilling a hole for the motor shaft in the cooler wall, bend a mounting bracket or 1/16" aluminum to secure the motor to the wooden mounting plate. Extend the motor shaft (using tubing) so that the fan will be located about ¾" inside the cooler. Attach the motor mounting to the cooler as shown in Fig. 2.

Control Circuit. The control circuit is mounted in a suitable chassis, the bottom plate of which is affixed to the cooler on the side opposite the fan as shown in the photo in Fig. 3.

With the exception of the thermistor (*TH1*), the triac, *T1, R10, R11,* and potentiometer *R3*, the circuit can be assembled on a small perf board, which is mounted in the upper portion of the control chassis. Potentiometer *R3* is mounted on the front panel and provided with a vernier dial drive.

The thermistor is connected to the end of a length of twisted-pair wire which is fed through a narrow tube 3" or 4" long. The tube is then inserted through the Styrofoam so that the thermistor is located within the box and the twisted pair can be connected to the perf board. The triac is mounted on a small heat sink isolated from the metal chassis. Range switch *S2* and power monitor connector *J1* are mounted on the front panel. The transformer is mounted on the outside of the control chassis.

Power resistors *R10* and *R11* are mounted on a three-piece heat radiator whose configuration is shown in Fig. 4. The radiator consists of three pieces of thin brass sheet at least 2" wide and 4" long. Use heat-sink grease between the pieces of the radiator and between each power resistor and heat sink.

When the electronic assembly is complete, temporarily disconnect the triac and connect a 10-volt dc voltmeter between points A and B of Fig. 1. With *R3* set to a low resistance, no dc voltage should be indicated between the test points. As the resistance of *R3* is increased, a 10-volt signal will appear. Make a check for both positions of range switch *S2* and note that the dc voltage appears at a much higher resistance on *R3* when *S2* is in the low range. If everything is OK, disconnect the unit from the power line and replace the triac.

Air Baffle. The baffle covers the fan and directs the air to the rear and thus counterclockwise around the interior of the chamber. The layout is shown in Fig. 5. The baffle is made of thin metal stock but you should make a pattern using a piece of paper first to get the proper size and configuration. The baffle will be fixed to the side wall and bottom of the box using ¼" square pine blocks. Once the shape has been determined, cut the metal stock and install.

Ice Basket. The basket is an open-topped cube, about 3" on each edge, made of wire screen. Four ⅜" round dowels are glued to the corners with epoxy and the dowels are used to secure the basket to a plywood or plastic plate which is secured to the base of the chamber as shown in Fig. 6. When the basket is in place, cut a small hatch directly over it as shown in Fig. 7. Note that the hatch is cut with sloping sides so that the cover cannot drop into the cooler. Any small handle can be used on the cover.

Input Terminal Block. A minimum of ten 5-way color-coded binding posts should be provided for input, output, and power supply connections to the equipment being tested. The terminals are affixed to a piece of plywood as shown in Fig. 2, with their leads protruding through the cover of the cooler.

Internal Circuit Board. As shown in Fig. 8, the internal terminal block is made from a 4½" by 6" glass-epoxy laminated board mounted in a frame of ⅜" pine strips so that the board is far enough from the cover to be well within the chamber. Make sure that the wooden frame is waterproofed with varnish. The various input binding posts can be connected to color-coded perf-board pins on one edge of the board. Various combinations of sockets and perf-board pins can be attached to the board for testing different types of circuits.

Note also, in Fig. 8, that a conventional laboratory-type immersion themometer is inserted through the cover to check the internal temperature. The thermometer must have an appropriate temperature range so that it can be read from the outside of the chamber.

Test and Calibration. Recheck the mechanical assembly of all cooler-mounted components, making sure that all elements are firmly secured and that all glued joints are hard and dry. Recheck all the wiring in accordance with Fig. 1. Keep in mind that power-line ac is present on some leads and be very careful to avoid the possibility of an electrical shock.

Set the vernier dial on *R3* to 10 and slip

HOW IT WORKS

The environmental chamber creates hot or cold temperatures by balancing a heater against the cooling effect of dry ice. A fan continuously circulates the air in the chamber, while a thermistor-controlled regulator circuit (Fig. 1) adjusts the temperature to the desired value, which is set on a dial. Transistors *Q1* and *Q2* form a complementary Schmitt trigger which normally has about 1.5 volts of lag (hysteresis). Since the trigger is powered by full-wave rectified dc with no filtering, the circuit voltage sweeps from zero through about 17 volts at a rate of 120 times per second. This varying power reduces the hysteresis to a few millivolts and thus provides control to ±1 degree.

If the thermistor resistance is below the set point (temperature dial setting), both *Q1* and *Q2* are cut off and *R7* keeps the triac cut off. As the chamber cools, the thermistor resistance increases until *Q1* starts to turn on. Shortly after that *Q2* turns on and feedback through *R9* increases the turn-on signal for *Q1*, causing the trigger to snap full on. A pulse of current through *R8* turns on the triac until the end of that half cycle of ac power. As the power passes through zero, the triac turns off and the cycle starts again. If the thermistor resistance is greatly out of balance, the triac will be turned on early in each cycle; a small unbalance will delay the triac turn-on until late in the cycle. Consequently, heating power (triac current in *R10* and *R11*) is applied in proportion to the difference between the actual temperature measured by the thermistor and the temperature set by the control dial.

Range switch *S2* and potentiometer *R4* extend the control range to low temperatures, without losing the resolution on *R3*. Consequently, the set point resolution approaches 1°F per division on the specified control dial.

the shaft of *R3* until the in-circuit resistance is about 3000 ohms. Set the range switch to high and set the control dial to zero. Connect a 150-volt ac meter to *J1* and, with a thermometer inserted into the chamber, turn on the power. The fan should start to run and the voltmeter should indicate zero.

Advance the temperature control dial toward 10 until the voltmeter indicates upscale and note the dial indication. Advance the control toward the next major dial graduation and wait until the voltmeter shows that the heater power is cycling on and off every four or five minutes. Record the dial indication and the thermometer temperature. Continue this process until the control dial has reached 10 or the temperature reaches 70°C (158°F). Slip the shaft on *R3* until the 10 on the temperature control dial causes the temperature to stabilize at 70°C.

Set the range switch to low and the temperature dial to 5. Put approximately 3 cu in. of dry ice into the ice basket (through the small hatch on the top) and operate the system until the voltmeter shows that the heater circuit is cycling. Note the temperature and try new settings until the dial setting for 0°C (32°F) is found. At this point, the operation has been checked and the end points of the operating range have been found and calibrated. You can now fill in a calibration chart by recording temperatures at other major dial settings on both ranges. Here is a typical calibration chart.

Control Dial Settings (Major Div.)	**Temperature (°F) (S2 Position)** (Low)	(High)
0	7	43
1	10	49
2	13	55
3	18	60
4	21	66
5	24	74
6	29	86
7	32	94
8	38	108
9	—	129
10	—	161

One-half pound of dry ice (usually available from ice cream stores) is sufficient for most tests. *Do not* handle dry ice with the bare hands as severe frostbite can result. A wide-mouth thermos bottle can be used to store dry ice for as long as 8 hours, but *do not* close the lid tightly. Long-term storage of dry ice is essentially not possible for the home experimenter, but between 25% and 50% of a given amount will remain after 24 hours if stored in a good thermos. To break dry ice into chunks, wrap it in a heavy cloth and pound with a hammer.

The power monitor jack (*J1*) can be replaced with a neon lamp if desired since, once the monitor is calibrated, there is no further need for the jack—unless recalibration becomes necessary.

Using the Chamber. To test a circuit, you can assemble the circuit on the chamber's internal perf board or attach a finished board to the internal board mounts. Connect the power leads, inputs, and outputs to the cover

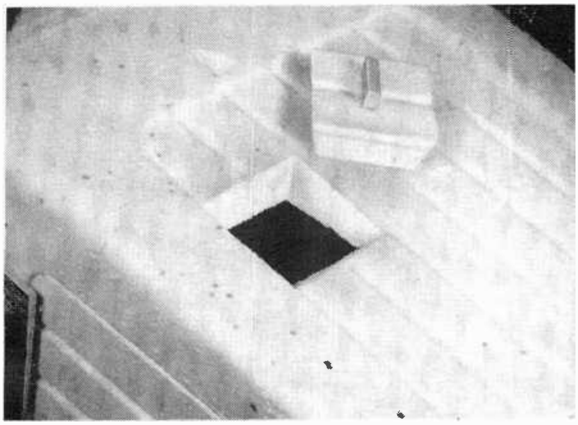


Fig. 7

binding posts and check for normal operation of the circuit with the chamber at room temperature.

Then supply power to the chamber, set the desired elevated temperature and see how your circuit works. If it passes this test, cool the chamber, checking circuit operation along the way. If the circuit doesn't pass the temperature test or (more commonly) if its operation drifts with temperature, the circuit must be temperature-compensated to limit drift to allowable levels. This means selecting components whose temperature coefficients compensate for temperature change or adding components that drift in the opposite direction.

The term "temperature coefficient" simply means how much a component will change in value with changes in temperature. This is usually expressed as % per °C. For example, a fixed resistor of 1000 ohms having 0.1%/°C temperature coefficient will change 1 ohm for each 1°C change in temperature. A +0.1%/°C coefficient indicates that the resistor will increase 1 ohm for each 1°C change in temperature. If the 1000 ohms is measured at 25°C, the resistor will measure 1050 ohms at 75°C and 975 ohms at 0°C.

There are capacitors with either positive or negative temperature coefficients. Most thermistors are resistors with negative temperature coefficients, though some companies also make thermistors with positive temperature coefficients. Also, silicon or germanium diodes can be added to a circuit to compensate for temperature drifts in transistors of the same material.

As an example of temperature compensation, consider the circuit in Fig. 9A, where *Q1* is a current source feeding a load, *Rx*. Resistors *R1* and *R2* set the reference level, while *R3* determines the amount of current flowing through the load. As the circuit elements heat up, the current through *Q1* will

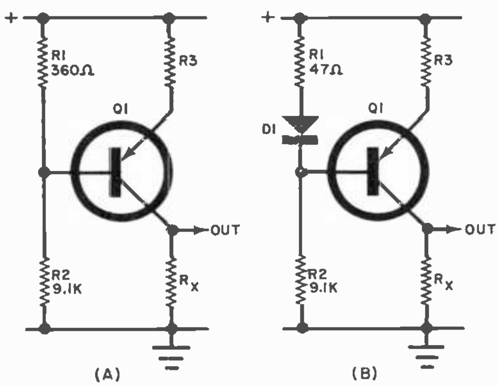


Fig. 9. Temperature compensation circuits.

start to increase, thus increasing the load current. One way of compensating for this increase is shown in Fig. 9B, where a diode has been added in series with *R1*. If *Q1* is a silicon type, the diode must also be silicon. The modified circuit acts exactly the same as before except that the reference voltage is now the voltage across *R1* and *D1*. Resistor *R2* helps to control the current through the diode, but has less effect than it did in Fig. 9A.

To make a complete and proper compensation of load current with temperature, it is now necessary to vary *R2* and *R3* to get the desired current level and good stability with changes in temperature. You will see this method of temperature compensation used in many commercial units. ◈

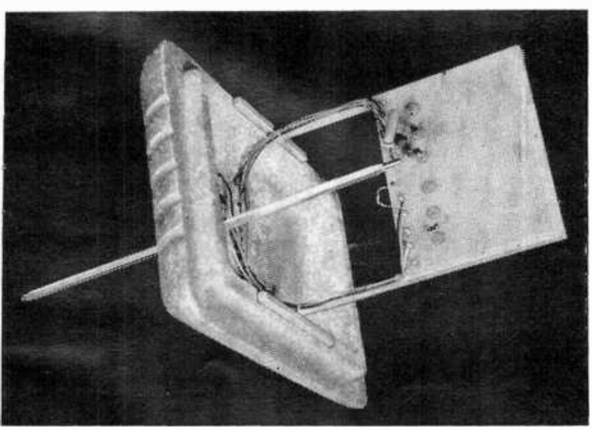
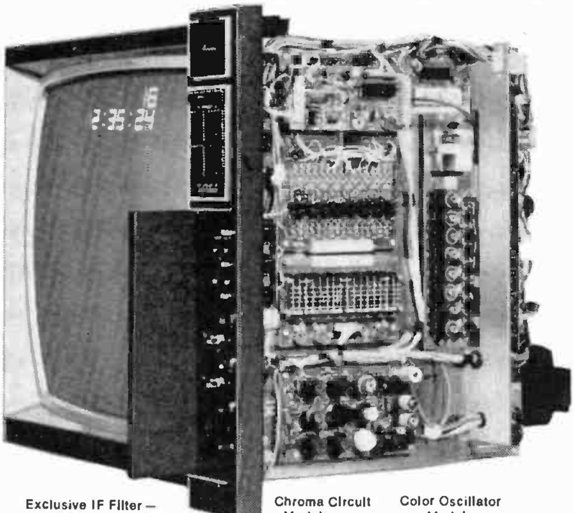
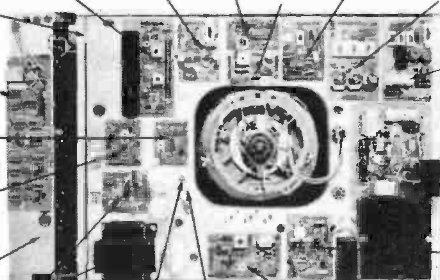
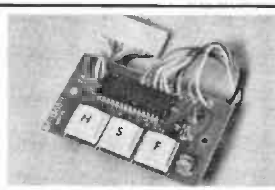


Fig. 8

The all-new digital-design







Eleven-Function Touch-Tune Remote Control for the Heathkit GR-2000 ... 79.95*

This all solid-state ultrasonic system utilizes 13 integrated circuits, 28 transistors to give you wireless armchair control of on and off, volume, VHF/UHF channel selection, up or down color intensity, and tint. Plus, a touch of the volume button automatically recalls the digital readout to the screen. Kit includes receiver for in-chassis mounting and handheld transmitter. Operates from 20-feet away from set.

Kit GRA-2000-6, 4 lbs. **79.95***

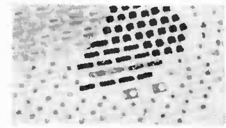
Optional Digital Clock for your GR-2000

In just a couple hours' time you can build the GRA-2000-1 Digital Clock Accessory. Everything mounts on one small board that plugs into the readout board in the GR-2000 service drawer. That's all there is to it. Clock circuit board has slow, fast and hold pushbuttons for setting time, jumper wire for selecting 12 or 24-hour format. You set your on-screen display for hours and minutes, or hours, minutes and seconds using the programming circuitry on the channel readout board. Order with your GR-2000, or add it on later, if you prefer.

Kit GRA-2000-1, Digital Clock Accessory, 1 lb. **29.95***

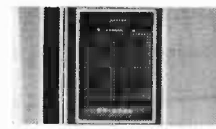
It offers you these important advances in technology, quality, and performance:

Programmable Channel Selection through digital up-down counter with computer-like programming board.

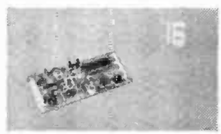


100% Solid-State Design — the picture is the only tube-type device.

Silent All Electronic Tuning with new combination UHF/VHF Varactor Tuner located inside the chassis — completely shielded.



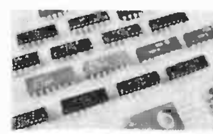
Touch Tuning at front panel (or remote) — touch to change channels up or down — hold in to sweep all channels.



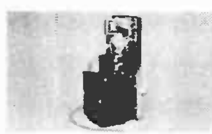
On-Screen Channel Readout — big, bright 1½" numerals for both UHF and VHF.

On-Screen Clock Readout gives time in 4 or 6-digit format, 12 or 24 hour time.

Fixed Filter IF totally eliminates instrument IF alignment forever.

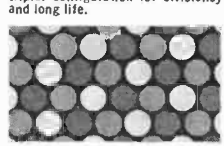


19 Integrated Circuits simplify kit building and permit ultra-sophisticated technology with long-term reliability.



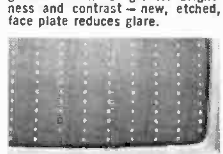
Solid-State Hi-Voltage Supply in tripler configuration for efficiency and long life.

Solid-State Low-Voltage Supply has short-circuit proof integrated circuit regulators.



New Deluxe Black (Negative) Matrix Picture Tube — fully illuminated color dots with black background matrix for greater brightness and contrast — new, etched, face plate reduces glare.

New Vertical Sweep Design gives better picture interlace, improved picture detail; complementary power transistors eliminate output transformers for better linearity.



True Digital Design Dot Generator makes picture convergence easier and more precise.

Twelve Wiring Harnesses — prefabricated, connectors installed, pre-stripped, ready to solder — this TV is easier to build.

CONSTRUCTION

Single-IC Capacitance Meter

PE TESTED

MEASURES FROM 100 pF TO 1 uF ON A LINEAR METER SCALE

BY HARRY GARLAND AND ROGER MELEN

THERE are meters available to the electronics experimenter and service technician that can be used to measure just about any quantity in electronics. However, when it comes to measuring capacitance, the meter is probably complex and expensive. There are some instruments that have a capacitance measuring feature; but they usually have some form of bridge circuit that requires the nulling of a meter through the simultaneous operation of two or more (sometimes interacting) controls. In using this type of instrument, it is often difficult to find the correct meter null unless the approximate value of the capacitance is known before the measurement begins.

The simple capacitance meter described here is very easy to use, requiring only the connecting of the unknown capacitance to a pair of binding posts and operation of a single rotary switch. When the correct range is found, the meter will indicate upscale to give the capacitance value. The indications on the meter scale are linear and the instrument covers a range from 100 pF to 1 μF. If desired, an external digital multimeter or VTVM can be used as the readout instead of the built-in meter. Since the meter is powered by batteries, its operation is independent of the power line.

How It Works. Most of the circuit (Fig. 1) is contained on a single IC, a CMOS quad NOR gate whose extremely low power requirement ensures long battery life.

Gates *IC1A* and *IC1B* are connected to form an astable multivibrator whose frequency of operation is determined by the value of *C1* and a resistor selected by *S1A*. This signal is coupled through *C2* to trigger *IC1C* and *IC1D*, wired as a monostable pulse generator whose output pulse duration is determined by the value of the unknown capacitance *(Cx)* connected between *J1* and *J2* and the resistance value selected by *S1B*. If the selected resistor value is accurately known, the output pulse duration is then determined by the unknown capacitor.

In the prototype meter shown in the photo, the output pulse duration is measured by the circuit shown in Fig. 2A, where the readout is on a milliameter. In this circuit, *Q1* is used as a saturating switch while *R8* is used to calibrate the meter. Since the meter indicates dc current flowing through *Q1*, and since the amount of dc current is directly related to the pulse duration, the meter can be calibrated directly in capacitance. Capacitor *C4* is used to integrate the dc pulses appearing across the meter; it thus removes the ac component.

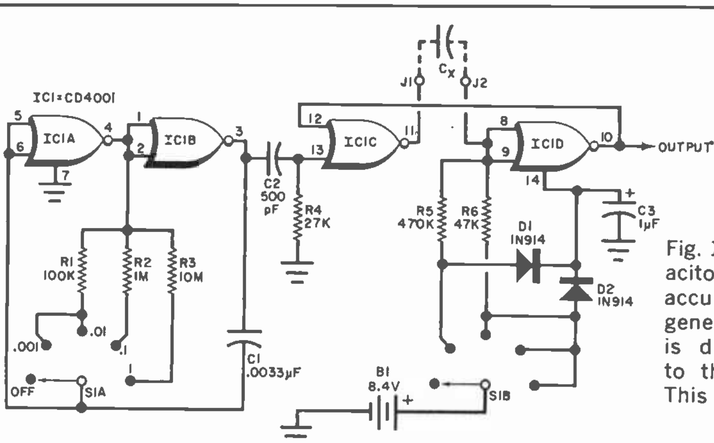


Fig. 1. The unknown capacitor forms part of an accurate pulse duration generator, whose output is directly proportional to the unknown value. This output is metered.

PARTS LIST

B1—8.4-volt or 9-volt battery
C1—0.0033-μF capacitor
C2—500-pF capacitor
C3, C5—1-μF capacitor
C4—2000-μF electrolytic capacitor
D1, D2—1N914 silicon diode
IC1—CD4001 CMOS quad NOR gate
J1, J2—5-way binding posts
Q1—2N3565 transistor
M1—0-1-mA, dc meter
R1, R11—100,000-ohm, ¼-watt, 5% resistor
R2—1-megohm, ¼-watt, 5% resistor
R3—10-megohm, ¼-watt, 5% resistor
R4—27,000-ohm, ¼-watt, 5% resistor
R5—470,000-ohm, ¼-watt, 5% resistor
R6—47,000-ohm, ¼-watt, 5% resistor
R7—10,000-ohm, ¼-watt, 5% resistor
R8—5000-ohm potentiometer
R9—470-ohm, ¼-watt, 5% resistor
R10—2700-ohm, ¼-watt, 5% resistor
R12—100,000-ohm potentiometer
S1—2-pole, 5-position rotary switch
Misc.—Perf board, suitable chassis, switch knob, mounting hardware, etc.
Note—A kit of all the above parts (not including case) is available from the authors, 565 Arastradero, Suite 310, Palo Alto, CA 94306, for $19.95, postpaid.

The circuit in Fig. 2B is used when an external digital voltmeter or VTVM (1-volt dc range) is used as the readout instead of *M1*. In this circuit, *R11* and *R12* operate as a voltage divider while *C5* filters out the ac component.

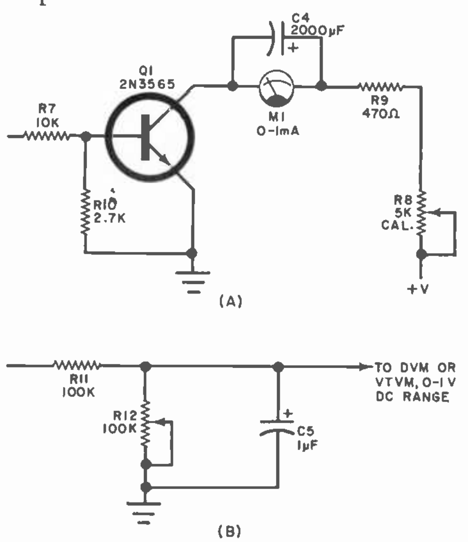


Fig. 2. (A) is used when you desire built-in metering, and (B) for external metering.

Construction. The circuit can be assembled on a piece of perf board, using a socket for *IC1*. Switch *S1*, the two binding posts and the meter (if used) are mounted on the front panel of the selected chassis. The battery is mounted in a holder on the perf board.

Calibration. Connect a known value of capacitance (5% or better tolerance) between *J1* and *J2*. Place the range multiplier switch, *S1*, in the appropriate position and adjust *R8* until the meter indicates the correct capacitance. If you are using the external metering device, set it to its 1-volt dc range and adjust *R12* for the correct indication. The calibration on one range suffices for all other ranges.

The accuracy of the instrument is limited by the accuracy of resistors *R1*, *R2*, *R3*, *R5*, and *R6*. Although 5% tolerance is adequate in most cases, you can use more precise resistors or trim each range individually with small potentiometers. If you decide to trim each range separately, use a separate precision capacitor for each range. Trim *R1* before trimming *R5*. ◈

VHF/UHF SCANNING MONITORS

A COMPREHENSIVE BUYING GUIDE

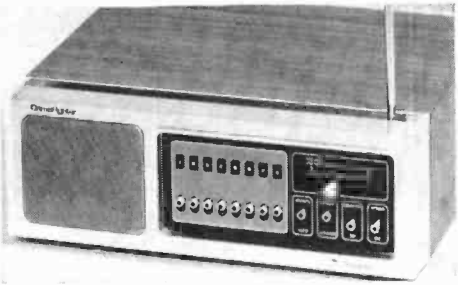
WIDE VARIETY OF MODELS
FOR LISTENING TO POLICE, FIRE, AND WEATHER

BY HERB FRIEDMAN

BACK in the not too distant past, outside of the people directly involved in emergency services (fire, police, smoke jumpers, etc.), there were few eavesdroppers on the Public Safety frequencies—those parts of the radio spectrum from 30 to 50 MHz (low band) and 152 to 174 MHz (high band). But when SWL's and the general public discovered they could listen in on private radiotelephone calls, hear weather reports, and monitor the G-men on a stakeout, police-fire radios (vhf monitors as they are more commonly termed) became the hottest thing in consumer electronics since CB.

Since we have just about run out of available frequencies, many other services have been crowded into what were the old police-fire bands; the crowding became so bad, in fact, that it was necessary to open up another Public Safety band—the so-called uhf band between 450 and 470 MHz. Today, the three Public Safety bands still have the old police and firefighters, plus air rescue, marine ship-to-shore, police walkie-talkie, common-carrier, regional weather forecasts, back-country search and rescue, and just about any other safety service imaginable.

The fact is that some of the most interesting radio "programs" can be found on the Public Safety frequencies rather than on the broadcast band. No news report or fictional radio or TV show can truly duplicate the high adventure of actually listening to police track a thief through your local shopping center, or to your local Coast Guard crew handling a marine disaster.

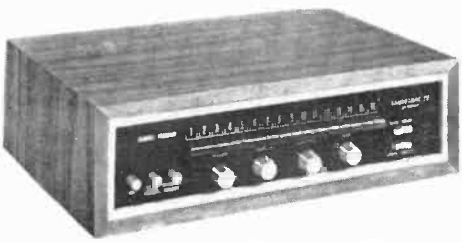


Teaberry Crimefighter

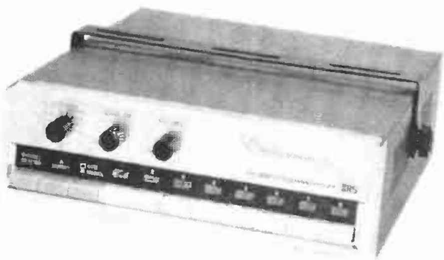
Pace 108

Sonar FR-2516

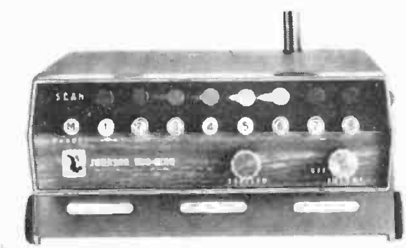
Robyn Hi-Bander



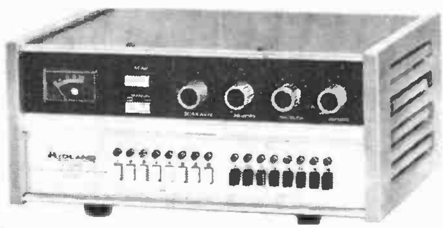
Tennelec Tennetrac IV



Radio Shack Realistic Pro-88



E. F. Johnson Duo-Scan



Midland 13-950

VHF/UHF SCANNING MONITORS

Manufacturers and model	Price ($)	No. of Channels	Bands	Features
Electra				
JR-1H;-1U	80	2	Hi vhf; uhf	Has AM BCB radio, portable
Bearcat III	140-160	8	Any 2 of 3	R-f plug-in modules select bands
Heath				
GR-110	120	8	Hi vhf	Digital channel readout, kit
Hy-Gain				
618	130	10	Any 1 of 3	R-f plug-in module selects band
625;626	150	4	Hi vhf; uhf	Pocket size
E. F. Johnson				
Duo-Scan	170	8	Lo, hi vhf	Dual conversion, mobile or base
High-Band, UHF	180	8	Hi vhf, uhf	Same as Duo-Scan
Mono-Scan	140;160	8	Hi vhf; uhf	Two separate models
Lafayette				
Monitorscan-8	100	8	Hi vhf	Dual conversion
Portascan-4	100	4	Hi vhf	Pocket size, 150-160 MHz or 160-170 MHz
Midland				
13-906	120	4	Hi vhf	Pocket size 4 ch, 152-159 MHz
13-912;-914	100;125	4	Hi vhf; uhf	Portable
13-930;-934	200	8	Lo,hi vhf;hi vhf,uhf	Mobile mounting bracket
13-940;-944	220	8	Lo,hi vhf;hi vhf,uhf	Larger version of 930
13-950	280	8	Lo,hi vhf, uhf	Memory, S meter, adj. scan rate
Pace				
Scan 108L;H;U	140	8	Lo vhf;hi vhf;uhf	Built-in or remote speaker and antenna
Scan 208	170	8	Lo, hi vhf	Same as 108 with 2 bands
Scan 216	180	8	Hi vhf, uhf	Base or mobile with bracket
Scan 308	200	8	Lo, hi vhf, uhf	30-39, 152-164, 450-465 MHz
Scan 10-4H;-4U	90;100	4	Hi vhf; uhf	154-162 and 454-462 MHz
Pearce-Simpson				
Cheyenne-8	150	8	Hi vhf	Dual conversion, one priority channel
Cherokee-8+8	180	8	Lo,hi vhf	Dual conversion, one priority channel
Gladding HiSkan	115	8	Hi vhf	144-175 MHz, dual conversion
Comanche-16	200	16	Lo, hi vhf	Scans 16 high and 8 low channels
Radio Shack				
PRO-7A	120	8	Hi vhf	148-174 MHz, base or mobile
PRO-77;-7	150;120	8	Lo,hi vhf;hi vhf	30-50 and 148-174 MHz, base or mobile
PRO-88	200	8	Hi vhf, uhf	Base or mobile with bracket
Pocket-Scan	100	4	Hi vhf	Pocket size, built-in speaker and antenna

Enter the Scanner. With so much going on at more or less the same time, and spread out through three distinct frequency bands, how can the average listener keep track of everything at once? The solution is the use of a special monitor receiver known as a scanner.

A scanner is a crystal-controlled receiver with an automatic sweep trigger that activates each frequency in turn, or only those with crystals specifically selected (punched up) for monitoring at that time. It takes but milliseconds for the scanner to sweep from one crystal frequency to the next; if four frequencies are selected, the sweep will scan all four and then start over. As soon as a signal appears on a selected crystal frequency, the sweep locks to the signal and keeps the receiver tuned to that frequency as long as the signal remains on the air. As soon as the signal goes off, the sweep resumes its automatic check of each crystal frequency.

In a typical scanner receiver, the front end consists of a relatively broadband r-f amplifier, a crystal-controlled oscillator and a mixer. The crystals are switched into the oscillator circuit by diodes controlled either by a ramp or sawtooth waveform, or an electronic counter. It doesn't matter how the crystals are switched as long as the switching is fast. The mixer's output is generally

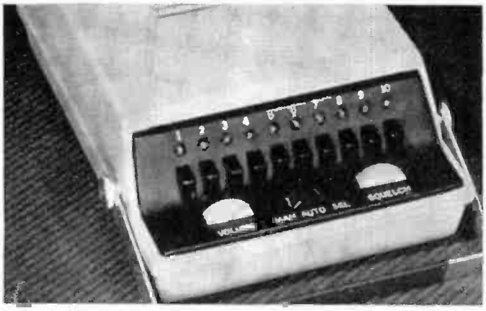
Regency				
ACT-E-8H/U;-8H/L	159	8	Hi vhf,uhf;hi,lo vhf	Base station, speaker & antenna jacks
ACT-E-8H;-8L	139	8	Hi vhf;lo vhf	Single bands, base station
ACT-E-16H/L/U;-16H/L	219	16	Lo,hi vhf,uhf;hi,lo. vhf	Two antennas, plus jacks
ACT-R-8H;-8L	139	8	Hi vhf; lo vhf	Base or mobile with mounting bracket
ACT-R-8H/L	159	8	Lo, hi vhf	Base or mobile with mounting bracket
ACT-R-10H/L/U	169	10	Lo,hi vhf, uhf	Base or mobile with mounting bracket
Robyn				
Hi-Bander	140	8	Hi vhf	Includes 2-meter ham band
200 FM	180	16	Hi vhf, uhf	Scans 8 channels in either or both bands
HL8+8	180	16	Lo,hi vhf	Dual scan speeds, covers ham bands
1000 Porta-Scan	110	4	Lo,hi vhf	Mobile, scans four vhf frequencies
SBE (Sentinel Series)				
1SM	170	8	Lo,hi vhf	Coverage 6 Mhz on low, 8 MHz on high
2SM	150	8	Hi vhf	Coverage 8 MHz
3SM	150	8	Lo vhf	Coverage 6 MHz
5SM	160	8	Uhf	Coverage 10 MHz
6SM	190	8	Hi vhf, uhf	Coverage 8 MHz on vhf, 10 MHz on uhf
7SM	150	8	Hi vhf	Marine channels
Sonar				
FR-104	140	6	Lo vhf	Similar model for hi vhf, base or mobile
FR-2512;-2513	170	24	Lo vhf;hi vhf	Dual conversion
FR-2516;-2517	160	10	Lo vhf;hi vhf	Can be set for priority channel
FR-2525	180	10	Uhf	Mounting bracket, antenna included
FR-2526;-2528	190	10	Hi vhf, uhf;lo,hi vhf	Mounting bracket, antenna included
Teaberry				
Crimefighter	199	8	Lo,hi vhf,uhf	Program card instead of crystals
T-Scan	129	4	Hi vhf	Pocket size
Tennelec				
Tennetrac II	180	12	Lo,hi vhf,uhf	Mobile or base station
Tennetrac III	200	16	Lo,hi vhf,uhf	Variable scan rate
Tennetrac IV	220	16	Lo,hi vhf,uhf	Local/distance switch, wood cabinet
Tennetrac V	250	16	Lo,hi vhf,uhf	Variable scan rate
TN-150;450	120	4	Hi vhf; uhf	Pocket size, earphone jack

AN IMPORTANT WORD ABOUT PRICES: Most prices exclude crystals, which are usually about $5 each. Although we have made every effort to obtain current prices for all products listed, because of the dollar devaluation, the lifting of certain price controls, etc., all prices are subject to some adjustment. The prices listed are the latest that manufacturers and/or importers were able to supply before press time—and are subject to change.

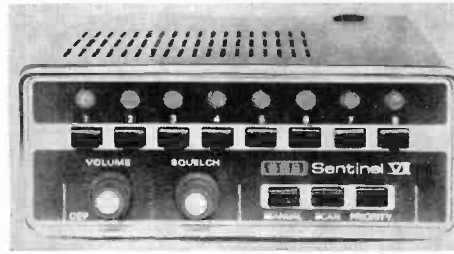
fed into a low-frequency i-f amplifier (for selectivity), an FM detector, and finally the audio amplifier. An audio squelch—to eliminate interstation and atmospheric noises—is always provided in scanners. This is mostly because the sweep is stopped by an audio signal, and if the squelch isn't set, the background noise will usually prevent sweep operation and the receiver will remain locked to one particular frequency.

To backtrack a little, since the r-f amplifier can be tuned to only part of each Public Safety band, for maximum sensitivity, the particular frequencies of interest must fall within the manufacturer's specified band. This is usually quite broad. However, it is not possible to monitor one station at, say, 152 MHz and another at 174 MHz. That is too broad a band for maximum sensitivity at both ends. As a rule, most, if not all, scanner manufactrers peak the receiver for the specific frequency bandwidth needed.

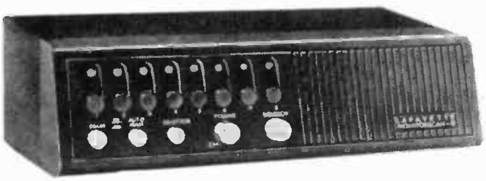
The typical scanner has from four to eight or more frequencies for a single band. The crystal sockets are easily accessible to the user so crystals can be added or changed almost at will. The front panel has an indicator lamp or digital display device for each crystal and a selector switch. The switch determines which crystals are activated and the indicators show that these frequencies are being scanned; the indicators



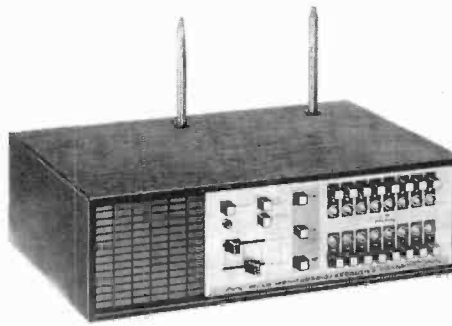
Hy-Gain 618



SBE 7SM



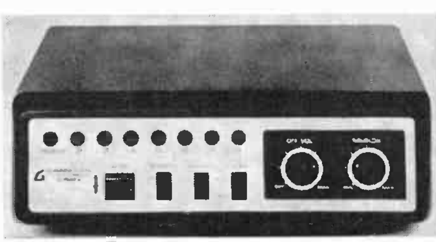
Lafayette Monitorscan-8



Regency ACT-E-16H/L

Electra Bearcat III

Heath GR-110



Pearce-Simpson Gladding HiSkan

Note: A few states have antiquated laws prohibiting the installation of monitors in vehicles. Also, the FCC prohibits private use of information heard, but not directed to, the listener.

for the channels that are off do not light. When the receiver locks onto a signal, the indicator shows the channel or frequency being heard. The front panel also contains a manual-sweep selector and perhaps a manual control touch-bar or selector. In the manual mode, the scanner remains locked to a crystal until the user deliberately switches to the next selected frequency.

Monitor receivers are available for mobile operation (12 V dc), base (117 V ac), or both. As a rule, most monitors are provided with only a coaxial jack or terminals for an external antenna. Some models, however, in addition to the antenna connection, also have a built-in telescopic antenna which delivers good performance for local signals. (A distance of 25 miles is considered local for a vhf base station.)

Some of the more expensive models have an r-f gain control, and external speaker output, a mobile mounting bracket, or possibly a line-level audio output jack for a tape recorder.

Multi-Band Scanners. When the stations to be monitored are on two or more bands, it is possible to cover all frequencies with a multi-band scanner. This is basically the usual scanner with two or three separate and independent front ends, each with its separate antenna input and/or individual built-in telescopic antennas. Each front end feeds into the i-f amplifier, and each is assigned part of the total number of crystal channels; or the front ends might share the total available channels.

In a two-band scanner with specific channels, the low-band front end might have, say, channels 1 through 4, while the high-band tuner has channels 5 through 8. In such an arrangement, there is usually an extra front-panel control with a designation such as LOW/HIGH/BOTH. Thus either the low, the high, or both bands could be scanned.

When a receiver has shared channels either a low- or high-band crystal can be installed in any socket. For example, channel 1 might be set up for low band, while 2, 3, 4, and 5 are high band, 6 is low band, 7 high band and 8 low band. The scanner will skip from channel to channel in order, regardless of how the crystals are arranged. The advantage of shared channels is that there is no fixed limit to the number of channels assigned to each band. All channels can be used for a single band if the need arises.

With activity increasing on the uhf band, more and more monitors are being equipped for both the high vhf and the uhf, or for all three bands: low vhf, high vhf, and uhf. Where there are two front ends for high vhf and uhf, there are usually two independent antenna inputs. When the receiver has three front ends to cover all three bands, the low- and high-band tuners will often share an antenna.

If a multi-band receiver includes uhf, several channels are generally reserved only for the uhf band, though new crystal switching circuits now allow shared crystal sockets to be used even for uhf reception. This convenience is probably reflected in a slightly higher initial cost.

If most of the action in a locality is on the low- and high-vhf bands, but expansion to uhf is desired, it is possible to obtain a monitor receiver with plug-in front ends. The plug-in arrangement, with prewired connectors, can be applied to any arrangement of the three bands.

Special Scanners. As the value of scanning techniques is realized by potential users, the conveniences of automatic scanning are being applied in unusual, but worthwhile, ways. A recent addition to the list of monitor radios is a portable AM broadcast radio with two vhf crystal-controlled Public Safety frequencies. In typical operation, the portable radio can be used as an ordinary two-channel scanner or a broadcast radio with vhf override. While tuned to the AM radio, the receiver silently scans the Public Safety channels. As soon as a signal appears on the vhf monitor, the AM radio is muted and only the vhf signal is heard. When the signal goes off, AM reception is restored.

An application of the scanner/override facility presently talked about but not yet available in production models is the combination of a channel-9 CB receiver with a vhf scanner for use by REACT and CB emergency teams. With such a receiver, the REACT team could keep tabs on the CB emergency channel as well as the local Public Safety frequencies.

Speaking of CB, one more-or-less standard CB transceiver has two independent channel selectors, each covering all 23 CB channels. The user selects two channels he wants to monitor; say channel 9 and local emergency channel 11. The scanner sweeps the two channels and locks onto the one that becomes active, simultaneously locking the transmitter to the received channel. When the received channel goes off, the receiver resumes scanning, just as with a Public Safety monitor.

While CB is a long way from eavesdropping on the Public Safety services, it is nevertheless true that many CB'ers are actively involved in emergency teams and services. Several CB transceivers presently come equipped with built-in low- or high-band monitors. These monitors are tunable, with one or two crystal-controlled channels. Logically, just as soon as there is sufficient interest, full Public Safety scanners will be built into some CB transceivers.

Frequency scanning is a very convenient, almost instantaneous way of monitoring several channels simultaneously. With modern solid-state techniques, the necessary electronic hardware causes almost no (or very little) increase in cost compared to tunable receivers. A scanner should therefore be a first choice when you're ready to listen to the Public Safety bands. ◈

LIGHT BEAM COMMUNICATIONS

New developments promise bright future for optical communications

The American Laser System's Slacom laser diode communications system incorporates a novel optical technique to cancel movement effects and permit handheld communications up to about 20 miles.

COMMUNICATING by the use of a light beam has been around since before recorded history when men signaled one another with fires, lanterns, and mirrors. More recently, in 1880, Alexander Graham Bell and Sumner Tainter transmitted high-quality voice and tones over a beam of reflected sunlight scores of years before radio was used for the same purpose.

Bell's "Photophone" consisted of a transmitter containing a flexible mirror. A beam of sunlight was modulated by projecting sound waves against the mirror. In the receiver to which the beam was "transmitted" were a selenium detector, a telephone receiver, and a battery. The transmitter's condensing and projecting lenses and the receiver's parabolic reflector yielded a range of several hundred meters.

In 1901, a German scientist sent intelligible voice signals a distance of 1 km by modulating the carbon arc of a searchlight. And during World War II, American amateur radio operators experimented with a variety of moderately long-range light-beam communicators.

Although some researchers predicted a possible role for modulated visible and invisible (infrared) light beams in communications of the future, most research ceased after the war until about 12 years ago when the introduction of gallium-arsenide light-emitting diodes sparked a revival. In early 1963, scientists at the Massachusetts Institute of Technology transmitted voice and TV signals some 30 miles using a LED and a photomultiplier receiver.

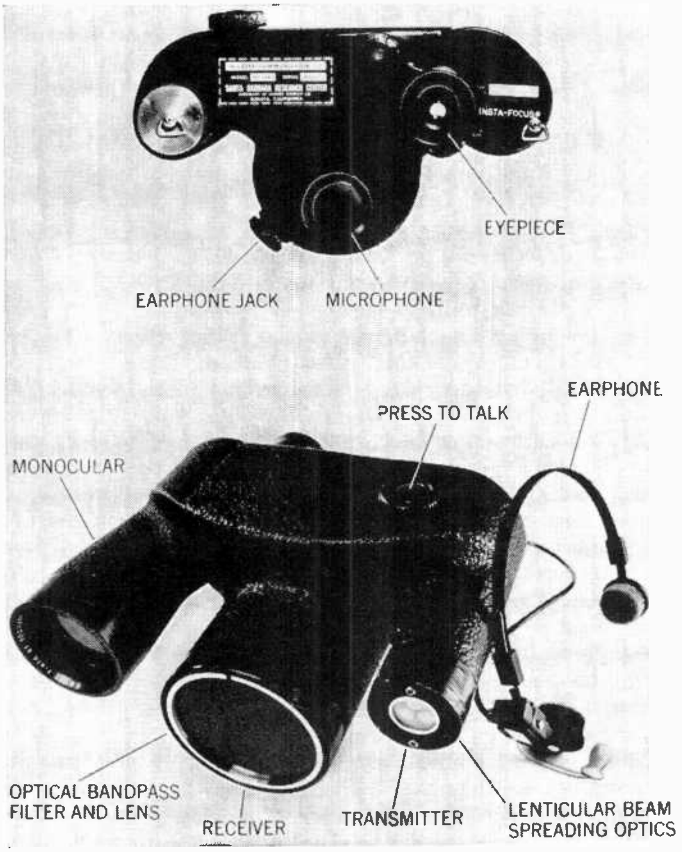
The laser, developed a few years before the MIT demonstration, was, as predicted, an excellent candidate for light-beam communication. With its development, optical communication began to emerge as a realistic alternative to communicating by wire.

Recent Developments. Ordinary noncoherent light sources emit radiation into a wide, uncollimated beam. Cumbersome optical arrangements are required to project the light into the narrow beam required for long-range light-beam communication. Most lasers, on the other hand, emit radiation in a relatively narrow beam. More significantly, the coherence of the laser beam permits an external optical system to collect most or all of the light and collimate it into a very narrow beam. And the ultrapure spectral output of some lasers permits incredibly high modulation rates.

Four recent developments have brought widespread light-beam communication closer to reality than ever before: new low-loss optical fibers, semiconductor lasers that permit very high pulse-modulation rates, a solid-state laser pumped by an array of LED'S, and ultrasensitive photodetectors.

Practical LED's have been available for a decade. They are ideally suited to transmitting multi-megabit data over medium-range atmospheric and fiber-optic links. For faster and more efficient communication, semiconductor lasers would be a better choice. But until 1970, they could not be operated continuously at room temperature. However, the degradation mechanism has recently become better understood, and

BY FORREST M. MIMS



Handheld laser communicator developed by Santa Barbara Research Center, subsidiary of Hughes Aircraft. The communicator is held like ordinary binoculars and it has a range on the order of several miles.

Don't miss next month's construction project article for building an LED Infrared Light-Beam Communicator.

reasonably long-life CW diode lasers have been developed.

Bell Labs recently announced a miniature YAG (yttrium aluminum garnet) laser that is pumped by a *single* LED. This laser is ideally suited for communication since it can be directly modulated by varying the current through the LED. It is much smaller and more efficient than conventional YAG lasers.

The development of ultrasensitive avalanche photodetectors with less than 1 nW (10^{-9}W) sensitivity means that long-range optical communication is now possible. Conventional semiconductor photodetectors operate with a carrier multiplication process that yields large internal gain. By biasing the detector just below breakdown, a low-power optical signal triggers avalanche and a large signal output.

Fiber Optics. Perhaps the most important development of optical communications is the new class of low-loss optical fibers. Practical non-atmospheric light-beam communication would probably not be feasible without these new fibers. AT&T long ago ruled out atmospheric links for telephone service due to the adverse nature of weather on atmospheric transmissions.

Until recently, the best available optical fibers had losses of about 1 dB/meter—far too high for more than short-range links. Now, researchers in Japan and the U.S. have succeeded in making glass fibers of such purity that losses have been reduced to only a few decibels per *thousand* meters.

A fiber with a loss of 5 dB/km will attenuate only 50 percent of an optical signal's power in 2000 ft—significantly less than conventional wire system losses. This means that repeaters can be placed farther apart in an optical system. One proposed fiber optic system using a 5-dB fiber, for example, would require repeaters every 8 miles, while conventional wire systems require 5-mile intervals.

Low-loss fibers mean that a ¼-in. cable of hair-thin glass fibers can carry the same volume of communications as thousands of conventional telephone cables, with existing technology. The glass cables, much smaller than metal ones, could be threaded through the spaces in existing conduits.

Since there is no radiating electromagnetic field around an optical fiber, crosstalk can be completely eliminated with a light-tight sheathing. Glass fibers are much smaller and have greater information capacity—not to mention greater strength—than hard wire systems. Although present costs for high-quality fibers are high, they are expected to drop sharply when the fibers are mass produced.

The major drawbacks of optical fibers include the need to develop efficient manufacturing techniques, the fact that electrical power cannot be transmitted through the fiber, and the need for new installation and repair techniques.

Operational Systems. In recent years, practical light-beam communication systems have made an appearance. Americal Laser Systems has developed a 15-20-mile-range hand-held laser communicator, the SLACOM (*s*tablized *la*ser *com*municator), that uses a 2-watt peak semiconductor laser and operates for 5 to 7 hours on its self-contained batteries. Portable laser diode communicators have also been built by IBM, RCA, Holobeam, and others—most of them patterned after early systems developed by RCA.

A number of moderate-range intracity atmospheric links using LED's and diode lasers are already in commercial operation in the U.S. The Telebeam Corp., for example, uses an LED system to transmit closed-circuit pay TV to several New York City hotels. The system puts out 20 mW and has a half-mile range.

Looking Ahead. The technology needed to implement practical widespread optical communication has virtually arrived. Whether or not light beams and glass fibers will replace or supplement conventional telephone lines depends on the cost and crowding conditions of the already overworked existing communication channels.

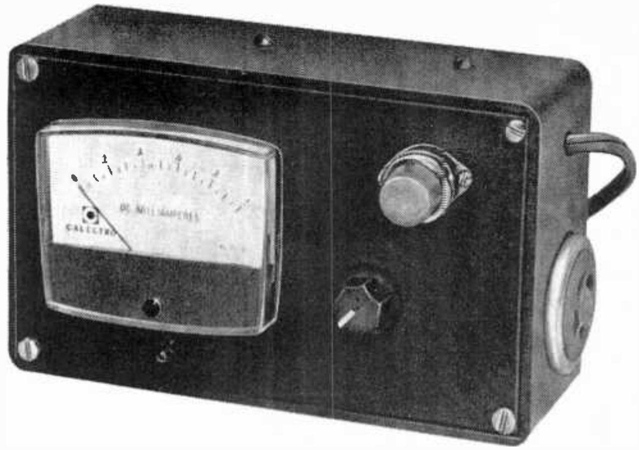
AT&T sees an important future for light-beam communication. If their Picturephone® is accepted by the public, AT&T will be forced to use optical transmission systems because this service requires about 100 times the transmission capacity needed for a single telephone channel. If only 1 percent of AT&T subscribers request Picturephone, present system capacity would have to be doubled.

Meanwhile, short-to-medium-range atmospheric and optical fiber links are ideal for interoffice and intracity communication. All in all, light-beam communication has a very bright future indeed. ◈

CONSTRUCTION

PE TESTED

LOW-COST SENSOR SOUNDS AN ALARM WITH AS LITTLE AS 50 PARTS PER MILLION OF MOST TOXIC GASES



POISONED AIR DETECTOR

BY HERB COHEN

IF YOU live in a large industrial area, the air you breathe may contain varying amounts of carbon monoxide, hydrocarbons, soot, smoke, cooking gas, and many other potentially dangerous contaminants. These toxic elements may be odorless; most of them are combustible, and some are dangerously explosive.

Even a home in the "clean" suburbs could contain excessive amounts of cooking gas, cleaning chemicals, paint fumes, carbon monoxide seepage from garages, or potentially dangerous smoke. In a closed camper or boat, you can get carbon monoxide or gasoline fume leakage due to faulty engine exhaust and chassis or deck leakage.

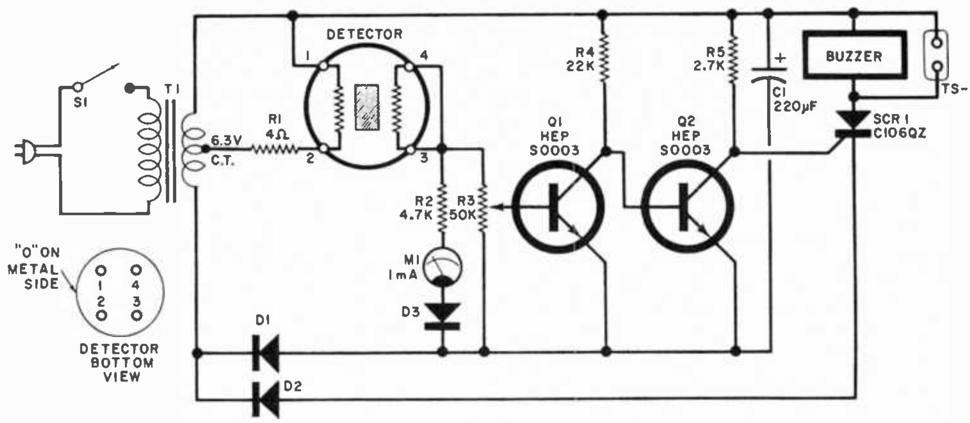
What do you do about all this? You can't do much unless you know it is there. Thanks to a simple new gas detector semiconductor you can now find out whether the contaminants in your air are dangerous or not. The semiconductor is used in construction of a low-cost (about $25) sensor system that can detect a considerable number of potentially dangerous gases at levels of less than fifty parts per million—well below the government safety standards for industrial hygiene. When the detector senses a sufficient amount of gas, a buzzer sounds off or, if a relay is added, an external alarm can be powered.

How It Works. The actual detector (*DET*) is an n-type semiconductor of tin dioxide, heated by a platinum wire. (Fig. 1.) In the presence of a gas, the difference in electron energy levels between the molecules of gas and the semiconductor causes electrons to move from the gas to the semiconductor, decreasing its bulk resistance. For example, with a propane gas level of only 1000 parts per million, the sensor resistance will decrease to 5% of its resistance in clean air.

The semiconductor's internal heater operates at 1.5 volts and 500 mA ac supplied by half of the secondary of *T1* through dropping resistor *R1*. Resistor *R2* is the output load for the detector and is connected in series with meter *M1*, which is used as a readout for sensor current—hence gas presence. Diode *D3* provides a constant 0.5-volt offset to allow the transistor amplifier to work at low levels of sensor current. Potentiometer *R3* determines the alarm amplifier's operating point.

When a gas is present, the voltage across *R2* increases (meter indicating up scale), and, depending on the setting of *R3*, transistor *Q1* turns on. Transistor *Q2*, which was in saturation while *Q1* was off, comes out of saturation causing its collector to go positive. This turns on the gate of *SCR1* causing current to flow through the alarm buzzer (or the external circuit connected to terminal strip *TS1*).

The SCR is isolated from the amplifier power supply by rectifier *D2*. This gives the SCR a source of half-wave ac which allows it to turn off at the next zero crossing after the gas level drops and the transistors return to their normal operating states. An optional LED and associated 470-ohm ser-



PARTS LIST

C1—220-μF, 12-volt electrolytic capacitor
D1-D3—1-A, 50-V PIV silicon diode
DET—Gas sensor (see note below)
M1—1-mA meter (Calectro D1-912 or similar)
Q1,Q2—HEPS0003 transistor
R1—4-ohm, 5-watt resistor
R2—4700-ohm, ½-watt resistor
R3—50,000-ohm, linear potentiometer with Switch S1 attached
R4—22,000-ohm resistor
R5—2700-ohm resistor
S1—Spst switch (on R3)
SCR1—Silicon controlled rectifier (C106Q2 or similar)
T1—6.3-VCT transformer (Lafayette 33E80490 or similar)
TS1—Two-connector terminal strip
Misc.—Seven-pin vacuum tube socket, suitable chassis, 6-volt buzzer, perf board, knob, etc.
Note—The gas sensor can be ordered as DET-2 from Detectron Inc., P.O. Box 313A, Sag Harbor, NY 11963, for $6.25 postpaid. N.Y. residents, please add sales tax.

Fig. 1. When detector senses gas, current flow in meter indicates relative level.

ies resistor can be connected across the buzzer for visual indication.

Construction. Other than the detector (*DET*), *T1*, *M1*, and the buzzer and *TS1*, the circuit can be assembled on a piece of perf board, using the meter terminals as the mounting. Almost any chassis can be used as long as it will hold the transformer and buzzer and has a front panel large enough to accommodate the meter and *R3* and the socket for the detector.

A conventional 7-pin vacuum tube socket can be used to mount the detector. The socket should be attached to the exterior of the front panel. Note that the detector has a small circle stamped on its side between pins 1 and 2.

Operation. Before applying power, set *R3* to its minimum position to keep the alarm from sounding off immediately. Apply power and note that the meter needle rises to full scale and remains there for some time. This large sensor current is due to the "burning off" of impurities collected on the detector's surface while it was not in use. In cases of severe contamination, it may take quite a while for the sensor to clean itself, during which time, the meter indication will gradually drop to some minimum value. Once the meter has dropped to its minimum, advance *R3* (sensitivity control) until the buzzer starts to sound off. Back *R3* off slightly until the buzzer stops and mark this point on the knob scale. This will be your local "normal." If the air is very clean, the buzzer may not sound, even at full sensitivity.

The unit is now ready for testing. You can blow cigarette smoke at the sensor or open a bottle of ammonia, perfume, etc., and blow the fumes toward the detector. The meter should suddenly jump upscale, and the buzzer should sound off.

For relative measurements, such as hunting for gas leaks, the buzzer can be silenced by rotating *R3* to its minimum with the meter indications used for probing for maximum gas concentrations. ◈

1974 ELECTRONIC EXPERIMENTER'S HANDBOOK

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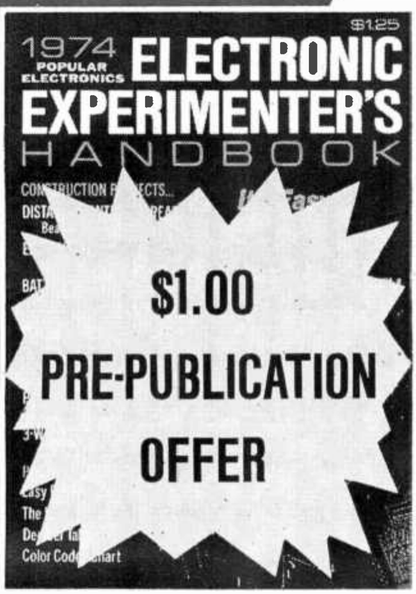

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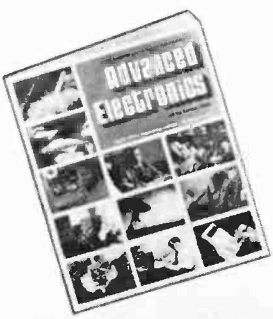

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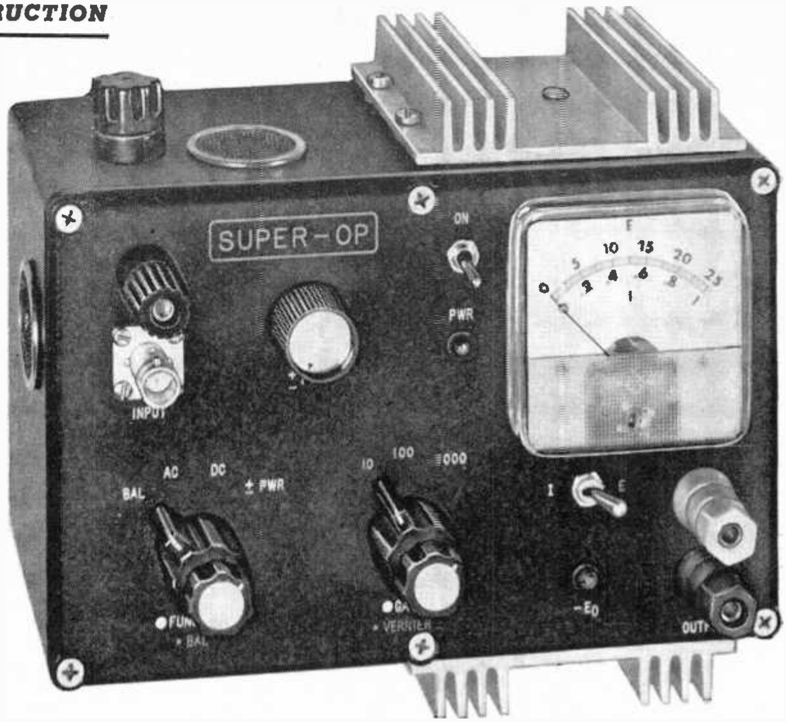


HOW THE 741 OP AMP BECOMES SUPER-OP

an ultra-versatile bench instrument

BY J. R. LAUGHLIN

ONE of the heroes of the electronics world today is the 741 operational amplifier. It is sort of like a jack-of-all-trades in the number of applications to which it is put. Of course, the op amp itself has certain limits, but the addition of outboard components increases its usefulness—as in the Super-Op described here. This instrument can be a valuable addition to any experimenter's work bench.

What can Super-Op do? It can be an adjustable, well-regulated positive/negative 20-volt power supply; a battery charger or eliminator (1-ampere output); a general-purpose ac or dc amplifier; a hi-fi audio amplifier; a servo amplifier; a chart recorder drive; etc. It also has built-in dc offset nulling, variable gain, and overload protection. The circuit retains all of the characteristics of the 741, such as frequency response, dc thermal drift, etc.

Note: The Superman "S" symbol is a trademark of National Periodical Publications Inc., used with their permission.

Construction. Any type of construction can be used, though a PC board using the foil pattern in Fig. 3 simplifies the wiring. The board is mounted directly on the meter terminals.

On the front panel are the BNC connector, *J1*; its associated ground jack, *J2*; output connector, J3; its ground connector, *J4;* the ±PWR control, *R32*; the power on/off switch; metering switch *S3*; power-on indicator *LED1*; $-V$ (or $-E_o$) indicator *LED2*; the meter; and switches *S1* and *S2*.

Resistors *R15*, *R16* and *R17* are attached to *J3* and *J4*.

The frame of the chassis supports the transformer, *T1*; capacitors *C1* and *C2*; the four rectifier diodes; the two fuses in their holders; and *Q6* and *Q7*, with their respective heat sinks.

If you are using a metal chassis, mount the power transformer so that its core is in good thermal contact with the chassis, using transistor thermal grease between the two. This keeps the transformer temperature down. The use of venting holes on the chassis bottom and sides and rubber feet on the bottom will allow cooling air to pass through the unit. When mounting the PC board, allow room for air to circulate around it.

The output transistors are mounted on heat sinks, one on each side of the chassis. The heat sinks should be mounted on short standoffs to allow air to pass on both sides of the sinks. If large venting holes are made in the bottom and sides of the chassis, they can be covered with snap-in grilles.

Checkout. The first thing to do is determine the values of *R23* and *R24*. While monitoring the emitter voltage of *Q1*, connect a 10,000-ohm potentiometer in the circuit where *R24* goes. Carefully adjust the potentiometer until +20 volts is indicated. To avoid damaging the op amps, do not allow this voltage to go above 22 volts. Once the correct voltage is obtained, measure the value of the potentiometer and install a fixed resistor of comparable value. Do the same for *R23* in the circuit of *Q2*, except that this time the voltage is −20.

With *S1* in the first (BAL) position and the GAIN VERNIER (*R29*) fully clockwise, try the various positions of GAIN switch *S2* and adjust the BAL control (*R30*) until the meter indicates zero.

With the FUNCTION switch in the second position (AC) and a signal applied to *J1* and *J2*, the instrument will act as an amplifier with a gain of 10, 100, or 1000, depending on the setting of *S2*. Similar gains will exist with the FUNCTION switch in the third position (DC).

To use the Super-Op as a positive or negative power supply, place *S1* in the fourth position (PWR), *S2* on 10, and *S3* on E (voltage). The output voltage is determined by the setting of the ±PWR control (*R23*). The −V light (*LED2*) should come on as the output passes through zero from positive to negative. An output of about −0.2 volt will turn on the lamp. The output regulation should be better

HOW IT WORKS

As shown in Fig 1, *IC1* (a 741) is connected as a non-inverting amplifier. Switched feedback resistors (*R2*, *R3*, or *R4*, selected by *S2*) allow control of the voltage gain. Input potentiometer *R29* provides front-panel gain adjustment. With an input signal applied to *J1*, switch *S1B* can select either ac or dc input. (With ac input, *C1* is in the circuit.) In the ac mode, *C3* is lifted off ground, and *C2* is connected through *S1A*. This produces a gain of one in the op-amp circuit and minimizes dc errors.

Input protection is provided by *D1* and *D2*, while *R30* is used to balance the dc of the op amp. The latter is necessary to set the output to zero in the dc mode. This control is critical when using high values of dc gain since any small offset is amplified by the remainder of the circuit.

The large output is provided by *IC2* and transistors *Q4* through *Q7*. The actual output transistors (*Q6* and *Q7*) are generously overrated to ensure that the output overload fuse *F1* will always open before the transistors can be damaged.

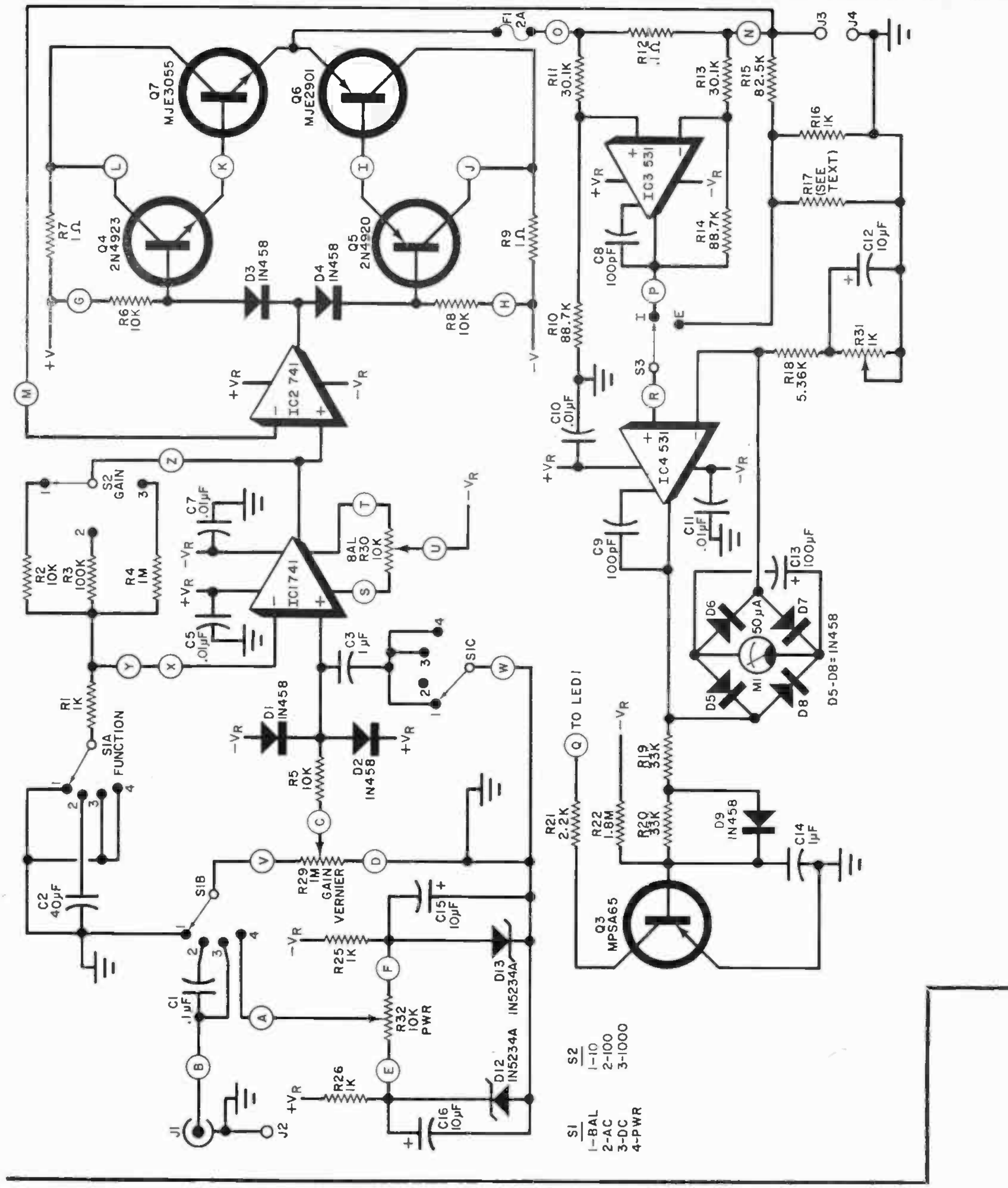
Output current to *J3* is monitored by *IC3*. The voltage output of this op amp is proportional to the current flowing through *R12* and can be either ac or dc depending on the mode of operation.

Switch *S3* selects either the output of *IC3* or the actual output voltage at *J3*. One or the other is applied to the meter driver, *IC4*, which is connected so that the same polarity is applied to the meter whether the input is ac or dc. To avoid confusion in measuring dc outputs, lamp driver *Q3*, which responds only to negative dc, causes a front-panel lamp to come on when negative voltages or currents are being indicated.

A pair of voltage regulators (*Q1* and *Q2*) are also included. Constant current is applied to the base of each transistor by a FET connected as a constant-current diode. The voltage at each regulator base is determined by either *R23* or *R24*, which are selected to provide the desired output voltage. Capacitors *C17* and *C18* prevent oscillation in the regulator stages.

A well-regulated and temperature-stable positive or negative reference voltage is provided by zener diodes *D12* and *D13* and is used by *R32* to select any value of either voltage. This voltage is used in the POWER mode when Super-Op is functioning as a regulated power supply.

The main power supply is shown in Fig. 2. Note that *R7* and *R9* of Fig. 1 are also shown in Fig. 2.



than 1% for load currents from zero to about 1 ampere.

With *S3* on E, use an accurate voltmeter to monitor the voltage between *J3* and *J4*. Adjust *R17* to bring the indication of *M1* to its correct value. The approximate value for *R17* is 6000 ohms.

With *S3* on I, use an accurate ammeter in series with a load that draws about 1 ampere. Adjust *R31* to get similar readings between *M1* and the external ammeter.

The common-mode rejection of *IC3* can be adjusted to zero as follows. Set *S3* in the I position and put an input of 100 Hz on the Super-Op, *without a load.* Connect a scope to monitor the output of *IC3*. Using a high-megohm resistor, shunt either *R13* or *R14* (but not both) until the scope

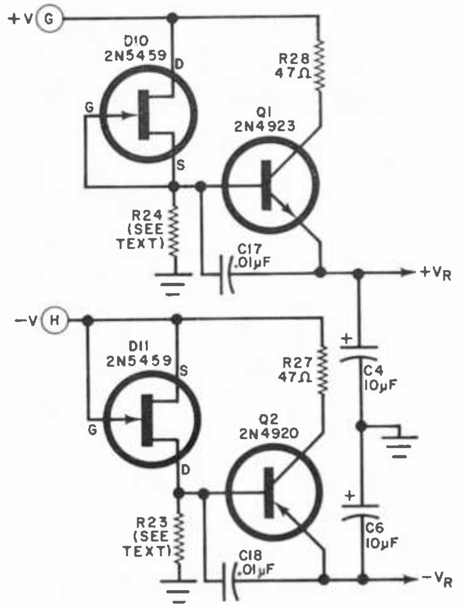
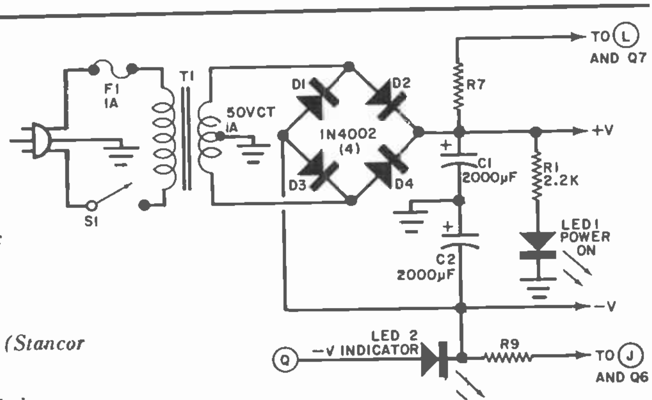


Fig. 1. The output of the basic op amp (IC1) is amplified by IC2 and Q4-Q7 to deliver 1 ampere. (Main circuit on opposite page.) The circuits above provide regulated voltages for the op amp.

PARTS LIST

C1—0.1-μF, 50-volt disc capacitor
C2—40-μF, 25-volt, non-polarized capacitor
C3,C14—1-μF, 25-volt, capacitor
C4, C6, C12, C15, C16—10-μF, 50-volt electrolytic capacitor
C5, C7, C10, C11, C17, C18—0.01-μF, 50-volt ceramic capacitor
C8, C9—100-pF, 50-volt ceramic capacitor
C13—100-μF, 30-volt, electrolytic capacitor
D1-D9—1N458 diode
D10, D11—1N5309 diode or 2N5459 FET
D12, D13—1N5234A zener diode
F1—8AG, 2-A fuse and holder
IC1, IC2—741 op amp
IC3, IC4—531 op amp
J1—BNC connector
J2-J4—5-way binding post
M1—50-μA meter (Monarch PMC1L or similar)
Q1, Q4—2N4923 transistor
Q2, Q5—2N4920 transistor
Q3—MPSA65 transistor
Q6—MJE2901 transistor
Q7—MJE3055 transistor
All resistors ¼ watt, 10% unless otherwise specified
R1—1000-ohm, 1% resistor
R2—10,000-ohm, 1% resistor
R3—100,000-ohm, 1% resistor
R4—1-megohm, 1% resistor
R5, R6, R8—10,000-ohm resistor
R7, R9—1-ohm, 1-watt resistor
R10, R14—88,700-ohm, 1% resistor
R11, R13,—30,100-ohm, 1% resistor
R12—0.1-ohm, 1% resistor
R15—82,500-ohm, 1% resistor
R16, R25, R26—1000-ohm resistor
R17—See text
R18—5360-ohm, 1% resistor
R19, R20—33,000-ohm resistor
R21—2200-ohm resistor
R22—1.8-megohm resistor
R23, R24—See text
R27, R28—47-ohm resistor
R29—1-megohm potentiometer
R30—10,000-ohm potentiometer
R31—1000-ohm potentiometer
R32—10,000-ohm, 10-turn potentiometer
S1—3-pole, 4-position rotary switch
S2—1-pole, 3-position, rotary switch
S3—Spdt slide or toggle switch
Misc.—Suitable chassis, heat sinks (2), mounting hardware, knobs, etc.

Fig. 2. Power supply is a full-wave rectifier. R7 and R9 are also shown in Fig. 1.



PARTS LIST

C1, C2—2000-μF, 50-volt electrolytic capacitor
D1-D4—1-A, 100-V silicon rectifier
F1—1-A fuse and holder
S1—Spst slide or toggle switch
T1—50-volt, CT, 1-A transformer (Stancor P8197 or similar)
R1—2200-ohm, ½-watt resistor
LED1, LED2—Any light-emitting diode

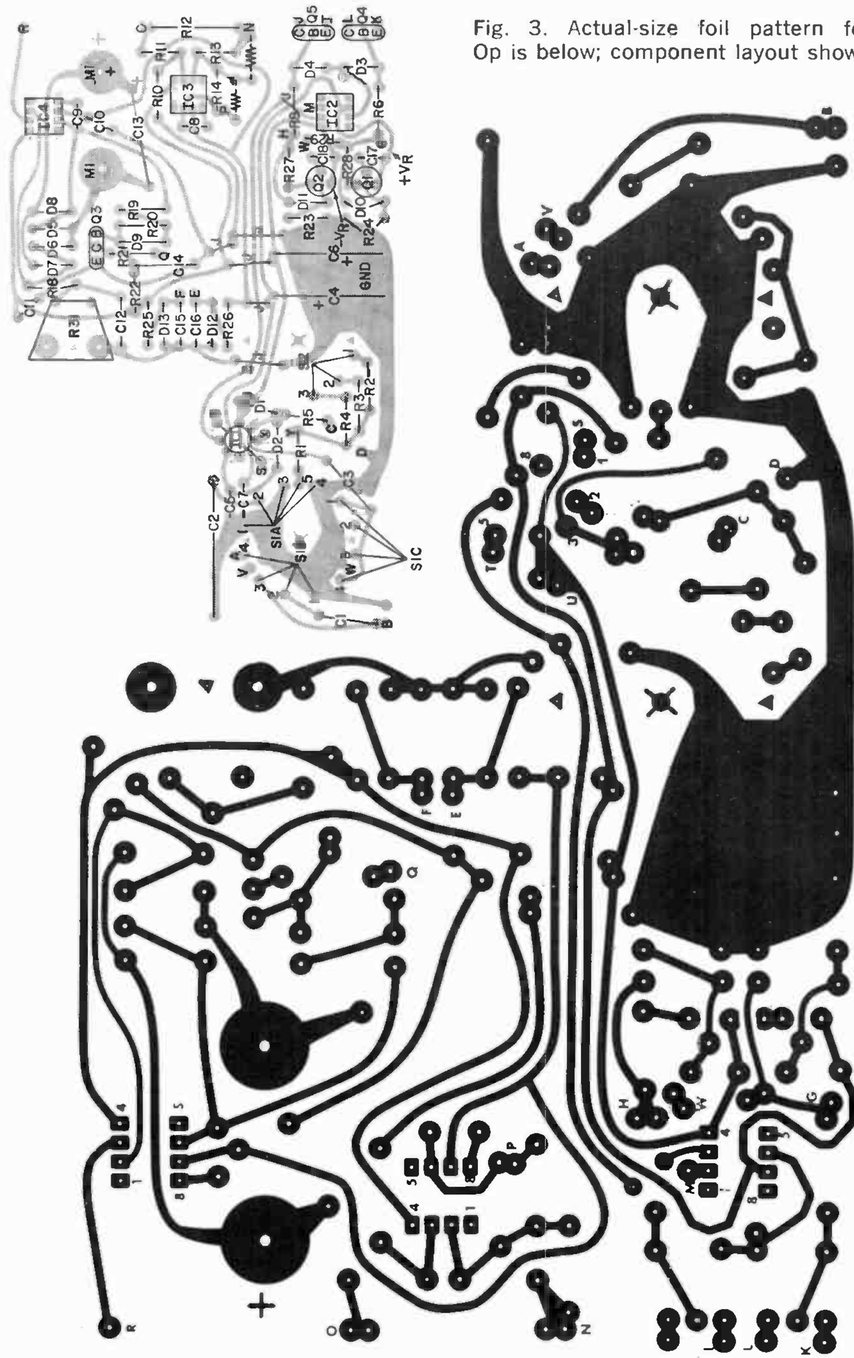


Fig. 3. Actual-size foil pattern for Super Op is below; component layout shown at left.

indicates a zero output. Once this resistor value is determined, it can be connected in its appropriate place on the board.

If the panel meter voltage indication changes significantly as the output current goes from zero to maximum, a ground loop may be present. In this case, the output jack ground and the circuit-board common ground should be connected to the power supply ground through separate leads. If there is a slight residual hum voltage when the amplifier is at maximum gain, it may be due to magnetic induction from the power transformer. ◈

CONSTRUCTION

FAST-ACTING RESETTABLE ELECTRONIC FUSE

PROVIDES ADJUSTABLE (1 TO 5 A) CIRCUIT-BREAKER ACTION

BY WILLIAM A. RUSSO

FOR THE protection of your own life and limb and that of your equipment, electronic apparatus should be protected by fuses or circuit breakers in their ac line inputs. But all too often, searching for the correct fuse and holder to use with a project and wiring them into place are chores that are dispensed with. While you can get away with doing things this way most of the time, sooner or later a puff of smoke or a nasty shock or burn are going to make you wish that you had taken the proper precautions in the first place.

The Electronic Fuse described here is designed to act as an adjustable *temporary* circuit breaker for projects undergoing tests or for any line-powered device rated at up to 600 watts while it is being tested or serviced at your workbench. Operating currents of from 1 to 5 amperes (in 1-A steps) can be selected. Detection of even a small overload results in fast (less than 0.5 second) interruption of both lines feeding the load. Then, instead of replacing a blown fuse, you simply flip a switch to restore normal power—after remedying the overload problem, of course.

Theory of Operation. Referring to the schematic diagram (Fig. 1), load current flowing through *R1* and, depending upon the setting of *S2*, *R2* induces a voltage drop that is sensed at the gate of the triac *Q1* through the appropriate gate resistance (*R3-R11*). When sufficient gate current flows to turn on *Q1*, the triac energizes *K1* and indicator *I1*. The contacts of *K1* are wired in a latching arrangement, while at the same time isolating the load when the relay is energized. Interrupting power by opening *S1* resets the circuit.

Pushbutton switch *S3* and resistor *R11* reduce the sensitivity of the sensing circuits to the turn-on transients of reactive or incandescent lamp loads. Potentiometers *R4* through *R8* are used for calibration.

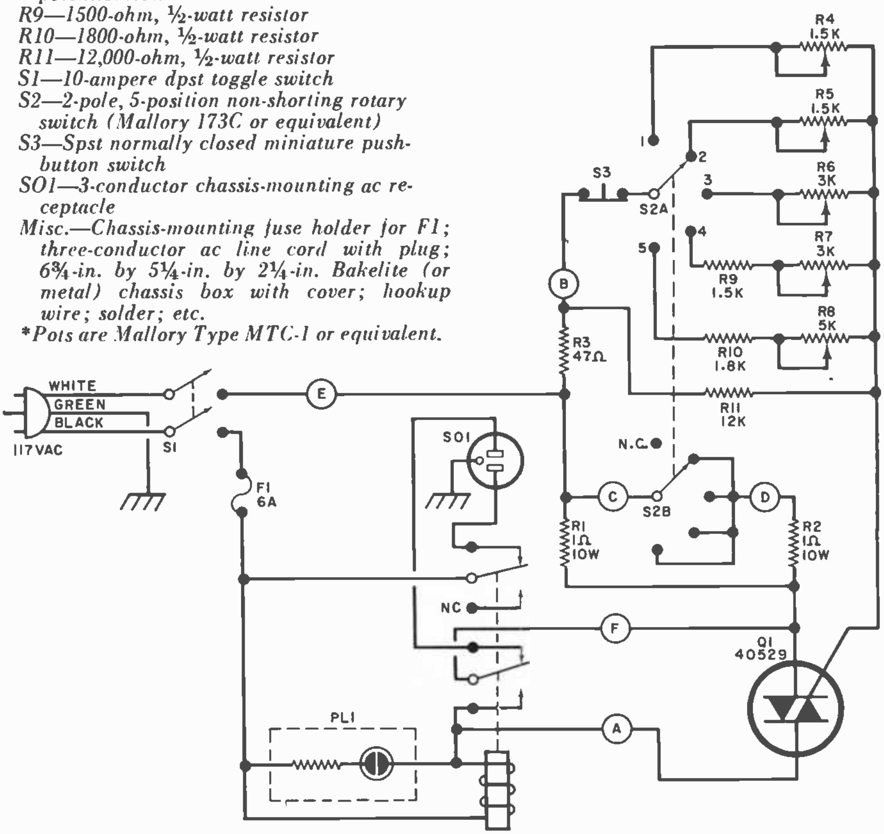
Construction. Shown in Fig. 2 are the foil pattern and component placement diagram to be used when making the PC board and mounting components on it. Once the board is wired as shown (substitute heavy-duty perforated board if you wish), 1-in. spacers permit the board to be safely mounted on the underside of the chassis box's top. Mount the board in place before making any external connections to it.

Next, mount and wire S2 and S3, followed by *K1* and the remaining components, into the system. Use 18-gauge insulated wire for all leads carrying load current. When routing the power cord through a hole drilled in the chassis box, it is best to use a standard force-fit strain relief to hold it in place. However, lacking a standard strain relief, you can tie a figure-eight knot in the

PARTS LIST

F1—6-ampere fuse
K1—117-volt ac relay with 5-ampere dpdt contacts
PL1—Neon pilot lamp assembly
Q1—Triac (RCA 40529)
R1,R2—1-ohm, 10-watt power resistor
R3—47-ohm, ½-watt resistor
*R4,R5—1500-ohm vertical-mounting trimmer potentiometer**
*R6,R7—3000-ohm vertical-mounting trimmer potentiometer**
*R8—5000-ohm vertical-mounting trimmer potentiometer**
R9—1500-ohm, ½-watt resistor
R10—1800-ohm, ½-watt resistor
R11—12,000-ohm, ½-watt resistor
S1—10-ampere dpst toggle switch
S2—2-pole, 5-position non-shorting rotary switch (Mallory 173C or equivalent)
S3—Spst normally closed miniature pushbutton switch
SO1—3-conductor chassis-mounting ac receptacle
Misc.—Chassis-mounting fuse holder for F1; three-conductor ac line cord with plug; 6¾-in. by 5¼-in. by 2¼-in. Bakelite (or metal) chassis box with cover; hookup wire; solder; etc.
**Pots are Mallory Type MTC-1 or equivalent.*

Fig. 1. In the fast-acting electronic fuse circuit, a triac is used to actuate the relay to cut off the power.



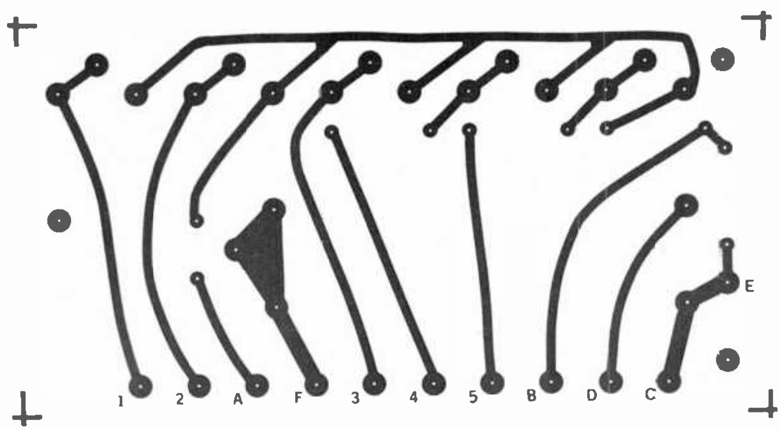
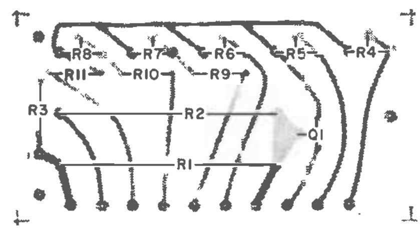


Fig. 2. A foil pattern that can be used for the electronic fuse is shown above, while the diagram at the right shows component layout.



cord after routing it through a hole with a rubber grommet.

Align and drill five ¼-in. holes through the side of the chassis box to provide direct-in-line access to the adjustment slots of *R4-R8* when the Electronic Fuse is fully assembled. Before finalizing the project, check to make certain that *K1's* armature operates freely when the chassis box is assembled. Then, use an ohmmeter and visual inspection techniques to make absolutely certain that no current-carrying portion of the circuit touches chassis ground. The only grounded items in the circuit should be the green (neutral) wire of the power cord and *round* contact of *SO1*. Sometimes this socket contact has a green-tinted screw for easy identification.

Calibration and Use. For calibration, you will need the following loads:

S2 SETTING (A)	OUTPUT LOAD (W)
1	150
2	275
3	375
4	500
5	650

Incandescent lamps connected in parallel can be used in conjunction with S3. For heavier loads, heating coils (hair dryer, toaster, etc.) are ideal. You will also need an *insulated* screwdriver to adjust *R4-R8*. (Note: If you lack an insulated driver, you can slip over the shank of an ordinary metal driver a length of insnlated tubing. Alternatively, you can drill the holes oversize and line them with rubber grommets.)

To calibrate each range, set S2 to the proper position and plug into *SO1* the required load. Set the appropriate calibration pot to its maximum resistance setting and turn on the Fuse, using *S3* as necessary during turn-on. If *K1* pulls in, check all settings and repeat the turn-on procedure.

With the load operating, slowly adjust the pot with the insulated screwdriver until the relay just pulls in. Turn off the project and repeat the above procedure for each setting of S2.

Now, with the Fuse plugged into an ac outlet, plug the device to be protected into *SO1* and set the range switch for the proper fuse current. Turn on the Fuse, then the load. If the Fuse trips, reset it by turning off the power and then on again. Restart the system by momentarily pressing S3 while switching on the Fuse with the load turned on. If the Fuse's relay trips again, check the setting of *S2* to verify whether or not it is switched to the correct current range, or look for a malfunctioning load. It should be noted that, if the load is incandescent lamps, it may require three or four starting attempts. ◈

Design Your Own BASS REFLEX HI-FI SPEAKER SYSTEMS

PART 2. CONSTRUCTION DETAILS

BY DAVID B. WEEMS

IN PART ONE of this article theoretical considerations in the design of bass reflex speaker systems were discussed in detail. In this second part, our discussion focuses on the practical construction details concerned with the reflex enclosure.

Construction Details. All speaker enclosures should be made from good-quality lumber and should be securely joined along all abutting edges. This is particularly important with such large enclosures as the floor-standing reflex. Large unsupported panels, such as the rear wall, should be braced with 1" X 2" or larger lumber that is glued and screwed on edge to the inside of the panel.

If a single brace is used on a panel, it should run along the panel's longer dimension (or diagonally) to divide the panel into two narrow strips that are more rigid than two square pieces. Opposing panels that are equal in size should theoretically be braced differently to stagger their resonances, but this is only for the purist. The speaker mounting board will always be braced differently from the rear panel owing to the speakers mounted on it.

Edges of the enclosure should be fitted together by means of internal glue blocks and screws. The back panel should be screwed down with a rubber-tape or caulking-compound gasket to eliminate leaks. The more carefully put together, the better the system will operate as a true reflex, and the more accurate and predictable will be the tuning.

Simple Vented Enclosures. The classic bass reflex is a speaker box with a simple hole in the baffle. There is no tunnel behind the port. There are more variables and more design steps to the bass reflex than to the closed box system, but the procedure is similar. If the C_{ms}/C_{mb} ratio is used, first measure the suspension compliance of the speaker (see "Closed Box Speaker System Design," Part 1, June 1973). Then choose a box compliance to yield the desired ratio.

Here is an example. Tests show that a 12-in. speaker has a 50-Hz free-air resonance and a 0.7×10^{-6} cm/dyne suspension compliance. If the C_{ms}/C_{mb} ratio is to be 1.4, a box compliance of 0.5×10^{-6} cm/dyne would be chosen, obtained from: $(0.7 \times 10^{-6})/1.4$. From the box compliance chart in Fig. 1, locate the line for 0.5×10^{-6} and follow it up to the diagonal line for 12-in. speakers. From the junction of the lines, move to the left of the chart to find the optimum box volume: 6 cu ft.

Now refer to Fig. 2 to locate the curve for 50 Hz and follow it to where it crosses the 6 cu ft line on the vertical scale. Where the 50-Hz and 6 cu ft lines cross, the port area is 30 sq in., as shown along the bottom of the graph. It should be noted that Fig. 2 shows the values of port area for a rectangular port with a length-to-width

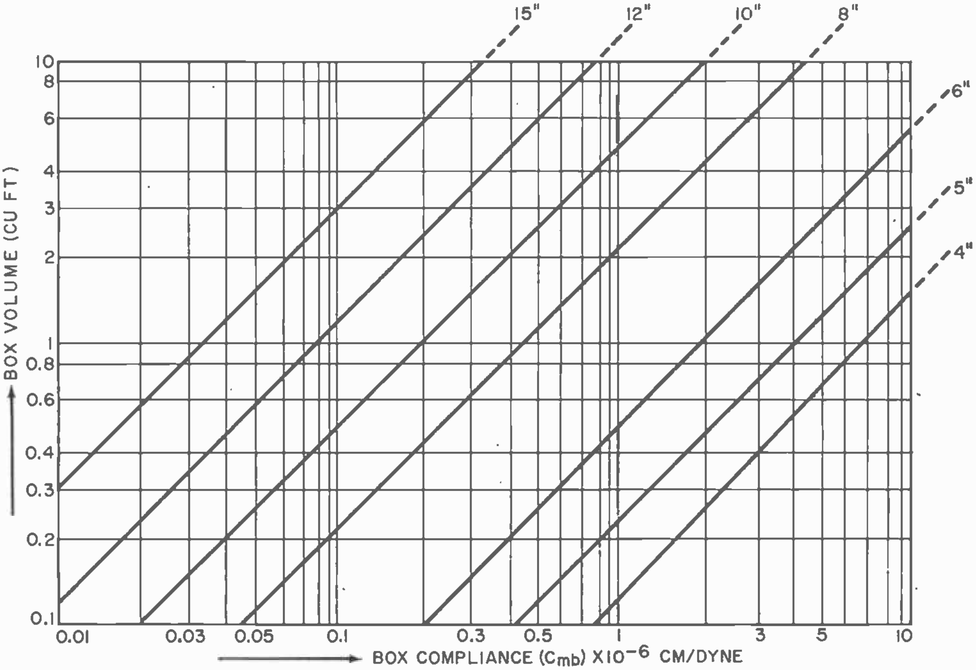


Fig. 1. Enclosure volumes for various values of box compliance and speaker size.

(aspect) ratio of 4:1, the shape usually found in large reflex boxes. If the port can be made square or round (1:1 aspect ratio), the area can be increased by about 33 percent. If possible, the aspect ratio should not be greater than 4. Long narrow slits add resistance to the vent; they should be avoided unless they are an integral part of a special design.

If the required port area is found to be very small—say 5 sq in.—it should be enlarged and a tunnel should be installed behind it.

Simplified Method. The builder with no test equipment can estimate the proper enclosure size for his speaker. From Fig. 2, he can choose a volume that will permit a port area of 30-100 percent of the speaker's effective cone area as follows:

NOMINAL SPKR DIA.	PORT AREA RANGE
8 in.	9-28 sq in.
10 in.	15-50 sq in.
12 in.	24-78 sq in.
15 in.	40-133 sq in.

For example, for an 8-in. speaker with a 70-Hz cone resonance, Fig. 2 shows that the largest volume, for a 28-sq-in. vent, is 3 cu ft. The smallest recommended volume, for a 9-sq-in. vent, is 1.8 cu ft. Because 70 Hz is a relatively high resonant frequency by today's standards, an enclosure volume at the upper end of the scale would be chosen to provide satisfactory bass response. If the resonant frequency were much lower, more latitude could be used in choosing an enclosure volume. For low-resonance speakers, the 30-percent-minimum rule can be violated, but the absolute minimum of 5 sq in. must be observed.

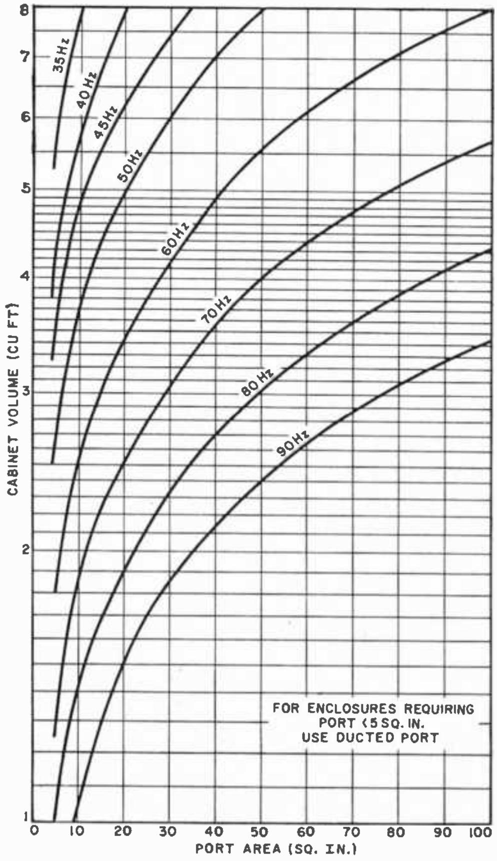
If possible, the vent should be located on the speaker board, about 3 or 4 in. from the speaker. The distance between vent and speaker can be greater than 4 in. but not less than 3 in. Where there is no room on the speaker board, the vent can be located on another board.

Tuning Reflex Enclosures. Perfect tuning is not required to obtain good results in a bass reflex system. The proper use of design charts will generally yield satisfactory performance, but the listener with test equipment will likely want to verify tuning accuracy. Most published instructions suggest adjusting the area of the vent until the two impedance peaks are equal in amplitude and equally spaced from the tuned frequency. These instructions are valid only if certain precautions are observed.

First, the specification that the peaks be equally spaced is correct only if the curves are graphed on the proper logarithmic scale. And the equal-amplitude requirement assumes the availability of accurate test equipment and little or no acoustical damping at either peak. The last requirement is subject to several variables, such as damping material and the type of lumber used in the box. Even without damping material, the wood walls of a speaker box will, by vibration, absorb a significant amount of energy at low frequencies. In a typical enclosure with 3 in. of damping material on the walls, the box will absorb about half as much energy as the damping material at 40 Hz; at 80 Hz, the damping material will absorb many times as much energy as does the box. These differences in energy absorption can upset tuning procedures, particularly if the damping material is changed during tuning.

The easiest way to avoid these problems is to note the free-air resonance on the audio generator; then tune the enclosure for a minimum impedance at that frequency. Note that this method does not require an impedance curve, an accurately calibrated signal generator, or even knowledge of the exact tuning frequency.

Fig. 2. Design chart to be employed for bass reflex enclosures with the simpler vents.



To tune a reflex, the port should be made somewhat larger than the correct value as indicated on a design chart. Then a movable panel can be clamped across part of the port and adjusted until the trough of the impedance curve occurs at the same frequency as the free-air resonance of the speaker. While tuning, care should be taken to prevent rattles that can produce confusing results. If clamps are used to hold the panel, they should be very tight and their handles should be taped to prevent vibration. Air leaks also destroy tuning accuracy. So precautions to insure a sealed enclosure, except for the port, are advised.

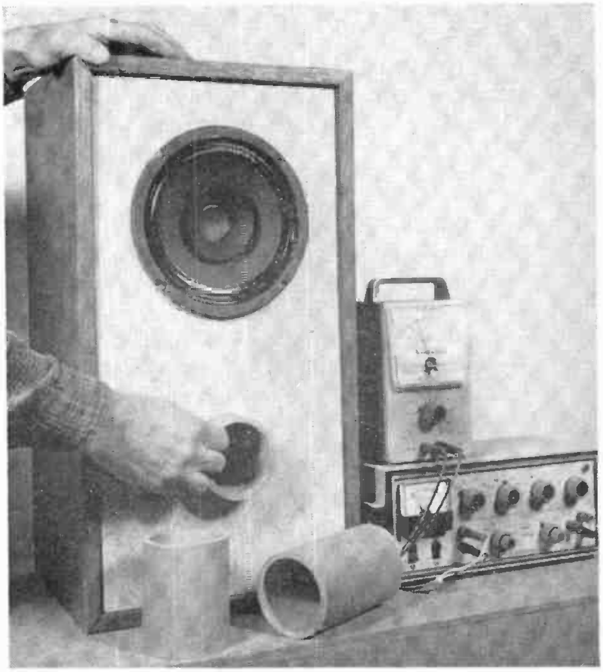
Some manufacturers, notably JBL and Altec, do not recommend tuning the enclosure to the free-air resonance, fr, of the speaker. They contend that optimum low-frequency response can be obtained only be extensive testing of a particular speaker/enclosure combination. These manufacturers furnish detailed cabinet plans that should be followed when using their loudspeakers. Unless such information is available, the enclosure should be tuned to the speaker's free-air resonance.

Damping Material. All speaker systems must be adequately damped to prevent the reflection of midrange and high frequencies within the cabinet and through the woofer's cone or port. The damping material should cover all walls except the speaker board. The proper thickness depends on the material's absorption characteristics and density, but 1-3 in. is typical. Fiberglass or rock wool batting are common damping materials.

In cases of excessive boom, home builders can often attempt to cure the problem with damping material. This step usually fails because most damping materials are not effective at low frequencies, particularly when they are applied to the box walls. But stuffing the enclosure can change the tuning volume by "expansion." The apparent increase in volume occurs because the stuffing decreases the velocity of sound by changing the operation of the enclosed air from adiabatic to isothermal. Stuffing can also lower system Q, reducing the amplitude of the upper resonance while the volume expansion lowers its frequency. Care must be used to prevent overdamping and excessive bass loss, although slight overdamping can be compensated for by bass boost in the driving amplifier.

Sometimes damping material is put across the vent. This lowers the ability of the vent to damp the speaker and reduces efficiency, defeating two purposes of the ported enclosure. A better method of system damping is to staple a sheet of damping material over the back of the speaker itself. Damping material behind the speaker damps both the speaker and the enclosure without interfering with vent operation.

Ducted-Port Reflex Enclosures. There has always been a demand for small speaker systems, even when the sound from small systems was frequently bad. The advent of stereophonic sound (and, more recently, quadraphonics) put increasing pressure on manufacturers to decrease the sizes of their enclosures. One result of this pressure was the compact closed box. But with it came a new kind of reflex—new to the trade, although the principle had been known for many years. This was the reflex with a duct behind the port.



Method of tuning ducted port reflex with cardboard tubes. Various duct lengths are tried until proper tuning is achieved; then correct length tube is glued into speaker panel.

Candles in front of ported enclosure show relative cone and port air velocity at resonance. Lower flame is violently displaced at resonant frequency while upper is barely affected.

Any increase in the thickness of a vent, either by using a thicker baffle or by a duct, increases the mass of vibrating air. Vibrating against the compliance of the trapped air in the box, this greater air mass lowers the resonant frequency of the system. A small enclosure can be tuned to a lower frequency with a duct than with a simple vent of the same area. A small box with a duct can have the same vent area as a large box without a duct tuned to the same frequency.

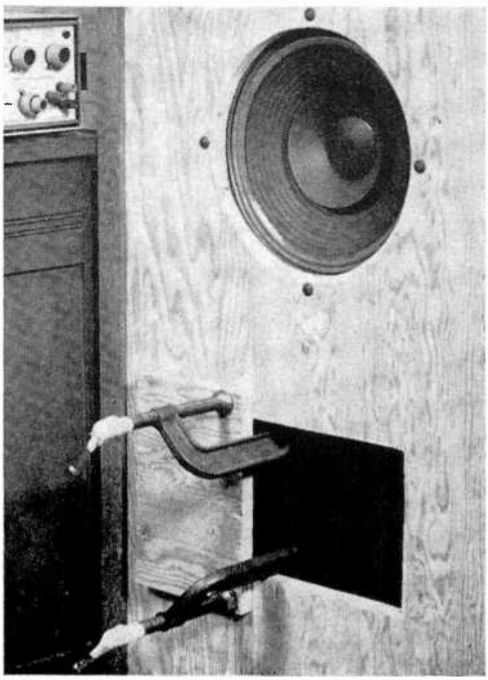
This does not mean that the small ducted enclosure will provide the same performance as the larger box. Important system characteristics, such as bass cutoff frequency, are determined by other factors like the C_{ms}/C_{mb} ratio that is independent of the method of tuning. This fact is sometimes overlooked by enthusiastic experimenters and advertising men who claim that their small enclosures are the equal of much larger ones. It is true only if the volume of the smaller enclosure is about optimum for the specific speaker used in it.

Although modern loudspeakers require larger optimum-volume enclosures than past speakers did, they can be used with satisfactory results in smaller cabinets. This is due to their low resonances, a by-product of high compliance. It is especially true if the low resonance is obtained by increased cone mass, rather than by higher compliance alone. Small boxes raise the bass cutoff frequency above that of large enclosures. But if the speaker's free-air resonance is low enough, the combination will yield acceptable bass response. Thus, the development of low-resonance speakers not only made possible the modern compact closed-box system, but also the compact ducted-port reflex.

The same factors that determine the design of a simple vented enclosure apply to the ducted-port box. The inertance of a duct varies directly with its length and inversely with the cross-sectional area. So, to lower the tuning frequency, either the duct must be lengthened or its cross-sectional area must be reduced.

A duct must be used if tuning charts indicate a simple vent of less than about 5 sq in. Any enclosure that requires a vent of less than about one-third the effective

Tuning a large bass reflex. Tape on clamps prevents vibration from affecting the tuning.



cone area of the speaker is a candidate for a duct. Small vents produce increased air velocity through them, which can increase distortion and even add the spurious sound of rushing air. They can also add resistance that wastes energy and makes the enclosure operate like a leaky box instead of a tuned system.

For small vents, a cardboard tube or a plywood duct of square cross-section can be used. Heavy cardboard mailing tubes, when used, require that the hole in the baffle be cut to match the *outside* diameter of the tube. An extra advantage of the cardboard tube is the ease with which the system can be tuned. With other types of ducts it is necessary to remove the back panel to make changes in duct length.

If a cardboard tube is used, it is possible to permanently assemble the speaker system, except for the grille cloth, and then tune the enclosure. The duct hole must be carefully pre-cut to allow a snug fit when the tube is pressed into it. The audio generator and ac voltmeter are then connected

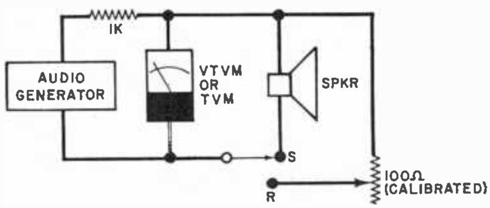


Fig. 3. Setup for running impedance curve. First calibrate variable resistor using ohmmeter and mark resistance at various settings of control knob. With equipment as shown, feed 200-Hz signal into speaker. Then, vary frequency downward, taking voltage readings at close frequency intervals. To read impedance at any frequency, note value of ac voltage on meter with switch in position S. Then switch to position R and vary knob setting to obtain the same meter reading. Record the resistance reading indicated by the exact frequencies of the peaks and valleys. Then plot the curve on a sheet of semilog paper.

to the speaker system as shown in Figure 3, and different lengths of tube are tried until the impedance trough occurs at the speaker's free-air resonance. The tube can protrude outside the box while testing because tuning is hardly affected by its position.

When the correct length of tube is prepared, glue it flush with the outside of

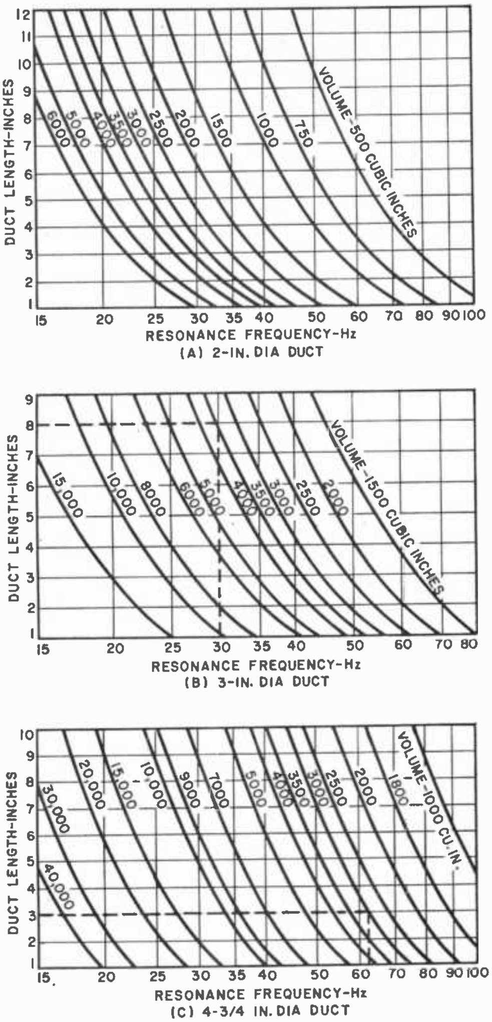


Fig. 4. Design charts for cardboard tube ducted enclosures developed by J. F. Novak, Chief Engineer, Jensen Sound Laboratories. Various tubing diameters are inside measurements; duct length is measured from cabinet front. Tubes can be obtained from business supply houses, stationery stores, or ordered from Service Manager, Jensen Sound Labs., 4310 Transworld Rd., Schiller Park, IL 60176.

the speaker board. All that remains to be done is to attach the grille cloth to the front of the cabinet.

Holes cut for square ducts should match the *inside* dimensions of the duct. The duct can then be glued and screwed to the front panel. Note that the effective duct length in this case will include the length of the duct and the thickness of the front panel.

No matter what kind of duct is used, a free space of at least 1½ in. must be provided between its rear edge and the back wall of the enclosure. This will place a limit on the permissible duct length, which—together with the volume and desired tuning frequency—determines a useful cross-sectional area and length of duct for a given enclosure.

The effective length of any duct is slightly greater than the length of the tube itself due to the tendency of the air outside the end of the tube to vibrate with the moving air in the tube. This phenomenon would have to be accounted for if a formula were used to find the correct duct length for an enclosure. But when using design charts, this factor can be neglected; the correction has already been made by the chart maker.

To use James F. Novak's charts in Fig. 4, the largest possible duct should be selected to tune an enclosure to a speaker. For a speaker with a resonance of 62 Hz that will be used in a 3000-cu-in. box, a 3-in. length of 4¾-in. duct is correct as shown. But for a speaker with a free-air resonance of 30 Hz that is to be used in a 2-cu-ft. box (about 3500 cu in.), even a 10-in. long duct is far too short. For this speaker and box combination, it is necessary to go to the next smaller, 3-in., duct where an 8-in. length will properly tune the box to the speaker.

The duct can be made to any convenient shape if test equipment is used to assure proper tuning. But if the tuning charts are used without further testing, it is imperative that the cross-sectional shape of the duct be either round or square.

Some experimenters and speaker engineers advocate the use of damping material in the duct to improve transient response and smooth the impedance curve of the speaker. This is a controversial practice because, like simple resistive vents, it decreases cone damping in the octave above resonance and reduces efficiency. It does eliminate the possibility of midrange radiation from the port, but it is rarely necessary for that purpose. The naturally high reactance of the port to midrange and high frequencies, plus the judicious use of damping material inside the box, will usually take care of unwanted reflections through the port. Duct stuffing is useful only when accompanied by adequate testing to achieve a specific design goal. It should not be used indiscriminately. ◈

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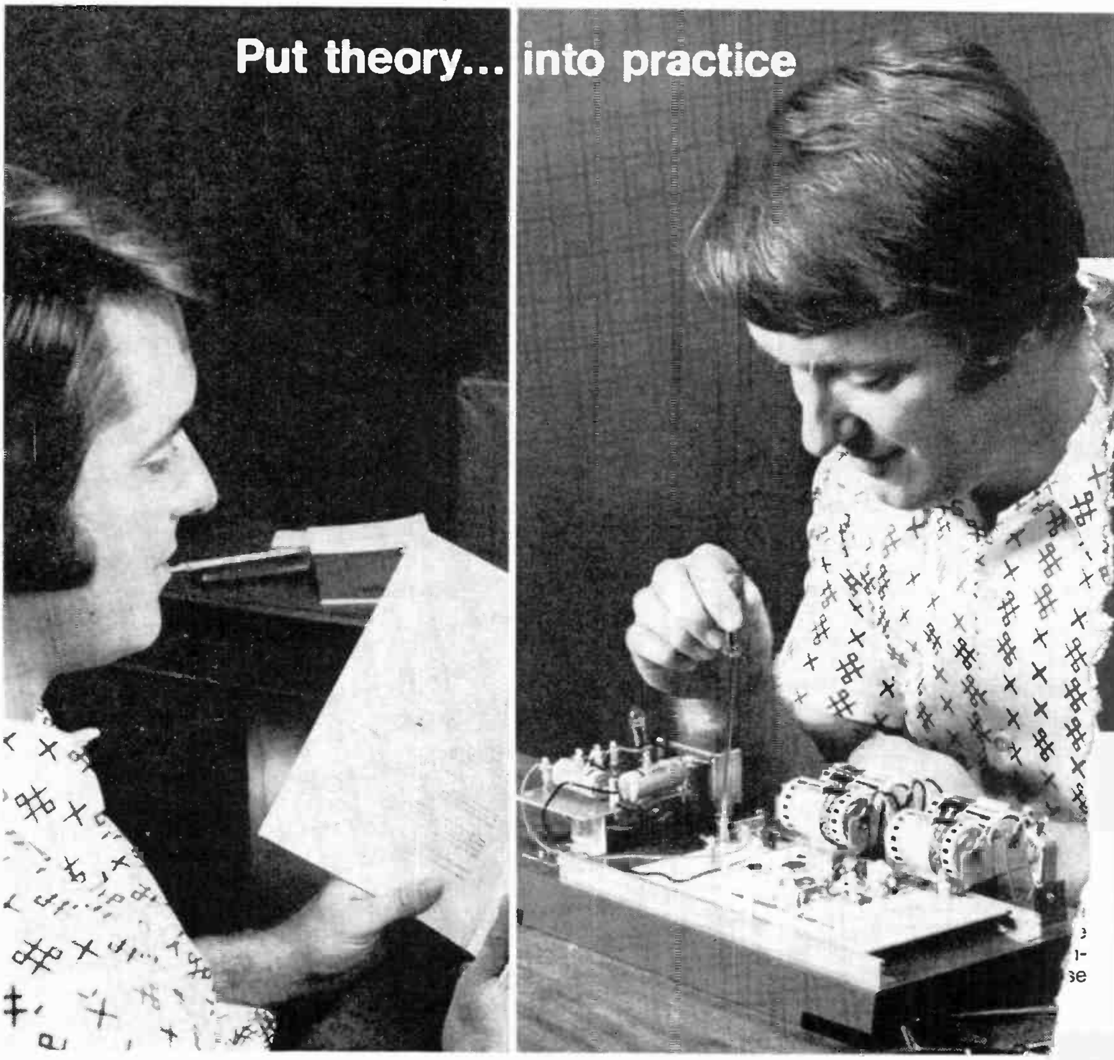

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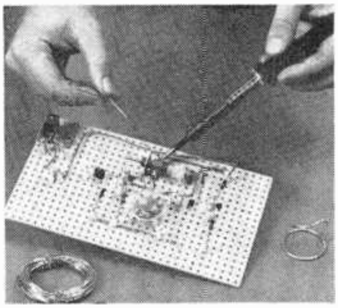

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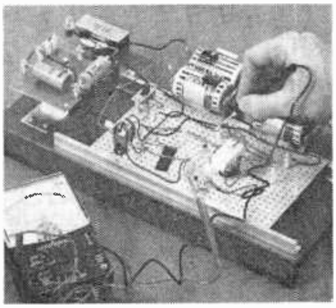

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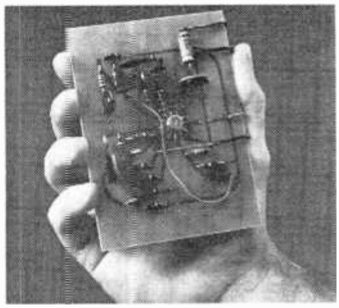

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Product Test Reports

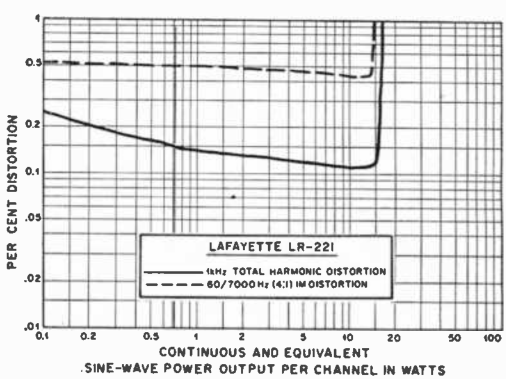
LAFAYETTE MODEL LR-221 4-CHANNEL RECEIVER
(A Hirsch-Houck Labs Report)

THE FULL directional effect of an SQ™ record can be heard only when the disc is played through a decoder that can sense the dominant direction at any instant and shift the relative channel gains to enhance the inherently limited front-to-rear directivity of the SQ system. The so-called "full-logic" (or wave-matching) system can yield the most effective separation in all directions with SQ discs. It is quite complex and, therefore, expensive. Until recently, the only 4-channel receiver to incorporate full-logic SQ decoding was the Lafayette Radio Electronics Model LR-4000. This receiver has now been joined by the lower cost ($360) Model LR-221.

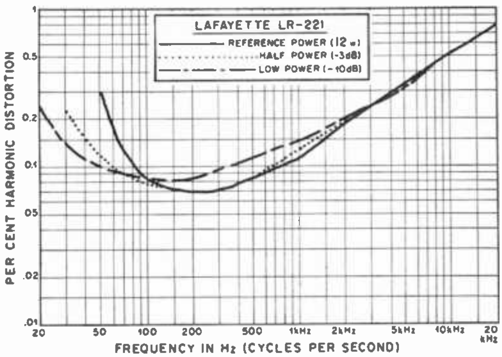
The LR-221's FM tuner section boasts performance specifications that are typical of many receivers in its price range—notably, 2.2 μV IHF sensitivity, 0.25% distortion, 65 dB S/N ratio, 35 dB midrange stereo separation, and 40 dB alternate-channel selectivity. The 4-channel amplifier section is rated at 26 watts/channel into 4 ohms with one channel driven, while the THD at 1000 Hz is specified as less than 1 percent at full rated power and less than 0.125 percent at 1 watt output.

On the rear of the receiver are a HI/LO sensitivity switch for the magnetic phono inputs and two 4-channel AUX inputs. Two sets of speakers can be connected and driven simultaneously or singly. The outputs for the REMOTE speakers are phono jacks, while screw-type terminals are used for the MAIN speakers. AM and FM antenna terminals (with provision for using the line cord as an FM antenna), a pivoted ferrite-rod AM antenna, an FM DET OUT jack for use with a future discrete 4-channel FM broadcasting system, and a single unswitched ac outlet are also on the rear apron. The tape recording and playback circuits, brought out through jacks on the rear of the receiver, are suitable for both 2- and 4-channel tape decks.

The front panel contains the tuning dial, tuning meter, an FM STEREO light, 2-channel TAPE OUT and separate front and rear headphone jacks, and all remaining controls and switches. The input selector has positions for AUX 1 and AUX 2, PHONO, AM, FM, and FM high-frequency blending (to reduce noise on weak signals). The FUNCTION SWITCH has positions for 2 CH (pairs both left and both right channels), COMPOSER A and COMPOSER B (matrices for decoding RM discs and synthesizing the rear channels



from 2-channel programs), SQ FULL LOGIC, DISCRETE (for external tape source or a CD-4 demodulator), and REVERSE. The latter operates with discrete sources, reversing the left/right and front/rear positions to effectively turn the 4-channel array through 180°.



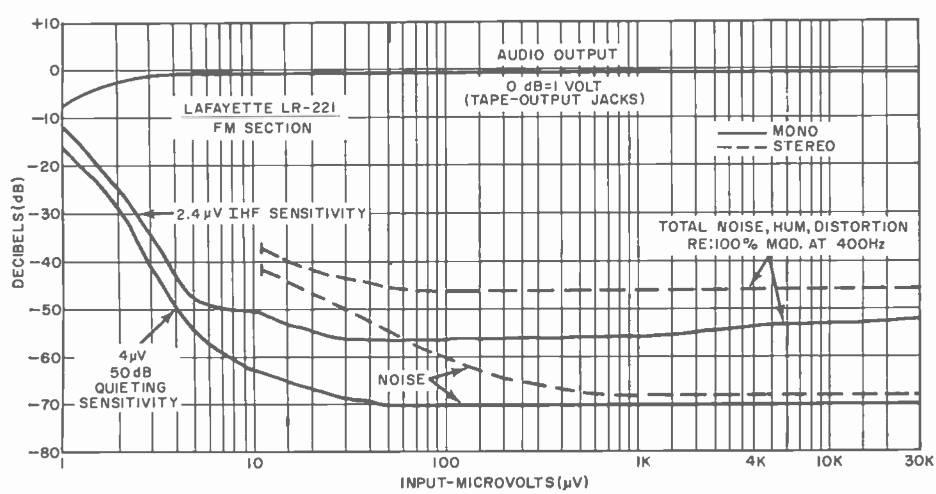
The BASS and TREBLE tone controls are concentric potentiometers, as is the L-R balance control for the front and rear channels. The master volume control is also concentric, slip clutched to permit adjusting the front-to-rear balance as well as overall volume. Pushbutton switches are used for TAPE MON, STEREO/MONO, LOUDNESS, HI FIL, and FM MUTE switching.

Laboratory Tests. With all four channels driven simultaneously at 1000 Hz into 8-ohm loads, the outputs clipped at 12.9 watts/channel. Driving only two channels increased the clipping output to 16 watts/channel. With 4-ohm loads and 16-ohm loads, the figures were 16 watts/channel and 11.4 watts/channel respectively.

The 1000-Hz THD was below 0.25 percent from 0.1 to 16 watts, and was typically between 0.1 and 0.15 percent. The IM distortion was almost constant (0.4-0.6 percent) over the full range of power outputs from 10 mW to 12 watts. Using 12 watts as a reference full-power level, the THD at all power outputs from 1.2 to 12 watts was between 0.07 and 0.15 percent at frequencies from 65 Hz to more than 1000 Hz. The distortion increased with increasing frequency, to 0.5 percent at 10,000 Hz and 0.75 percent at 20,000 Hz. As with many receivers, the LR-221 had a limited low-frequency power capability so that its THD reached 0.25 percent at 20 Hz with a 1.2-watt output, at 30 Hz with 6 watts, and at 55 Hz with 12 watts output.

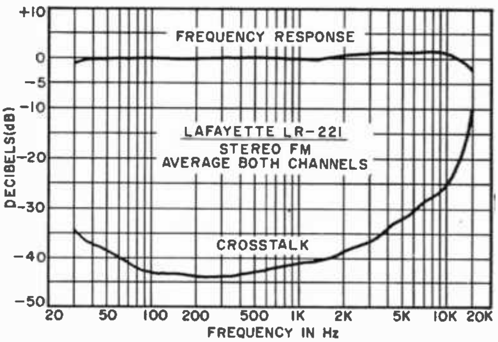
The tone control characteristics were good, with the bass inflection point sliding upward from 100 Hz to 500 Hz as the control was moved from center, and the treble slope hinged at about 2000 Hz. The HI filter had a gradual 6-dB/octave slope, with the -3-dB point at 2700 Hz. The loudness compensation boosted both lows and highs moderately, and the RIAA phono equalization was within ±0.5 dB from 70 Hz to 15,000 Hz (down less than 2 dB at 30 Hz).

The amplifiers could be driven to 10 watts output by a 180-mV AUX input or a 1.65-mV HI phono input or a 3.75-mV LO phono input. The corresponding phono overload levels were 22 mV and 50 mV. The former is too low for most cartridges; we recommend using the LO setting to avoid



preamplifier overload distortion. The noise levels were very low, −75.5 dB and −73 dB for the AUX and phono inputs respectively, referred to 10 watts output.

The FM tuner has a 2.4-μV IHF sensitivity, with a 50-dB S/N ratio (mono) reached at only 4 μV input. The ultimate quieting in mono was 70 dB, with a residual distortion of only 0.17 percent. The automatic stereo threshold was 11 μV, and the ultimate stereo S/N ratio was 68 dB (with 0.5 percent distortion). The FM capture ratio was 1.6 dB, AM rejection was very good at 62.5 dB, and image rejection was an excellent 89.5 dB. Alternate-channel selectivity—55 to 59 dB on the two sides of the desired channel—was considerably better than the receiver's 40-dB rating.



In stereo FM, the frequency response was flat within 1.5 dB overall from 30 Hz to 13,000 Hz. It was down 2.5 dB at 15,000 Hz. Channel separation was exceptionally good, exceeding 40 dB between 64 Hz and 1100 Hz, better than 30 dB from 30 Hz to 12,000 Hz, and still 10 dB at 15,000 Hz. The 19-kHz pilot carrier leakage in the audio outputs was 66 dB below full modulation.

The AM tuner, like many such, had limited high-frequency response.

User Comment. The FM tuner performance was comparable to what we have measured with many 2-channel receivers in the LR-221's price bracket. The tuning was not critical, and the muting allowed only a slight burst of noise to be heard when tuning through a station.

Although the audio amplifiers were much less powerful per channel than those of most 2-channel receivers, the total output of up to 64 watts at mid-frequencies from all four channels should be more than adequate for most listeners. Similarly, a comparison of the audio distortion in this receiver with that of a 2-channel receiver at the same price might seem to place the LR-221 at a disadvantage. However, under normal program conditions, the distortion is not likely to exceed 0.15 percent.

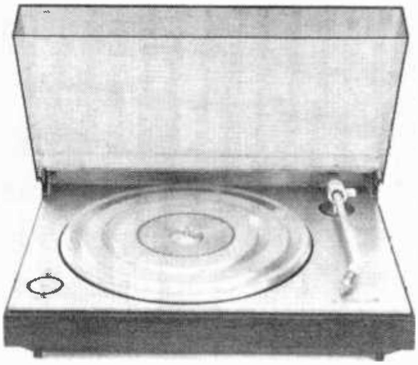
The SQ performance of the LR-221 is the receiver's most noteworthy feature, and it acquitted itself admirably. The center-front to center-rear separation was most impressive, as was the left-front to right-front separation. Between the rear channels and along the sides of the room, the separation was notably less, but distinct. Listening to a number of SQ discs, we were never in doubt as to the effectiveness of the full-logic decoder in this receiver. Compared to the vague directionality of a simple SQ matrix (used in almost all 4-channel receivers currently on the market, regardless of price), the quadraphonic performance of the LR-221 receiver was vastly superior.

BANG & OLUFSEN MODEL 3000 TURNTABLE/TONEARM (A Hirsch-Houck Labs Report)

THE Danish-made Bang & Olufsen Model 3000 is an integrated record playing system that is supplied on a wooden base to which is hinged a plastic dust cover. The system consists of a two-speed (33 ⅓ and 45 rpm) belt-driven turntable and a slender tubular aluminum tonearm to which is fitted B&O's Model SP12A phono cartridge. The characteristics of the tonearm, phono cartridge, and turntable have been carefully matched for optimum performance, something not so easy to accomplish when assembling a record player from its component parts.

General Description. The 11¾-in. nonferrous platter in the system is relatively light. It rests on a smaller internal turntable that is belt-driven by a 2750-rpm motor. The operating speed is adjustable over a nominal 6-percent range by a thumbwheel control located under the edge of the base. The tonearm mounting is rigidly coupled to the turntable system, and both are floated from the motorboard on very compliant springs. The 4-Hz or so system resonance is low enough to avoid acoustic feedback problems but high enough to prevent undue susceptibility to jarring.

After the tonearm is balanced by an adjustable counterweight, the desired tracking force is set by a small knob on the pivot housing. The force calibrations cover a range of from 0 to 3 grams in 0.5-gram increments (B&O recommends a 1.2-gram force for their SP12A cartridge). Antiskating is applied by a non-adjustable system within the arm's pivot structure.



The cartridge supplied is identical in structure to the SP12 which B&O sells for installation in other tonearms. However, it is designed to simply plug into the end of the Model 3000's tonearm. It has a replaceable, polished, 0.2 × 0.7-mil elliptical diamond stylus.

The system has a uniquely simple control setup. A single LIFT button is concentric with the speed-select switch. The latter is used for selecting the standard turntable speed/arm index combination. When the selector is set for 10- or 12-in. discs, a touch of the button starts the turntable at 33⅓ rpm, moves the arm over the leadin groove, and gently lowers the arm to the disc's surface. The same thing happens in the 7-in. position except that the operating speed is 45 rpm. At the end of play, the arm returns to its rest position, safely supported clear of the motorboard (there is no rest post), and the motor shuts off.

At any time during play, pressing the LIFT button raises the pickup and shuts off the motor. A second push of the button starts the motor again and lowers the pick-up with no tendency for the arm to drift laterally.

There is also a MANUAL selector setting that merely turns on the motor. The arm must be manually indexed (although its vertical motion is controlled by the LIFT button, and the automatic shut-off feature remains in effect at the end of play). Discs that do not fit the standard size/speed scheme, such as a 7-in. record designed to operate at 33⅓ rpm, must be played using manual arm indexing.

The turntable platter has a retractable 45-rpm spindle built into its hub. A ring of stroboscopic markings on the platter facilitates easy initial speed adjustment.

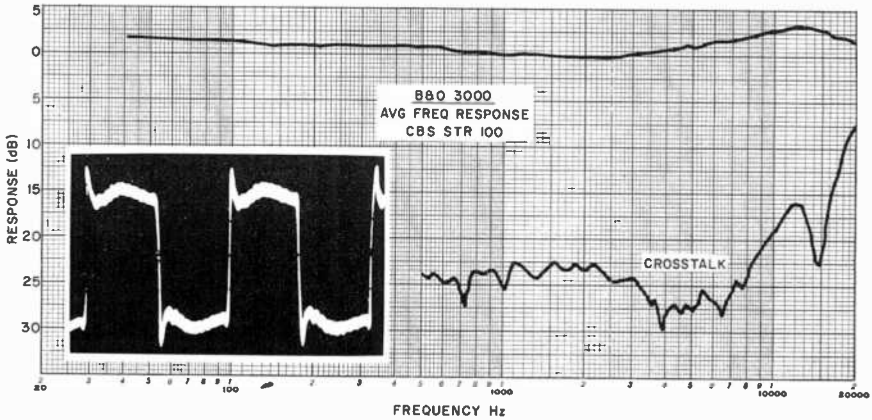
The Model 3000 record player system, measures 17$\frac{5}{16}$ in. by 13 in. by 4½ in. and weighs 20 pounds. It retails for $265.

Laboratory Measurements. On our test bench, wow and flutter tested out, respectively, at 0.05 and 0.04 percent on both speeds. Unweighted rumble was a very low −45 dB in the lateral plane and −38.5 dB when vertical rumble components were included. With RRLL weighting, the rumble was −54.5 dB, typical of today's turntables. Speed was adjustable over a range of from +7.3 to −1.7 percent, relative to the correct speed.

Tonearm tracking error was very low, less than 0.25°/in. of radius from 3 to 6 in. It increased to a still good 0.6°/in. reading at a 2½-in. radius. Balancing the arm according to instructions, we measured a tracking force slightly higher than the dial calibration indicated—by about 0.2 gram at a 1-gram setting. This small error is in a "safe" direction. But for maximum accuracy, an external pressure gauge could be used to check the force. Once set correctly at 1 gram, the dial error was less than 10 percent at any setting.

The cartridge had an output of 4.5 mV at 3.54 cm/s. Its frequency response was within ±2 dB from 500 Hz to 20,000 Hz (the constant-velocity range of the CBS STR100 test record), and channel separation was 20 to 25 dB or more over most of the audible frequency range, decreasing to 10 to 15 dB beyond 15,000 Hz.

The 1000-Hz square wave of the CBS STR-111 disc was reproduced with a single over-shoot. We evaluated the "trackability" with the Shure TTR-103 disc which has special test signals for testing cartridge performance at high, middle, and low-middle frequencies. Although the numerical results could be used only to compare this cartridge with others tested in exactly the same man-



ner, our studies showed that it has extremely good tracking capability—quite comparable, in fact, to what we have measured on the best cartridges previously tested.

User Comment. The Model 3000 player system is certainly one of the simplest players to operate with its control limited essentially to pushing a single button. Operation was smooth and flawless, with no undesirable characteristics.

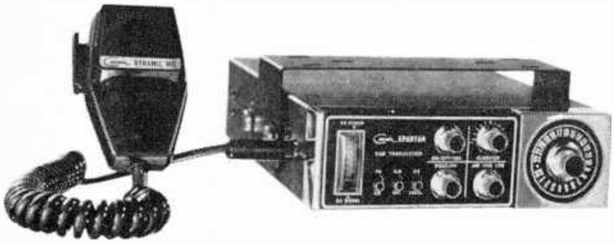
The SP12A cartridge proved to be a superb performer. The most severe tracking tests to which we could subject it revealed that the SP12A cartridge could match the best we have yet tested for "trackability." It would be safe to assume that any distortion heard when playing a disc with this unit would be in the record grooves.

The mass of the tonearm, which is somewhat lower than that of a typical general-purpose tonearm, enables the pickup to track severely warped discs that had proved previously to be unplayable with conventional arms. Since no antiskating adjustment was available, we could not judge its accuracy. But indications were that it was inoperative or too low on the test unit. Even without this aid to tracking, the Model 3000 system was able to outperform many players with full antiskating correction.

All in all, this is one of the most attractive and better performing record players we have seen. It is an excellent value, especially when one considers that it is a ready-to-play unit that requires only plugging into an amplifier and power line to put it into immediate service.

Circle No. 66 on Reader Service Card

COURIER SPARTAN SSB CB TRANSCEIVER



THE Courier Spartan SSB is a single-sideband CB transceiver with provisions for AM operation. It is a mobile, 23-channel solid-state rig that has most of the features incorporated in a combined AM/SSB unit.

A clarifier control allows the user to put both the receiver and the transmitter right on frequency when operating SSB. There are an adjustable squelch for AM and SSB, a noise blanker that can be switched in or out, jacks for external receiving and for speaker hookup to the built-in PA system, and an r-f S/relative transmitter output power meter. Operation is from a nominal 13.8-volt dc, *negative-ground only* source. The microphone supplied is a push-to-talk dynamic noise-cancelling type.

Several of the functions are selected by miniature toggle switches, while others employ conventional rotary switches. The meter movement is an edgewise-mounting type. The rig measures 9½ in. by 7½ in. by 2 5/16 in. and weighs 6 pounds.

The Spartan SSB transceiver is list priced at $330, including microphone and mobile mounting hardware.

The Receiver. The receiver section employs a front end that is common to both SSB and AM. It provides an excellent sensitivity figure of 0.1 μV for 10 dB (S + N)/N on SSB and 0.25 μV on AM with 30 percent modulation at 1000 Hz.

Many transceivers of this type use an r-f gain control to minimize overload by strong local signals, but the Spartan SSB has a LOCAL/DISTANCE switch; in the LOCAL position, it drops front-end gain by about 20 dB and reduces sensitivity to 1.5 μV and 3 μV on SSB and AM, respectively.

The 7.8-MHz i-f goes directly to the SSB section where USB or LSB selection is obtained with a 2.1-kHz bandpass crystal-lattice filter. The overall a-f response at the 6-dB points is 600-2700 Hz. Unwanted-sideband rejection with this setup was better than 70 dB at 1000 Hz.

Dual conversion is used on AM, with the 7.8-MHz i-f converted to 455 kHz. A ceramic filter in the i-f section provides a minimum of 30 dB of adjacent-channel rejection. The overall response of the a-f section was 550 to 2150 Hz, resulting in easily understood voice quality.

The receiver's image rejection was 80 dB. Other spurious signals were down a minimum of 60 dB.

A four-diode product detector is used for SSB, and dual diodes function as an envelope detector for AM. The a-f amplifying and output setup is switched between detectors and for PA operation. It was capable of producing more output than is usually the case, measuring 4.8 watts with a good sine wave distorted only 2.9 percent (1000 Hz into 8 ohms) and 6 watts with slight clipping and 4 percent distortion.

Individual agc systems are used for AM and SSB, with 14-dB a-f output change occurring with an 80-dB (1-10,000 μV) r-f input change. The S meter was somewhat conservative, requiring a 300-μV signal to produce an S9 reading. The squelch had a threshold sensitivity of 0.1-500 μV on SSB and 0.4-3000 μV with AM.

The noise blanker operates on AM and SSB. When used, a series-gate a-f noise limiter is simultaneously switched into the AM section. In either mode, the overall attenuation of impulse-noise peaks amounted to 20 dB. The system was quite effective in preventing receiver desensitization by noise pulses.

The Transmitter. A frequency synthesizer with 14 crystals provides a nominal 19-MHz output at a four-diode balanced mixer and provides the heterodyning signal for the receiver mixer. It also goes to an IC transmitter mixer where it is combined with a 7.8-MHz SSB signal that is generated in the usual manner with a balanced modulator and the crystal filter. This produces the on-channel signal that is amplified by two stages and drives the r-f power amplifier which contains the customary output-matching and filtering network. For AM, the on-channel carrier is produced by mixing the synthesizer's output and a 7.8-MHz signal. The power amplifier and driver are collector-modulated by the receiver's a-f system. A "power controller" holds the AM input voltage down at the r-f stages for operation within the legal power limit.

Automatic level control is provided for SSB. On AM, automatic modulation control takes over.

Operating from a 13.8-volt dc source, the transmitter's PEP output on SSB was almost 12 watts (rated 8 watts). The third-order distortion products at the automatic level control threshold were 26 dB below maximum output. Carrier suppression was 55 dB, and unwanted-sideband suppression was the same as on receive.

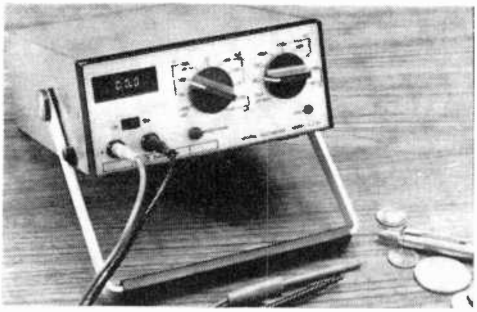
With AM, the carrier output was 3.75 watts. A full 100-percent modulation was attainable with a good waveform exhibiting only 2 percent distortion (with 1000 Hz) at the onset of complete modulation. With 6 dB of clipping, the distortion rose to 10 percent.

At the center position of the clarifier control, the frequency of any channel was within 100 Hz. The clarifier range was nominally ±500 Hz.

The transceiver is designed for use only in negative-ground systems. Reverse-polarity protection is furnished by a diode that conducts and places a virtual short circuit across the supply line when the polarity is incorrect, blowing the line fuse. A filter in the supply line minimizes transient spikes and ignition-noise pulses.

Circle No. 67 on Reader Service Card

BALLANTINE MODEL 3/24 DIGITAL MULTIMETER



UNTIL fairly recently, some of the finest test equipment available for high-level scientific study and research and development was made by companies whose names were unknown to the majority of the people involved in electronics. Recently, however, a few of these companies have been producing test gear within the price range reachable by technicians, experimenters, and radio/TV-service shops.

One of the top-flight test instrument manufacturers that has established an impressive reputation in engineering circles is Ballantine Laboratories, Inc. This company is currently making its debut into the low-cost test equipment market with the introduction of their Model 3/24 digital multimeter that retails for only \$195—this from a company whose wares in the past were priced nearer the thousands than the hundreds of dollars.

General Description. The Model 3/24 gets its designation from the fact that it is a three-function, 24-range instrument. It is designed to measure dc voltages to 1, 10, 100, and 1000 V full-scale with an accuracy of 0.5 percent or better. The same four ranges are available for measuring ac voltages to 1 percent accuracy. (On the 1- and 10-V ac ranges, the frequency response is 40 to 20,000 Hz, while on the 100- and 1000-V ranges, it is 40 to 1000 Hz.) Input resistance on dc V is 10 megohms, and on ac V the input impedance is 10 megohms shunted by 75 pF.

Five direct current ranges are provided, going out to 100 μA, 1 mA, 10 mA, 100 mA, and 1 A full-scale with an accuracy of 0.5 percent plus one digit. The voltage drop is approximately 1 volt. There are also five similar ac ranges, all with an accuracy of 1.5 percent plus two digits, approximately a 1-V drop, essentially infinite common-mode rejection (on battery operation), and a frequency response of 40 to 2000 Hz.

Six resistance ranges round out the instrument's functions, covering decade steps from 100 ohms to 10 megohms full-scale. Accuracy is 1 percent plus one digit. The test current is 10 mA on the 100-ohm range, decreasing in decade steps to 0.1 μA on the 10-megohm range.

Among the other features to be found are automatic zero setting, automatic polarity indication, and a LED display BRIGHTNESS control that can be used to adjust the display to any brightness level within the instrument's range. Two front-panel controls are provided for selecting the function and range. The readout system is a cluster of 3½ LED displays. All displayed indications are made at a 3/second rate, producing an almost instantaneous updating of the measured parameter's value. In the event of an overrange, the most significant digit flashes on and off.

A front-panel ZERO control permits the user to compensate for the resistance of the test leads when making very low resistance tests. The only other control on the front panel is the power ON/OFF switch.

Evaluation Comments. We were pleasantly surprised when we first unpacked the 7-in. by 5-in. by 2½-in. instrument. It weighed only 2 pounds with its single 9-volt battery installed. (The battery, it should be noted, is said to supply 300 hours of life when the instrument is put into normal use.) The carrying handle that comes affixed to the case of the DMM also doubles as a tilt stand for bench use.

Checking the DMM against our laboratory-standard dc voltage supply and our "standard" set of close-tolerance precision resistors revealed that the instrument functioned well within its published specifications, which was no surprise. Its small size and ac-line-independence made the DMM very useful on our workbench where it could be placed just about anywhere—even inside large TV receiver chassis. In field-service use, the instrument performed flawlessly.

We feel that the Model 3/24 DMM from Ballantine is an excellent buy. It is hoped that other OEM companies will follow this one into the consumer area.

Circle No. 68 on Reader Service Card

BRANSON MODEL B-220 ULTRASONIC CLEANER

Sometimes we run into things that don't appear to fit any "electronic" category. But after using them for a while, we wonder how we ever got along without them. Just such a situation existed when we were handed a Branson ultrasonic cleaner to test. Frankly, we have to admit that we didn't have the faintest idea what to do with the thing (aside from cleaning jewelry, of course). The more we used it, the more uses we could see for the cleaner, especially in electronics work.

The Branson ultrasonic cleaners come in nine models that range in tank capacity from the 1-pint Model B-2 ($55) to the 8-gallon Model B-92 ($750). Looking for a convenient size for electronics applications, we decided to test the 3-quart (9" × 5" × 4" tank dimensions) Model B-220. This unit retails for $115, which puts it into an attractive price range for repair shops that have to contend with component and assembly cleaning jobs.

How It Works. The theory behind ultrasonic cleaning is relatively simple. A high-power ultrasonic generator drives one or more transducers that couple the high-frequency energy into the liquid in the tank. Since the liquid (detergent solution or industrial solvent) does not heat up and the tank is made from stainless steel, almost any type of cleaner can be used.

The object to be cleaned is immersed in the solution in the tank. After power is turned on, the 50-60-kHz sound waves cause the solvent in the tank to undergo cavitation wherein millions of tiny bubbles form and collapse. The result is a "scrubbing" action on the immersed parts wherever the liquid contacts them. The cleaning action also goes around corners, into deep crevasses, and can even pass through some barriers. Hence, the insides of the immersed objects are cleaned simultaneously with their outsides.

Although the bulk of the cleaning jobs can be accomplished with warm water and a little household detergent, other types of additives—such as ammonia and bleach—or solvents (kerosene, commercial cleaning fluids, degreasers, etc.) can be used. Selection of the cleaner to use depends on the job to be done.

By the Numbers. We had a crack at cleaning some noisy potentiometers and a couple of well-used, over-lubricated television tuners. The ultrasonic energy developed by the unit blasted them clean. We say "blasted" because the puffs of cloudy material leaving the items in the tank looked like they were blasted out. We noted afterward that because the cleaner does such a thorough job, cleaned switches or tuners require relubrication.

Because we build many projects, we used the ultrasonic cleaner to scrub the copper foil of PC boards. Soldering is no longer a problem, and items such as capacitors and resistors turn out so clean that no doubt is left as to their values by color code or number imprint. Knobs, especially those with grease-collecting knurled perimeters, really come clean.

Having used the ultrasonic cleaner for several weeks, we now find ourselves cleaning things electronic and non-electronic several times a day.

Circle No. 69 on Reader Service Card

ERRATUM

In last month's Product Test Reports, the price of the EL Instruments Model DD1-K Digi-Designer was incorrectly listed as $50. It should have been $59.95.

MAC'S SERVICE SHOP

Servicing Without Service Data

By John T. Frye, W9EGV, KHD4167

BARNEY had been working on a combination AM-stereo FM and 8-track tape player for half an hour, grumbling under his breath all the while. Finally Mac, his employer, switched off the sweep generator he had been using after replacing an i-f transformer in a TV receiver and asked, "OK, Irish, what's all the muttering in your beard about?"

"Aw, I'm sick and tired of having to work on foreign-made transistor equipment for which we have no service data. It's like fighting with one hand tied behind your back."

"I know," Mac sympathized. "More and more of this equipment comes into the shop every day: transistor radios, hi-fi's, tape players, and recorders, all bearing names we do not recognize. Almost no information is available on many of these units. If any helpful data came with the equipment, the owner threw it away or lost it long ago. The model number, and quite often the make itself, are not listed in the index of our service literature. If a rare wiring diagram is found on the chassis or in the cabinet, it's about the size of a credit card and of little help.

"Now servicing without service literature can be tedious and time-consuming; yet a diagnosis and repair of a piece of this maverick equipment must be made quickly to turn a profit. The owner simply will not pay for a great deal of time spent on it. Replacement cost—especially of the small radios—is low enough that the customer will buy a new receiver if the repair cost exceeds a few dollars."

"Yeah, I know," Barney chimed in. "Many smart technicians refuse to touch one of these 'Made in Japan, Hong Kong, Taiwan, etc.' electronic devices. They figure they will invest more time in flying-blind servicing than they will be able to recover in charges."

"I don't think that's so smart," Mac said. "Any time you see a service going begging because it has disagreeable features, you're staring an opportunity right in the face. Garbage collectors, plumbers, and undertakers have found this out, and they seldom die broke. The trick is to find ways to nullify the unattractive qualities of the work for you personally while these same qualities scare off your competition."

"Sounds good," Barney said dubiously, "but how are you going to take the blank, blank headaches out of servicing without service data?"

"By using your knowledge and experience to work out a diagnostic procedure that keeps unnecessary moves to a minimum, makes maximum use of generalized service data, and employs different techniques than the ones used with service data; then stick to that procedure religiously.

Check the Easy Things First. "Take that business about keeping unnecessary procedures to a minimum. Nothing is more frustrating than to remove a hard-to-get-out chassis for a lot of fruitless voltage testing only to discover the trouble was a broken antenna lead you could have repaired in a minute. Always check easily repaired possibilities first. Battery voltage and current drawn should be checked routinely, even if the customer says the battery is brand new. It could have grown old on the shelf, or the set could have a high current drain that exhausts the battery quickly. The milliammeter can be inserted in a snap-connector battery lead easily by removing one snap and using the meter leads to restore the connection. In case individual cells in series furnish the current, use a special jig made up of a couple of pieces of brass shim stock cemented to opposite sides of a piece of thin fish paper. When this is inserted between the end connector of one of the batteries and its contact, milliammeter leads touched to the two pieces of shim stock will read the total current being consumed. Your experience will serve as a guide to normal current for the number of transistors used.

"Carefully look over the chassis with a pair of magnifying glasses for loose connections, broken wires or charred resistors. Look especially for dangling fine wires going to the antenna. These leads are often broken by the customer in changing batteries or in attempts at do-it-yourself servicing. With the volume full on, try gently moving resistors, capacitors and i-f cans, with an insulating diddle-stick. Be sure to wiggle the tuning capacitor. Quite often one of its solder connections to the board is broken when the radio is dropped or by rough handling of the tuning knob on direct-drive tuning capacitors. Gently flex the printed circuit board itself, especially along the edges. What you're hoping for, of course, is a sudden restoration of normal functioning, indicating a broken or loose connection has been temporarily corrected."

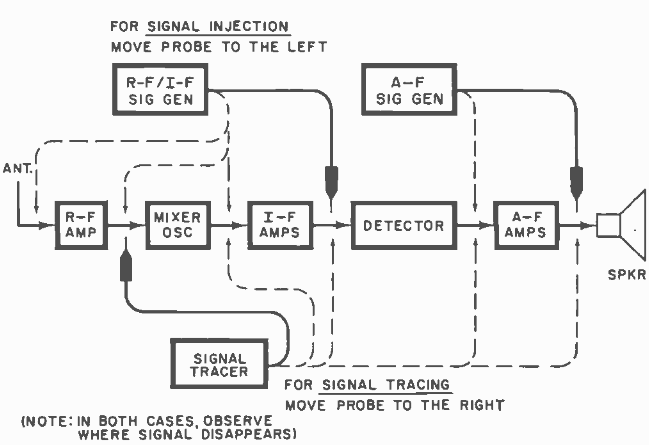
"If you can't find anything wrong that way, do you take the chassis out and do voltage checks on the back side?"

Signal Injection and Signal Tracing. "Not yet. The next thing to try is signal injection and/or signal tracing. With the proper equipment, even voltage checks can be made from the top of the PC board. Just listening for a click when the set is switched on will tell you if the output transistor is drawing collector current and if the output transformer and speaker voice coil are O.K. If you hear the click, they are; if not, something is wrong with one of these components. Another crude signal-injection test is to touch the 'hot' or center lead of the volume control with the volume full on. If this produces a quite noticeable hum, you know a signal can pass from the volume control clear through the audio amplifier.

"But it is usually better to use signal generators for injection and a signal tracer to pick off the signal at various points 'downwind' from where you put the test signal in. Look at this diagram I've drawn. If you know the audio amplifier is working, you can start right in by putting an r-f signal into the antenna and picking it off at the detector diode or as far forward as you need to go to pick up the signal. You can zero in on the defective component that is losing the signal from two directions."

"Yeah, but it's pretty tricky trying to work a signal-injection or signal-tracing probe into the proper points on top of the board without shorting out a couple of leads and possibly blowing a transistor," Barney pointed out.

"Not if you make up some special probes just for that purpose," Mac replied. "I solder two-inch lengths of fairly stiff, small diameter wire to pinjacks or banana jacks that will slip over the end of a test probe. The wire is covered with a piece of spaghetti tubing so that only about 1/16" of the end of the wire is exposed, and the spaghetti is cemented to the wire. The wire can be bent into any shape so that the end can reach in under a transistor case to contact a particular lead without fear of short circuits. These special extensions will slip over the probe tips of our VOM, VTVM, signal tracer, or signal generator. When not needed, they are quickly removed.



How to use signal generators and a signal tracer to check out an unfamiliar receiver.

"Once the loss of signal is cornered in a small portion of the circuit, you fall back on your technical knowledge and your generalized service data to pinpoint the bad component. By 'generalized service data,' I refer to such things as transistor and cross-reference manuals put out by many transistor manufacturers. The transistor and semiconductor manuals put out by RCA, General Electric, and Motorola and others contain not only characteristics of the devices they sell but also a wealth of theory, applications, and typical circuits of radios, TV receivers, CB transceivers, hi-fi amplifiers, mixers, and so on. By comparing the voltages you find in the circuit you suspect with typical voltages shown in the manual, you can quickly decide if everything is kosher. If a signal is present at the input of a transistor and its voltages are all within tolerance, but the signal is not present at the output, it doesn't take a whiz-kid to decide the transistor is very likely defective. A transistor tester can confirm this.

"I want to stress the value of such books as Sylvania's *ECG Replacement Guide and Catalog*, GE's *Entertainment Semiconductor Almanac*, Radio Shack's *Transistor Substitution Guide*, and Motorola's *HEP Semiconductor Cross-Reference Guide and Catalog*. These contain the manufacturers' substitutes for both domestic and foreign transistors, together with characteristics of the recommended substitute and installation hints. One of these books is the first thing I reach for when I suspect a transistor because it will tell me what voltages I can expect on that transistor, and, if need be, what easily available substitute to use. Also helpful are such catalogs as those from Lafayette Radio, Radio Shack and Calectro.

"If you've gotta change a component or repair a broken connection, you still have to remove the chassis board," Barney said.

"Not necessarily. In the case of a broken solder connection on a tuning capacitor lug, you can often apply heat to the top of the lug at the point where it goes down through the board and melt the solder on the other side of the board. In cases where the board is very difficult to remove because of the tuning mechanism or attachment to other components fastened to the case, I've even changed soldered-in transistors from the top of the board. I snip off the transistor leads with miniature diagonal cutters about an eighth inch or so above the top of the board, bend these over so they can't fall on through, and solder the leads of the replacement transistor to these stubs with a miniature iron. You have to decide whether it will be quicker to remove the board or improvise a repair from the top."

Other Suggestions. "Here are some other helpful things I've learned: don't try transistor replacement—especially if they're soldered in—as a form of first aid. Neither should you blindly assume the fault can't be in a transistor. Three times in the last month I've encountered open collectors in Japanese line-operated output transistors. In two instances the owners were hard of hearing, and in the other case children were permitted to play with the radio. Probably operating these receivers at high volume for long periods of time overheated the output transistors in spite of their being heat-sinked. I used recommended U.S. replacements, and none of the sets has bounced yet.

"Another help is to keep a card file by make and model number on these data-less receivers. List the symptoms, the service procedure by which the difficulty was found, and how it was repaired. In my file I also put such things as a short article on reading code markings on Japanese resistors, capacitors, and inductors that appeared in the November, 1973, *QST*.

"But the thing that will really determine whether or not you succeed at this kind of servicing will be your attitude. If you're convinced servicing can't be done without diagrams and voltage data and pictures with callouts, and if you're going to waste your time whimpering about how difficult data-less servicing is and cursing the manufacturer, you'd better not tackle it. On the other hand, if you consider this kind of servicing a challenge to your technical ability and if you're willing to invest some low-return time in working out a procedure that best suits you and your instruments, you'll end up making money. On top of that, don't be at all surprised if you suddenly discover you've become a much more confident and competent service technician when working on sets for which you *do* have data because of what you've learned from taking on those non-pedigreed devices others are turning away. After all, any lubber can make a landfall when he has detailed charts, depth-sounders, loran, radar, and radio communication to lead him by the hand; but it takes an experienced and shrewd navigator to make port by dead reckoning!" ◈

THE SHORTWAVE BROADCAST BANDS

120 meters—Tropical Band—2300-2500 kHz

Best reception: Evening to Central America; only few stations active. Frequencies in kHz; times in GMT.

2390 Guatemala, La Voz de Atitlan, to 0345 sign-off; Spanish, Indian languages

2390 Mexico, Radio Huayacoctla, to 0300 sign-off; Spanish, Indian languages

2446 Reunion, ORTF St.-Denis, rare at 0230 sign-on in French on East Coast of United States

2500 U.S.A., WWV Fort Collins, time and frequency signals, during darkness

90 meters—Tropical Band—3200-3400 kHz

Best reception: Throughout hours of darkness to Latin America; your local dusk to Africa and Brazil; around local midnight, to Africa; before and just after dawn, to Asia, Pacific, and Central America.

3200 China, Fukien Front Station People's Liberation Army; dawn

3277 Kashmir (India), Srinagar, Kashmir, Urdu, some English; dawn

3300 Burundi, Bujumbura, 0400 French and African languages

3315 Martinique, ORTF, Fort-de-France, sign-on in French 1000

3316 Sierra Leone, Freetown, sign-off 2330 (on East Coast), sign-on 0600, English

3325 Guatemala, Radio Maya, fine marimba music, evening and after dawn

3330 Canada, CHU Ottawa, time signals in English and French, all day in Northeast

3380 Guatemala, Radio Chortis, marimba music throughout the evening

75 meters—International Band (not assigned in Americas)—3900-4000 kHz

Best reception: Europe, Africa late afternoon until after midnight; Pacific midnight to dawn; Ecuador before dawn; Asia around dawn

3910 Japan, Far East Network (U.S. Forces) pops and news, dawn

3925 Japan, Nihon Shortwave Broadcasting, late night until after dawn

3952 Great Britain, BBC, European Service, many languages, around 0500

3985 Ecuador, Escuelas Radiofonicas, Riobamba, 1000-1130

3995 Solomon Islands, English and local languages, 0800-1000

60 meters—Tropical Band—4750-5060 kHz

Best reception: All hours of darkness, to Latin America; afternoon and around midnight, to Africa; midnight to dawn, to Pacific; late night to after dawn, to Asia; a few European stations active, times as for Africa

4820 Honduras, La Voz Evangelica, Tegucigalpa, evenings and mornings, some English

4820 Gambia, Bathurst, 0630 sign-on; 2300 sign-off on East Coast; English

4845 Bolivia, Radio Fides, La Paz, early evening, 2300-0100; Catholic religious

4877 South Vietnam, VTVN Saigon, Vietnamese until after dawn

4890 Senegal, Dakar, sign-on 0600, sign-off 2300, native languages, French

4955 Colombia, Radio Nacional; fine classical music, evenings, morning

4970 Venezuela, Radio Rumbos; leading commercial station, a few English ID's; all night

5000 U.S.A., WWV, Fort Collins, throughout hours of darkness

5010 Dominican Republic, Radio Cristal, Santo Domingo; all night

49 meters—International Band—5950-6200 kHz

5955 Guatemala, TGNA, missionary station, sermons often in English evenings

5995 Vatican City, Vatican Radio, English to N. America daily 0100-0115

6025 Portugal, Radio Portugal, English 0200-0245, 0345-0430 daily

6040 United Arab Emirates, Saut-as-Sahil, Dubai, rarely 1300-1400

6065 Spain, RNE Madrid, English to N. A. 0100-0145, 0200-0245, 0300-0345

6070 Canada, CFRX, Toronto, 1 kW, daytime to Northeast, night everywhere

6085 Canada, CBC relay of Deutsche Welle, German 0155-0430, English 0435-0550

6080 Luxembourg, Radio Luxembourg, English pop service to 0200 sign-off

6100 West Germany, Deutsche Welle, German to N. A. 0000-0615

6110 Great Britain, BBC, English to N. A. 2115-0415

6115 Congo, LVRC, Brazzaville, partly in French 0400-0600. African music

6140 Burundi, Bujumbura, French and Swahili, 0400 under good conditions

6195 South Africa, Springbok Radio, English/Afrikaans commercials all night

—AND WHAT TO FIND ON THEM

BY RICHARD E. WOOD

41 meters—International Band (not assigned in Americas)—7100-7300 kHz

7130 Great Britain, BBC to Atlantic Islands 2115-0330
7150 U.S.S.R., Radio Moscow North American Service, 2300-0500
7265 West Germany, Sudwestfunk, Baden-Baden, nighttime under good conditions
7300 Albania, Radio Tirana, English to N.A., 0130-0200, 0230-0300, 0330-0400, 0430-0500
7335 Canada, CHU, Ottawa, time signals all day / / 3330 kHz

31 meters—International Band—9500-9775 kHz

9505 Japan, Radio Japan, English news on hour 0600-1400
9510 Ascension Island, BBC relay, English to N. A. 0200-0330
9515 Turkey, Radio Ankara, Turkish sign-on 0330
9535 Switzerland, SBC, English to N. A. 0145-0215, 0430-0500
9560 Ecuador, HCJB, Quito, missionary station, English to N. A. 0100-0600
9570 Nigeria, Radio Kaduna, Koran chants, English, Hausa, sign-on 0430
9570 Qatar, Radio Qatar, Doha, sign-on 0230, Arabic, rare catch
9605 Vatican City, Vatican to N. A. / / 5995 above, English 0100-0115
9615 Morocco, RTM Rabat, Arabic chants all night; 24-hour operation
9645 Costa Rica, TIFC, Faro del Caribe, missionary, English sermons 0300
9670 Portugal, Voice of Hope, Adventist World Radio, English Sunday 0830-0900
9700 Bulgaria, Radio Sofia, nice Balkan music, English to N. A. 0400-0430
9780 Albania, Radio Peking relay, Tirana ana, English 0100-0155, 0300-0355 (not from China!)

25 meters—International Band—11700-11975 kHz

11705 Israel, IBA, English news 0500-0515 / / 9009, 11960 kHz
11710 New Caledonia, ORTF, French 0600-1200
11775 Spain, RNE Madrid, Spanish to Latin America 2200-0400
11800 Canary Islands, RNE Tenerife, often parallel above, same time
11920 Ivory Coast, Abidjan, French, to sign-off 2400 and at sign-on 0600

19 meters—International Band—15100-15450 kHz

15105 Japan, Radio Japan, English news on hour daytimes and early evening
15110 New Zealand, NZBC, mostly home service, evenings.
15170 Tahiti, ORTF, Papeete, English lesson 0230, Tahitian 0300-0500, French to 0800
15245 Zaire, Kinshasa, 24-hour operation, French, African languages
15310 Guinea, Rep., Conakry, French, revolutionary music, sign-on 0600, to 1400
15445 Japan, Radio Japan, English to N. A. 2345-0445
15446 Brazil, Radio Nacional de Brasilia, international service, evenings

16 meters—International Band—17700-17900 kHz

17720 Taiwan, Voice of Free China, English to N. A. 0200-0350, also 17780, 17890 kHz
17770 New Zealand, NZBC, English, evenings / / 15110 kHz
17810 Malagasy Rep., Radio Nederland relay, 1400-1520 English
17815 Sweden, Radio Sweden morning service to N. A. 1400-1530, English 1400-1430
17895 Zambia, Radio Zambia, English 1700-2100, African music

13 meters—International Band—21450-21750 kHz

21525 South Africa, Radio RSA, African service in English, mornings
21605 Finland, FBC, 1 kW, 1400-1830 to Latin America, English 1400-1430, 1800-1830
21640 Japan, Radio Japan, North & Latin American service 0100-0300
21740 Australia, Radio Australia, N. A. service, English 0100-0300

11 meters—International Band—25600-26100 kHz

25730 Norway, Radio Norway, 1100-1230 1300-1430, 1500-1630, English Sundays
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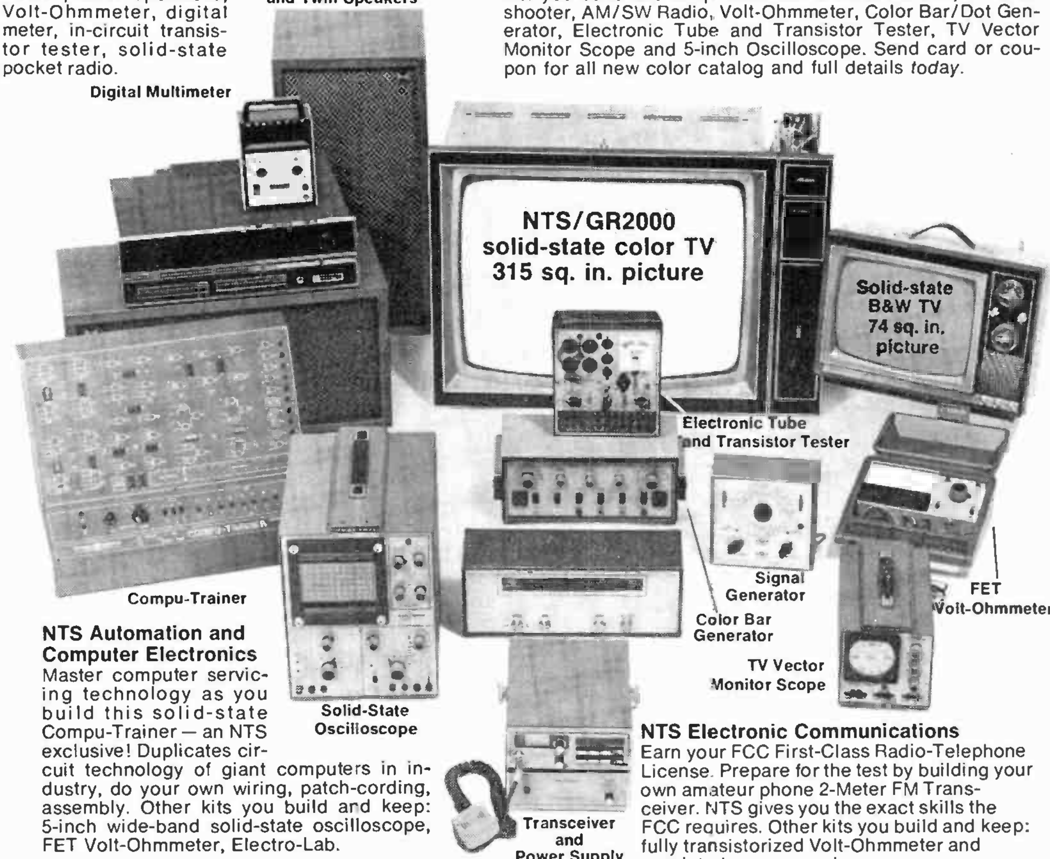

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PITCH GENERATORS for ELECTRONIC MUSIC

PART 1. SEPARATE VOICING AND VCO WITH SAMPLE-HOLD GENERATE NOTES ELECTRONICALLY

BY DON LANCASTER

LAST MONTH ("Electronic Music Pitch Standards") we discussed the frequencies wanted and stability needed in designing a useful electronic music pitch generator. In most cases, the equally tempered scale would be used, usually based on twelve notes per octave with each successive note 1.0595 (the twelfth root of 2) times higher in frequency than its neighbor below. To accompany some conventional musical instruments, it would probably be necessary to set the absolute pitch of A4 to 440.0 hertz. The overall stability should be within three cents of the desired pitch—one cent or better, if possible. (One-cent frequency stability is about 0.06% or 600 parts per million.)

The problem now is to determine what hardware should be used to generate all these notes; and the first thing to decide is whether or not more than one note at a time is needed. When working in a studio, with an elaborate tape recording setup, or when teaching or learning musical theory, the flexibility of the monophonic or single-note systems can be a tremendous advantage. This is particularly true when it comes to envelope generation and special effects involving the interaction with time of pitch, timbre, and envelope. When playing along with other instruments, single notes might not be too bad—particularly if the voicing is unique or is a stunning imitation of some classical instrument.

About half of the single instruments generate only one tone at a time (trumpets, clarinets, trombones, etc), while the remainder (organs, pianos, guitars, violins, etc.) can and do generate more than one (or overlapping) notes at a time. The kicker here is that we rarely listen to just one single-voiced instrument. For instance, have you heard any good bassoon solos lately?

At this stage of the music game, the single-voiced monophonic circuits offer flexibility and low cost but are pretty much limited to the tape studio or to use with

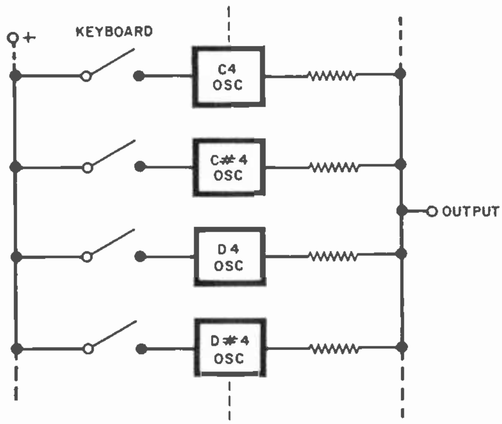


Fig. 1. Keying each oscillator individually is simple and eliminates crosstalk problems, but limits envelope characteristics.

other instrument ensembles. If the electronic music synthesizer is to stand by itself or be used in live concerts, then polyphonic, or multiple voicing is very desirable—almost essential. (An instrument with both polyphonic and monophonic capabilities is an interesting possiblity, but more on that later.)

Another decision to be made is whether or not rock-stable notes are always needed. For many voices of medium pitch, the addition of vibrato or frequency modulation adds an interesting and potentially realistic quality to the tone. On the other hand, vibrato sounds very phony on notes of lower pitch, particularly in imitating organ pipes. (Vibrato can be introduced after the pitch is generated by phase-modulation or analog-delay effects.)

By rocking the pitch around a little, we can tune to match other instruments and achieve special effects such as the waa-waa of a Hawaiian guitar. To really move the notes around (as on a slide trombone), a portamento or glide capability is necessary.

Probably the best compromise is a stable reference system that can easily be adjusted in frequency, but which will readily return to absolute pitch on command. From a usage standpoint, either no pitch adjustments, one main adjustment, or a circuit that is exceptionally stable is wanted. One other reason for changing pitch is for transposition—playing in a different key.

With these basic needs in mind, we will consider four popular ways of generating pitch electronically: separate voicing; vco (voltage-controlled oscillator) and sample hold; digital divider; and phase locked loop tracker. The first two are covered in this article; the last two next month.

Separate Voicing. In this type of pitch generation, an individual oscillator is used for each and every note and power is applied to only one oscillator at a time (Fig. 1); or a separate keyer is used for each note (Fig. 2). The first method has the advantages of using only dc voltage through the keyboard and the elimination of crosstalk since all the unused notes are off. Its disadvantages are that it is limited to very simple attack-sustain-decay shaping and it requires exceptionally good frequency-vs-supply-voltage performance during the rise and fall times.

Tuning is obviously difficult since one adjustment is needed for each oscillator. Free-running astable relaxation oscillators have traditionally been far too unstable for this sort of thing. So large inductors and Mylar capacitors were normally used in Hartley or Colpitts oscillators, with amplitudes held low enough that the active devices didn't cause serious problems. Typically, capacitor bridging was used for coarse tuning with a potentiometer for final adjustment.

With today's latest IC's, such as the Intersil 8038, it is possible to design a relaxation oscillator with a stability of 50 parts per million—eleven times better than needed—and it produces vibrato easily. This eliminates the need for the inductor and

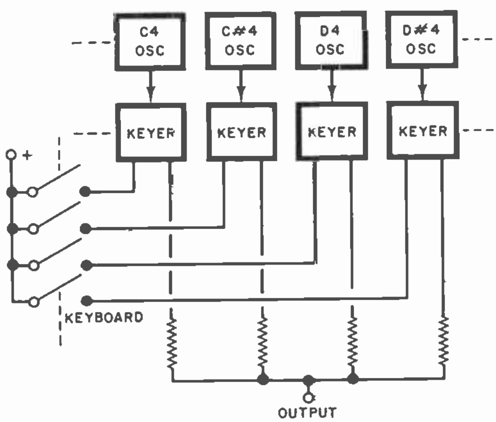


Fig. 2. Separate keying offers more flexible envelope control but adds complexity.

greatly eases tuning, but it still leaves a complex and expensive tone generation method.

The one place where separate voicing really shines is in faithful duplication of organ pipe ranks, particularly tibias, where a nearly perfect analog of the traditional pipe organ can be obtained with enough care. For any other system, the large number of parts and difficulty of tuning make the newer methods more attractive. Also, this approach is obviously polyphonic, and portamento is not easily introduced.

The VCO and Sample-Hold. The voltage-controlled oscillator (vco) pitch-generation technique is the one most often used today in "Moog-style" synthesizers. It is monophonic by itself, but there are tricks that can be played with the keyboard to get a two-note capability with a second vco and moderate additional complexity.

Figure 3 shows the vco technique. A vco produces a specified pitch in exchange for a fixed input voltage.

If a *linear* vco is used, the frequency output is linearly related to the input voltage, and the control or input voltage gets rather cramped at the low end where all the low notes have to be close together. This takes odd-ball precision or paralleled resistors of different values. It also severely restricts the stability and linearity of the vco.

A much better, but slightly more complicated, method is shown in Fig. 4. Here a logarithmic converter is used in front of the vco. A log converter exactly matches the ear's response capability, so a linear input can be used to generate the notes properly spread apart. For instance, a one-volt-per-octave system can be used, so that note C3 might require 3 volts, C4 would need 4 volts, and so on. This means a linear increase of $1/12$ volt for each successive note on the scale.

The log converter then automatically spaces out the notes to get the right frequency separation. One popular type of log converter places a pn junction in the feedback loop of an op amp. The junction has the required logarithmic characteristic. Usually, a pair of matched transistors is used, with the second transistor handling offset and temperature problems.

With the log converter, it is still necessary to have precision resistors on the keyboard, but they are all identical. Usually, the keyboard is driven by a constant-current source, and a selected number of series-connected resistors is shorted. The remaining voltage drop then equals the voltage needed for the note. This voltage is properly changed to a new voltage by the log converter; and the new voltage is converted to a frequency by the vco.

The basic vco method is low in cost, but it is single-voiced and extreme stability is needed for the keyboard controller, the log converter, and the vco. Pitch is easily changed by changing the current through the keyboard or the scale factor of the vco; and any number of notes per octave can be readily handled on a one-at-a-time basis.

One problem common to the vco and a number of the other single-voiced methods is the need for a memory of some sort. Whenever we release the key, we often would like the note to continue on and die out gradually. With the vco and log converter, releasing the key takes away the information (the input voltage) of what note is to be played. To overcome this, a sample-hold or analog storage system is added as shown in Fig. 4.

Pressing any key immediatly changes the sample-hold to a new note. After the key is released, the sample-hold remembers what the note was until the decay cycle is complete and a new note is generated. In this way, the decay cycle of the envelope shaping can continue beyond key release.

One simple sample-hold circuit is a reed relay and a capacitor looking into a voltage follower. The relay is closed for sampling and the capacitor then holds this value.

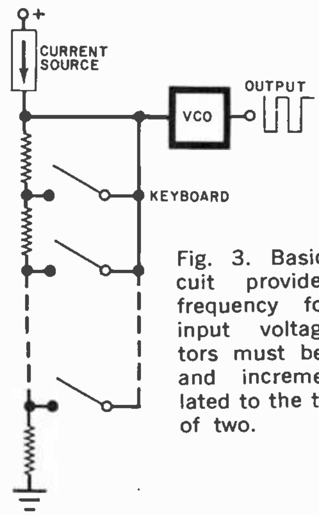


Fig. 3. Basic vco circuit provides output frequency for precise input voltage. Resistors must be precision and incrementally related to the twelfth root of two.

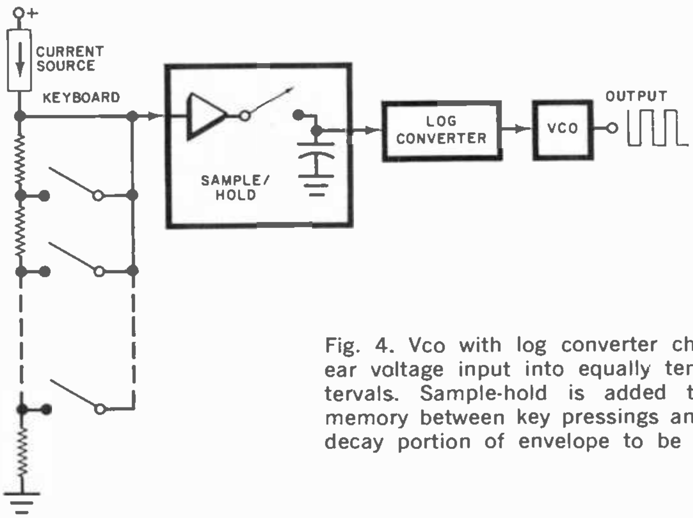


Fig. 4. Vco with log converter changes linear voltage input into equally tempered intervals. Sample-hold is added to provide memory between key pressings and to allow decay portion of envelope to be continued.

Other methods use an operational amplifier with a FET switch; or a CMOS analog multiplexer (such as the RCA CD4016) can be used directly.

The basic principle of most of the analog sample-hold circuits is to charge a capacitor rapidly when the key is pressed and then use the capacitor to hold the voltage as an analog memory after release. For the charge to be held without significant droop, a very high-quality capacitor and an absolute minimum of circuit loading are needed.

Glides and portamento effects are simply done by charging the capacitor somewhat more slowly. In this way, the notes glide from one to another in a trombone style rather than changing suddenly.

The major advantages of the vco system are the ease with which one can make glides, change pitch, introduce vibrato and waa-waa, or change the number of notes per octave. This approach can be used very inexpensively with the latest available components, but very careful attention to stability and accuracy is needed.

For instance, with a one-volt-per-octave control voltage, a voltage error, droop, offset, or crosstalk of only 2.5 millivolts will cause an objectionable pitch error. Extremely careful design is needed to get a good vco/log converter/sample-hold system going. On the other hand, this is certainly the simplest way to put together a low-cost system on an experimental basis. The results will be disappointing to a serious musician, however, if careful control and good design are not used.

Note-to-note tuning is inherent in the selection of the precision resistors on the keyboard, while overall instrument tuning is controlled by a single reference voltage or current and the stability of the rest of the circuits.

Using two vco's will provide two-note capability and more vco's can be added as needed. The problem that immediately comes up is, "Which vco goes with which note?" The answer is to use very brief sample-hold intervals and properly assign each key being pressed to the right vco. One possible way of doing this is with a *scanning* keyboard where each key being pressed is sampled in either digital or analog form; and priority logic then assigns the right vco to a selected key. This adds considerably to the cost and complexity of the system.

At present, the vco/log converter/sample-hold pitch generation approach is the most popular in commercial synthesizer products. This is, however, probably only a temporary stopping place along the way to total digital pitch generation systems. Voltage-controlled pitch generation systems will probably go the way of most other analog systems, but right now vco methods are attractive and offer a lot in the way of simplicity and low-cost performance.

Next month, we will discuss digital dividers and phase locked loop methods of tone generation ◈

Solid-State

By Lou Garner

Consumer Products Engineering

IF YOU'RE serious about electronics, whether as a ham, hi-fi enthusiast, R/C specialist, gadgeteer, experimenter, or student, you can look to the future with optimism and excitement. Comparatively recent changes in electronics manufacturing and marketing should, one day, permit the average hobbyist to tackle projects which, in the past, would have required a workbench full of components and a healthy wallet.

The situation is interesting not only for its potential effect on the hobbyist, but because it has resulted from an amazing change in the attitudes of a number of major manufacturers.

For years, consumer electronic product designers were considered as more or less the "black sheep" of the electronics engineering fraternity. Engineers working in such exotic fields as military electronics, aerospace, computers, industrial controls, medical electronics, instrument design, and communications felt that the consumer products field was less challenging and, therefore, tended to look down their sophisticated noses at their fellow engineers stuck with the (to them) unrewarding job of designing mass-produced products for the general public. Consumer product designers often were conspicuous by their absence at technical meetings and conventions, and exhibitors at technical shows paid them little attention.

There was, perhaps, a modicum of justification for the prevailing attitude. Faced with short lead times, consumer product designers could not afford the luxury of detailed and exhaustive mathematical analysis of their designs, nor of extensive precision tests of their prototypes. They couldn't afford to use expensive state-of-the-art devices in their circuits. Low production cost, consistent with acceptable performance, was the design criterion. Many circuit designs became standardized, with relatively few changes, except in detail, from year to year.

Consumer product design engineers frequently were paid lower salaries than their counterparts in more exotic fields and there were fewer positions available. A medium-size factory producing several different products by the tens of thousands and employing hundreds of assembly workers might require only two or three design engineers. A firm manufacturing high-price military or communications electronic equipment, on the other hand, might have an engineer for every two or three production workers.

The advent of solid-state technology, the introduction of MSI and LSI devices suitable for consumer applications, and the public acceptance of high technology products, such as pocket calculators, digital electronic watches, and sophisticated TV and radio receivers have all combined to change the traditional attitude towards the consumer product design engineer. In fact, today such specialists are well on their way to becoming the "darlings" of industry.

Manufacturers who once looked upon the consumer field with disdain are now undergoing an agonizing reappraisal of their policies. Semiconductor manufacturers who once scorned the idea of assembling complete equipment are now entering the battle for the consumer market.

Fairchild's Semiconductor Components group (464 Ellis Street, MS 19-115, Mountain View, CA 94042), for example, in a continuing bid for the automotive market, has recently announced a special pressure transducer designed specifically for automotive applications. This new thick-film, solid-state device for cars contains a single crystal diffused silicon strain gauge with a zero-pressure reference chamber, two linear operational amplifiers for temperature compensation, offset adjustment and scale factor control, and a single-chip voltage regulator. When connected to a pressure source, such as the intake manifold of an automobile engine, the module provides an accurate analog voltage output that is linearly proportional to the input. This signal voltage can serve as a control for electronic fuel injection, ignition advance and similar systems.

Looking ahead, we foresee a continued expansion of the high-technology consumer products market. As lucrative military and government contracts dwindle, as the advanced computer market becomes saturated, and as industry becomes fully automated, the really big electronics market will be the consumer.

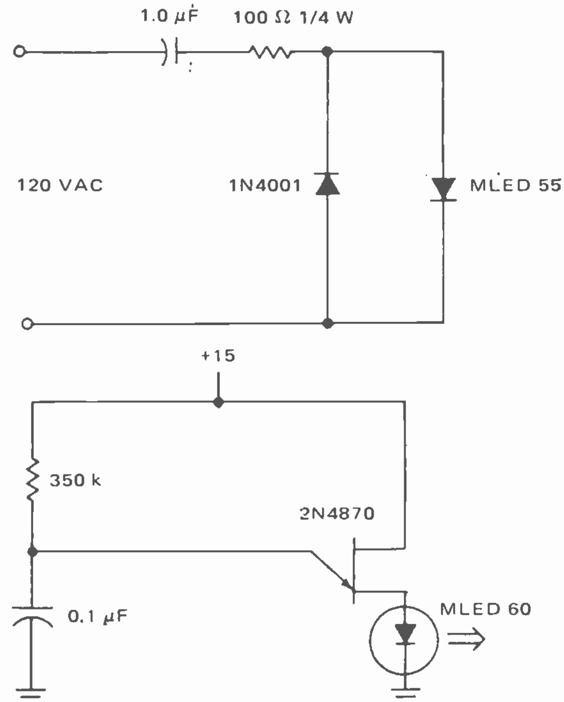


Fig. 1. Circuit (A), top, is LED line-voltage indicator; (B), bottom, is a pulser.

All of this bodes well for the experimenter, for as sophisticated MSI and LSI devices are developed for the mass consumer market, they will filter gradually into the hands of local distributors, becoming available at reasonable prices to the average hobbyist.

Circuit Potpourri. Although relatively simple, the LED circuits illustrated in Fig.

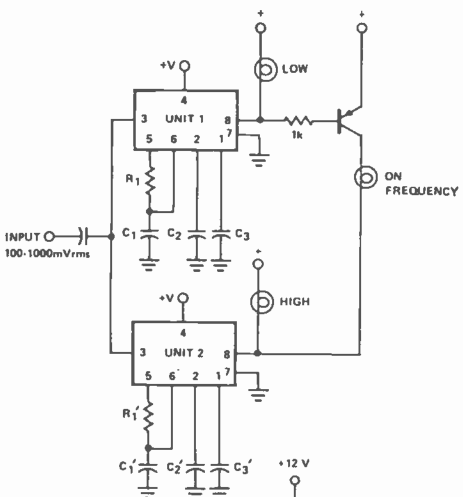
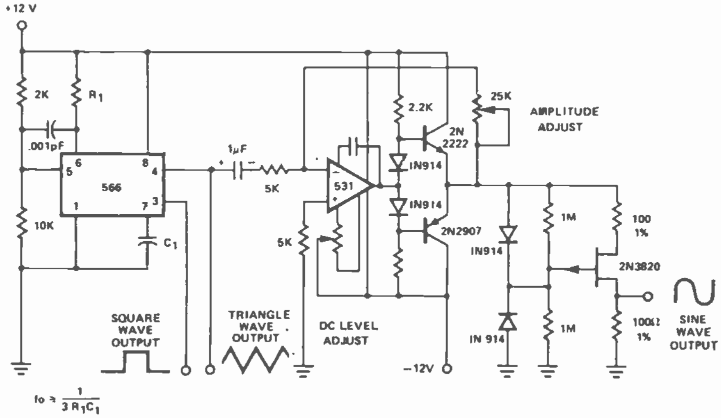


Fig. 2. Circuit (A), above, is a frequency indicator; (B), right, is function generator.



1 can be used in a variety of experimenter and hobbyist projects. Both were abstracted from Motorola's Application Note AN-570, an 8-page brochure entitled "Introduction to Light Emitting Diodes."

The line-voltage indicator circuit shown in Fig. 1A can be used wherever a long-life, low-power ac pilot lamp is needed, as in amplifiers, transmitters, appliances, receivers, recorders, or power supplies. In operation, the capacitor's reactance serves to limit the LED current, with the result that real power consumption is virtually nil.

Featuring a unijunction transistor as a relaxation oscillator, the pulser circuit given in Fig. 1B operates at a repetition rate of approximately 30 Hz with a pulse width of 1.5 μs. An infrared LED is specified, but other types may be substituted for the MLED 60. The circuit's output can be used as a light source for pulsed-beam burglar alarm systems and in similar applications.

Suitable for use in a number of instrument designs, the circuits shown in Fig. 2 are representative of the dozens of schematics described in an integrated circuit applications manual published by the Signetics Corporation (811 East Arques Ave., Sunnyvale, CA 94086).

Designed to monitor a single frequency tone, such as a control or test signal, the simple frequency indicator circuit illustrated in Fig. 2A utilizes a pair of type 567 tone decoder IC's in conjunction with a general-purpose pnp transistor and three low-power incandescent lamps (or LED's). In operation, the tone decoders' RC values (*R1C1* and *R1'C1'* are selected to set one unit 6% above the desired sensing frequency and the other 6% below the desired frequency. If the applied signal is within 13% of the desired frequency, either unit 1 or unit 2 will deliver an output, activating its lamp. If both units are on, the incoming signal is within 1% of the desired frequency.

The basic function generator, Fig. 2B, employs a type SE/NE 566 voltage-controlled oscillator IC to supply square and triangular signals. The triangle signal, in turn, is shaped into a sinusoidal waveform with less than 2% distortion by using the nonlinear transfer characteristics of a 2N3820 p-channel JFET. The JFET's input is provided by a 531 operational amplifier, serving as a buffer, and a complementary driver.

Device/Product News. Five new optical couplers/isolators with Darlington output transistors have been introduced by Motorola Semiconductor Products, Inc. (P.O. Box 20924, Phoenix, AZ 85036). Intended for applications where relatively high speeds (to 30 kHz) and high collector currents are required, the new series, types 4N29 through 4N33, has isolation voltages as high as 2500 volts and collector currents of up to 50 mA (for 10 mA input). The new devices are suitable for use in a variety of experimenter projects, including solid-state relays, alarm systems, remote controls, and equipment interfacing.

Several new devices which should be of particular interest to the serious hobbyist

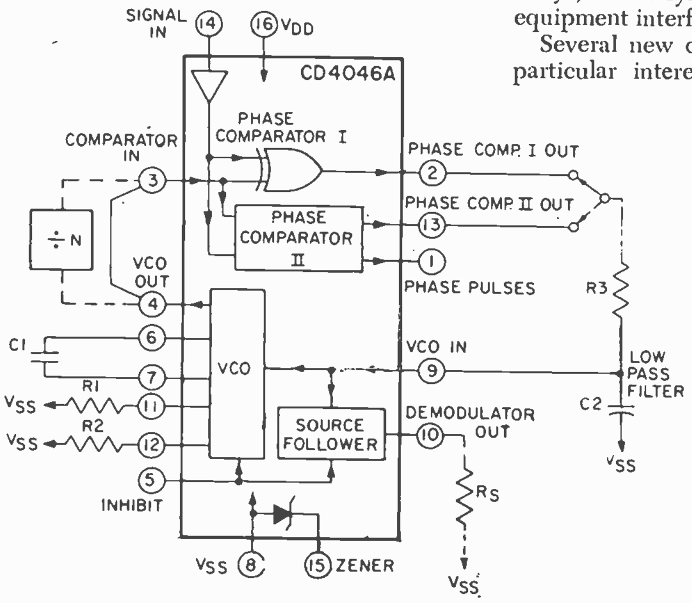


Fig. 3. Block diagram of RCA's new CD4046A COS/MOS micropower phase-locked loop IC device.

have been announced by RCA's Solid State Division (Route 202, Somerville, NJ 08876), including a COS/MOS micropower phase locked loop (PLL) IC, an inexpensive uhf oscillator transistor, a pair of medium-power transistors, and a COS/MOS dual complementary pair plus inverter IC.

Designated type CD4046A, RCA's new PLL consists of a low-power, linear voltage-controlled oscillator (vco) and two different phase comparators having a common signal-input amplifier and a common comparator input, as illustrated in Fig. 3. A 5.2-volt zener diode also is provided for supply regulation if necessary. Featuring very low power consumption (70 μW), an operating frequency range up to 1.2 MHz, a wide supply voltage range (5 to 15 volts), and low frequency drift together with high vco linearity, the new device can be used for such applications as FM modulation and demodulation, frequency synthesis and multiplication, frequency discrimination, tone decoding, data synchronization and voltage-to-frequency conversion. It is offered in a 16-lead DIP.

RCA is soon coming out with a COS/MOS dual complementary pair plus inverter IC, which is functionally similar to the CD4007A, but operates on lower voltages (down to 1.1V). Available in a 14-lead DIP, it is recommended for breadboard designs of battery-powered watches, clocks, fuse timers, timing circuits, and oscillators with supplies of from 1.1 to 6 volts. The device is ideal for projects operated on a single-cell battery.

A new monolithic counter/timer capable of generating precise ultra-long time delays with an external RC setting has been introduced by Exar Integrated Systems, Inc. (750 Palomar, Sunnyvale, CA 94086). Identified as the XR-2240, the device comprises an analog time base oscillator with a programmable 8-bit counter on the same chip. It can be used to generate programmable time delays from microseconds up to 5 days with an accuracy of 0.5% and a temperature stability of 40 ppm/°C. Two XR-2240 timers can be cascaded to generate programmable time delays of up to 3 years.

Litronix, Inc. (19000 Homestead Road, Cupertino, CA 95014) is now offering a new, inexpensive 0.6" high LED digit display, the Data-Lit 747. According to Litronix, the new device can be read clearly at distances of up to 20 feet. ◈

Test Equipment Scene

By Leslie Solomon, Technical Editor

Oscilloscope Vertical Amplifiers

SEVERAL readers have asked what features they should look for in buying a particular piece of test equipment. Of course, I can't recommend specific products; but I would suggest that readers watch the Product Test Reports that appear every month in this magazine. They contain lots of information about the newest gear that we have seen and tested.

To get down to specifics on one item, let's consider a few things you should be aware of in choosing an oscilloscope—whether it is your first one or a replacement for an older model.

Low-Cost and Expensive Models. Prices of scopes vary over a wide range. Sometimes there is as much as $100 difference between a low-cost model and an expensive one. However, keep in mind that, in many cases, the more expensive scope can prove to be cheaper in the long run since it may serve you longer, give you more accurate and repeatable results, and be much more versatile than the low-cost instrument. If you spread the price difference out over the years that you own the scope and consider the decent results you will be getting all that time, the difference may turn out to be only a few dollars per year. There are as many people who use the same good scope for 10 years or so as there are those who go through two or three low-cost units in the same period—without having the benefit of good results over the years.

Remember that, like a good speaker (that doesn't add its own "color" to the reproduced audio), a scope must be as "transparent" as possible, not adding its own distortions to the displayed waveform. Since scope "honesty" seems to be a function of its price, get the best you can afford.

I do not mean to denigrate low-cost, ac-coupled audio scopes. With their limited bandwidth, poor rise times, and touchy free-running and hard-to sync traces, they make excellent "first" scopes, and can be useful in non-critical applications. However, they leave a lot to be desired, especially when dealing with modern, high-speed circuits. If you are a beginner, remember that it will not be long before you advance to this type of circuit. If you are a long-time scope user, you will understand the problems involved with limited-band-width, free-running scopes.

AC and DC Coupling. The specifications for the vertical amplifier are of prime importance in determining what will be displayed. There are two major types: ac and dc coupled. (Usually the dc versions have ac-coupling provisions for the occasions when it might be needed.)

An ac-coupled scope responds only to an ac signal and the trace will do strange things when dc is applied (due to coupling capacitor charging). This ac response effectively removes all the dc component and one result is a "tilt" that distorts any waveform having flat tops or bottoms. Obviously, if you do any digital logic work, or square-wave testing, the ac-coupled scope is out.

Incidentally, the amount of tilt depends on the value of the coupling capacitor. Although some scopes use very large values to bring their ac response down to 2 to 5

Hz, they are still ac coupled. Also, don't get the idea that all you have to do is remove the input capacitor to get a dc scope. It won't work because there are also coupling capacitors within the amplifier and removing them can change all biases drastically enough to prevent scope operation. A dc amplifier is designed as a dc amplifier, not as an ac amplifier without coupling capacitors.

On the other hand, a dc-coupled scope will respond from zero (dc) up, so that it produces square waves properly. Besides this, such a scope will also display an ac waveform superimposed on a dc component and the scope displays the actual signal present. This is nice to know when you are working on dc systems, as you are simultaneously looking at both the ac signal and the dc component, which may be the bias for the following stage. This also means that a dc scope (properly calibrated vertically) can act as a pretty good dc voltmeter with high input impedance. So you get this important function free.

Dc coupling, unfortunately, costs money because more transistors and associated components are used to create the balanced circuits needed to reduce drift (slow movement of the display across the CRT screen).

Of course, dc coupling in both horizontal and vertical amplifiers allows accurate phase-shift measurements. In most cases, the horizontal amplifier does not have the wide bandwidth of the vertical section because it is so seldom used for very high frequencies.

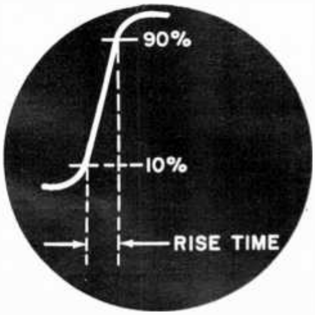
Bandwidth and Transient Response. The wider the vertical amplifier bandwidth, the better. So-called "narrow-band" scopes usually just span the audio range, while "broadband" units go out to several MHz.

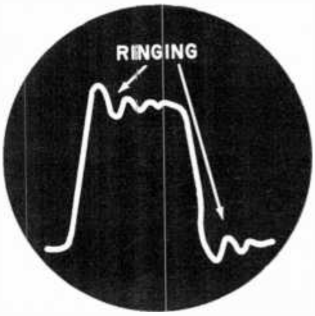
The need to measure steep wave fronts determines just what bandwidth is required. For example, the upper frequency limit should be at least 10 times higher than the fundamental frequency of the basic square-topped waveform if you want true reproduction. (Remember those high-frequency harmonics.) Keep in mind that this applies not only to square waves, but also to such things as sync pulses in TV equipment and tone bursts in audio systems. These signals have high repetition rates and steep leading and trailing edges, and you must be able to see these features as they actually exist before you can do any serious troubleshooting. You must also be sure that any distortion you see does not originate in your test equipment or you can waste many hours of searching for a non-existent fault. A scope that goes from dc out to a few MHz will suffice for most work.

As you start working on more advanced projects or more sophisticated commercial equipment (especially digital circuits), transient response is more and more important. Transient response determines just how fast the CRT beam (hence vertical amplifier) will deflect when following a steep wavefront. Most better scopes include rise time in their specifications.

If you are thinking of adding a front-end signal booster to your scope, remember that the transient response of a number of series-connected circuits is the square root of the sum of the squares of the individual responses. For example, an amplifier having a rise time of 3 μs feeding a scope with a rise time of 4 μs has an overall rise time of 5 μs. So rise time is sacrificed (slowed down) in exchange for gain.

Rise time and bandwidth are closely related. The product of the two should produce a value of between 0.33 and 0.35 for best displayed results. Values greater than 0.35 will produce a "ringing" on steep transients, thus distorting the reproduced waveform. Ideally, the rise time should be





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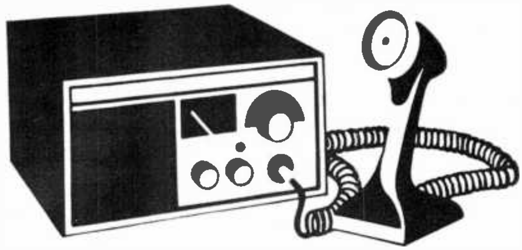
about ⅕ of the rise time expected from the signal to display the waveform with an error of less than 2%.

If you want to determine the bandwidth of your present scope, use the formula $RT = K/B$, where K is 0.35 and B is the upper −3-dB frequency limit in MHz and RT is the rise time in microseconds. For example, assume you have a 5-MHz scope. The value of RT is then 0.35/5 or 0.07 μs. Multiply this by 5 to get 350 ns, which is the fastest rise time the scope can reproduce with an accuracy of 2%. If 5% is all that is required, then multiply by 3 to get a rise time of 210 ns.

Dual-Channel Scopes. Going toward more advanced projects or servicing, you may find that a single trace is not enough. Then you should consider a dual-channel or dual-trace scope. It may be a luxury, but it can also be worthwhile. Two independent traces, each with its own attenuator, amplifier, and positioning control on a single horizontal sweep can make a big difference between seeing all that is going on between two related signals and just guessing at it.

Most dual-channel scopes also have provisions for "chopped" or "alternate" modes. In the chopped mode, a built-in electronic switch (at about 100 kHz) alternates the single trace between the two independent inputs. This is fine for low-frequency work until you hit the higher sweep speeds, where the switching-frequency square waves become apparent and cause viewing interference. At this point, you can switch to the alternate mode. Here, one of the two inputs is displayed for one complete horizontal sweep; and during the CRT beam retrace time, the other channel is switched in to occupy one full sweep. Because of the high switching speeds (faster horizontal rate) and the persistence of the CRT phosphor, the two signals appear to be displayed simultaneously.

There is one other function usually attached to dual-channel scopes. This is the X-Y position of the dual-channel selector switch. The signal from channel A is displayed on the scope vertical axis, while input B forms the horizontal axis. This is useful for generating Lissajous figures, phase measurements, or any function where one input must be measured with respect to another (instead of against time as represented by the conventional horizontal sweep). ◈



CB Scene

By Len Buckwalter, KQA5012

THE NEXT time you tune channel 10, you may hear talk of long-haul rigs, semi's and where to get the best chiliburger in the West. The reason: CB is enjoying a sudden surge in the trucking industry. Not only are the independents snapping up CB, fleet owners aren't far behind. Sales of equipment at truck stops are so good that CB manufacturers are starting to produce special models for the burgeoning market. One item by Antenna Specialists should delight the most grizzled trucker—a whip with its loading coil encased in a beer can.

How do the haulers use CB? They can talk to each other while highballing down the road and ease the boredom of a cross-country trip. (One manufacturer says CB may yet replace the tape deck on the dash.) Also, in an understandable spirit of comradery, truckers warn each other of highway hazards, especially the 4-wheel kind with flashing lights. To win good roadway communications the trend is to install dual antennas, one atop each side-view mirror. The whips are joined by a phasing unit to bulge the signal fore and aft, where other vehicles are most likely to be. Range is about 5 to 10 miles.

Stories about CB's boon to safety are starting to trickle in. Last winter one trucker rising over the crest of a long, icy hill in Pennsylvania had a remarkable experience. He was unaware that a jacknifed tractor rig blocked the road at the bottom. But he was monitoring channel 10. Warned by a voice on the speaker, he pulled the power, pumped the brakes—and slid to a halt within inches of disaster. He's convinced it would have ended differently without CB.

Rising to New Heights. After years of grumbling about limited range because of low power and antenna height, CB'ers may soon enjoy official relief. The FCC is seriously considering raising the maximum antenna height to 60 feet. (See last month's "News Highlights.") Today's rule holds the top of an antenna 20 feet above any existing structure. In the new proposal, the antenna may rise to 60 feet above ground level. One important limit, though, is that you'll probably be prevented from using a "gain" type antenna—one that multiplies power, like a beam.

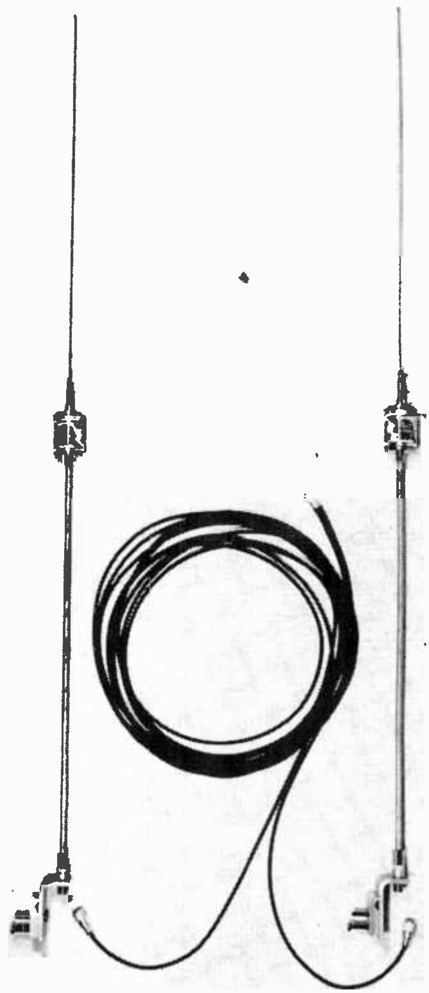
"What kind of improvement can we expect if the new rule becomes law?", I asked one antenna authority. He juggled his slide rule and came up with an enlightening figure. Increase height from 20 feet to 60 feet and you about double operating range. That may not sound dramatic, but remember that a widening circle puts your signal into hundreds more square miles. Most of the increase comes from peering over the earth's curve. CB mainly follows a straight-line path to the horizon and the loftier position enables the signal to "see" farther.

Greater height may also allow the antenna to clear more neighboring obstacles. Our antenna expert cautions that nearby obstructions are not usually critical if the antenna is an omnidirectional model. It's the beam antennas that are touchy because they're liable to be detuned by adjacent surfaces. The rule-of-thumb: if you're using

Antennas & Towers

a multi-element antenna, try to keep it one CB wavelength away from anything else—a distance of about 36 feet.

Tower Power. Let's say the 60-foot antenna rule is granted. Since the range benefits are attractive, there'd probably be a rush on masts, guy wires and longer transmission lines. What's more, the now-forbidden tower should become perfectly legal. And a tower may be the only practical way a low-lying or ranch home may thrust up an antenna all the way. A mast and guy-wire approach may take you 20 feet above the roof, but it's too unwieldly to go much higher. It takes a 40-foot tower planted on



Dual whips that were designed for mounting on the side rear-view mirrors of a truck.

the ground to bring a 20-foot antenna to the maximum.

Raising a 40-footer isn't a major engineering feat. Much of the job is in the preparation if you choose the self-supporting type, with no guy wires splaying across the property to snag kid's feet. It doesn't need anchor points in the neighbor's lot, either. A typical 40-foot aluminum tower needs a hole in the ground 3 feet square and 4 feet deep. After the hole is filled with 1½ cubic yards of concrete, you level a metal base on its surface. To the base you bolt ten-foot tower sections lying horizontally along the ground. A friend or two can help you "walk" it up, antenna and all.

The cost of this elaborate skyhook is about $200 including the 130-odd pounds of components and several hours of labor. But you could create a mighty CB signal that'll saturate the countryside and fill in those communication "holes".

The Plugged-up PL. CB equipment troubles are usually caused by sudden failures; a blown semiconductor, a ruptured mike lead, maybe a shorted capacitor. Silence is immediate. But in talking to one engineer in the field, I learned about a CB weakspot that usually goes unnoticed. It insidiously degrades the signal (on both receive and send) over a long period of time. The culprit is the PL-259; the coaxial connector found on the ends of most CB cables. It may work fine in the shelter of a car or home, but it often proves troublesome just under a base-station antenna. Not only is it difficult to inspect without ladderwork, it wasn't meant for outdoor service in the first place. An unprotected PL is an invitation to trouble because it's attacked by moisture, despite your efforts to tighten it.

There are several cures—preferably done when the antenna is on the ground, ready to be installed. Aerosol sprays, available from your local electronic distributor, give the plug a protective plastic coat. Spray *after* the plug is installed on the socket. A silicone rubber compound in a tube can also form a neat raincoat around a PL's vulnerable cracks. The final method uses material you might already have—black *plastic* electrical tape. Wrap overlapping layers around the whole connector, especially near any suspicious joints. These techniques prevent power loss that can creep into a system as little as six months after installation. ◈

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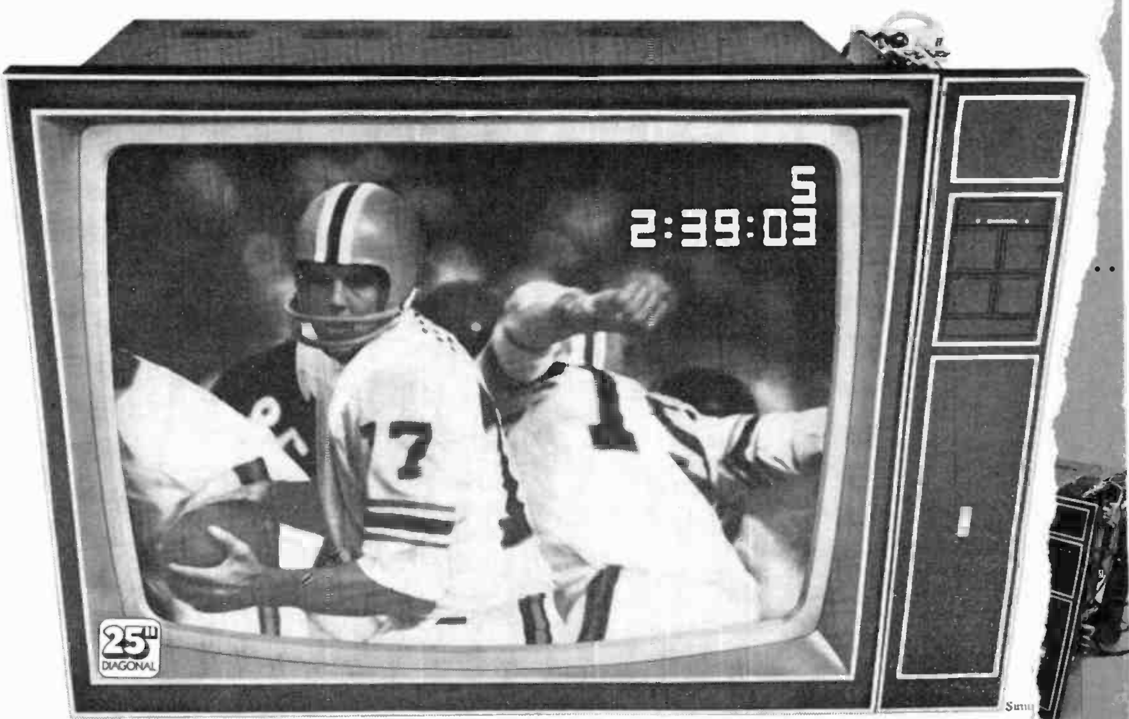
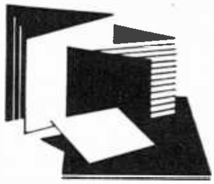




New Literature

GLADSTONE MAIL-ORDER CATALOG

The latest 64-page, cross-Canada, mail-order sales catalog is now available from Gladstone Electronics. With a special emphasis on high fidelity and kits, the catalog offers the Sinclair line of hi-fi amplifiers and tuner modules, as well as speaker kits by Philips Deforest, Marsland, Radio Speakers of Canada and Goodmans of England. Test equipment, hobbyist/experimenter parts and service components are also included. Address: Gladstone Electronics, 1736 Avenue Road, Toronto, Ontario, Canada, M5M 3Y7.

SIMPSON METER/TEST EQUIPMENT CATALOG

A new, 40-page Catalog 4200 describes the complete line of Simpson test and measurement devices available as standard stock items from electrical/electronic distributors. It lists over 1500 types, styles, sizes and ranges of panel meters, more than 100 meter relays, and a wide variety of general and special-purpose test equipment. New products include reed frequency meters, pyrometers, percent-load meters, load meter relays, digital VOM's, photo tachometers, illumination level meters, insulation testers and a new general-purpose oscilloscope. The catalog can be obtained free from any Simpson distributor or from: Simpson Electric Co., 853 Dundee Ave., Elgin, IL 60120.

AMPHENOL CONNECTOR CATALOG

An array of connector and socket devices designed for use in hobbyist equipment is described in a full-color pocket-sized catalog published recently by Amphenol. The new 16-page catalog provides details on the company's microphone, hexagonal and r-f connector families, and on its chassis, dual-in-line, and TO-can socket lines. The catalog also furnishes advice on selecting the proper soldering tool and offers helpful solder usage tips. A complete list of schematic symbols and resistor color codes is included. For a free copy of the "Quality Crafted Component Handbook and Buying Guide" visit an Amphenol general line distributor.

NORTRONICS RECORDER CARE MANUAL

The fifth edition of the company's popular Recorder Care Manual, which details proper maintenance of tape recording equipment, has been introduced. Designated Form #7310-E, the two-color 32-page illustrated manual includes information on the principles of magnetic recording, magnetic heads, recorder maintenance and a catalog section of the company's complete line of recorder care products. Also included is a bibliography for readers who want additional information, plus data on the company's replacement heads for more than 4400 foreign and domestic cassette, 8-track cartridge and reel-to-reel recorders and players. Copies can be obtained without charge from nationwide Nortronics dealers. A complete listing of dealers is available from: Nortronics Co., Inc., Recorder Care Division, 8101 Tenth Ave. North, Minneapolis, MN 55427.

TEN-TEC INSTRUMENT ENCLOSURE BROCHURE

Two new series of instrument enclosures have been added to Ten-Tec's present product line. Series D enclosures, available in widths between 8" and 14", are 4¼" high and 10¼" deep. Construction is 0.62" aluminum with molded plastic end panels. Series T, with two-piece aluminum construction, are small enclosures in four basic sizes ranging from 2" x 4" x 4" to 3" x 4" x 6". Both of the new series are available in two finishes: walnut grain vinyl with egg-shell white panel and black pebble vinyl with gray. A 4-page brochure on the enclosures is available from: Ten-Tec Inc., Highway 411 East, Sevierville, TN 37862.

RCA COS/MOS PRODUCT GUIDE

An up-to-date product guide on a broad line of COS/MOS IC's for low-voltage digital circuit design in industrial, commercial, and military applications is available from RCA. This 8-page designer's aid includes an easy-to-read wall-chart format permitting quick access to logic diagrams, functional diagrams, and applications for 58 COS/MOS types including: gates, flip-flops, latches, multivibrators, shift registers, counters, display counter/decoders/drivers, multiplexers, arithmetic circuits, memories and phase-locked loops. Copies of the guide may be obtained from: RCA Solid State Div., Box 3200, Somerville, NJ 08876.

SANSUI 4-CHANNEL BOOKLETS

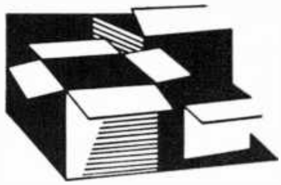
Five booklets on 4-channel sound are being made available by Sansui for five specific groups from the novice audiophile to the electronics engineer. For the consumer, "A Non-Technical Guide to QS 4-channel Sound", which will be available to all QS licensees and distributed by dealers, describes the various formats of 4-channel, their advantages, disadvantages and availability of material. Other booklets are slanted toward the audio equipment dealer, the recording engineer, the electronics engineer and the FM broadcaster. For further information contact: Sansui Electronics Corp., 55-11 Queens Blvd., Woodside, NY 11377.

STAR-TRONICS CATALOG FLYER

The latest Catalog from Star-Tronics contains a number of items of interest to the surplus electronics enthusiast. Included are such items as switches, reed switches, keyboards, photomultiplier tubes, coils, transformers, resistors and relays; also power supplies, semiconductor diodes, meters, knobs, hardware and capacitors. For a copy of the flyer write: Star-Tronics, P.O. Box 17127, Portland, OR 97217.

OLSON ELECTRONICS CATALOG FOR 1974

Hot off the presses is the 1974 catalog (No. 740) from Olson Electronics. Packed into its 244 pages are brand-name listings for hi-fi and communications gear, calculators, and digital wristwatches. Featured specialty items include alarms and security devices, automotive accessories, public address equipment, closed-circuit TV gear, telephones and accessories, etc. Separate listings are given for IC's, vacuum tubes, decimal readouts, resistors, capacitors, transformers, and other components. Tools and test equipment are also listed. Address: Olson Electronics, 260 S. Forge St., Akron, OH 44327.



New Products

Additional information on new products covered in this section is available from the manufacturers. Either circle the item's code number on the Reader Service Card inside the back cover or write to the manufacturer at the address given.

HARMAN/KARDON CASSETTE DECK

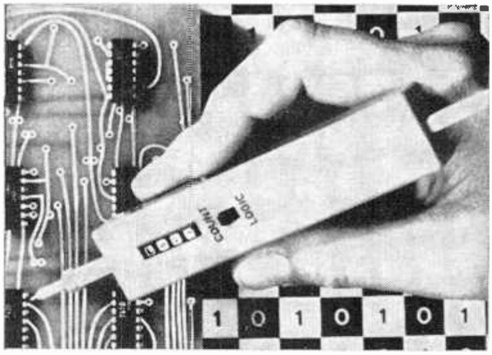
The HK1000 cassette deck has a S/N of –75 dB (weighted) with Dolby activated, a frequency response of 30 Hz to 16 kHz ±1.5 dB and a 0.15 (weighted) wow and flutter. Functions include a three-position bias switch for standard, low-noise and chromium-dioxide tapes. The deck has a "memory" control that permits the listener to key special selections

and play them back without searching for their starting location, a built-in microphone preamp with its own level set controls, and two professional-type VU meters that read peaks to prevent clipping of transients. It has a dc servo-controlled constant speed motor.

Circle No. 70 on Reader Service Card

AIKENWOOD LOGIC PROBE

A new DP-6000 logic probe has been designed to simplify testing of digital systems. The probe not only displays logic states but also functions as a fast-pulse counter. As a high/low discriminator, the probe indicates logic states and identifies faults in IC's. When switched to the counting mode, it acts as a fast-pulse counter with display. Its self-contained pulse counting



circuitry requires no accessories or options to detect multiple clock and trigger pulses, and it can indicate the presence of spurious oscillations. The three-bit counter is reset by a push button. The probe is suitable for any device using 5-volt DTL or TTL integrated circuits.

Circle No. 71 on Reader Service Card

LEE AUTOMOTIVE CIRCUIT TESTER

The new Model E-A automotive circuit tester introduced by Lee Electronic Labs provides a continuity test that may be safely used to check all accessories such as lights, horns and wiring without disconnecting them from the circuit. The tester can be used for locating short circuits. It will not become damaged in the event of accidental contact with hot battery leads or live wires. The tester can also be used as a handy portable spotlight.

Circle No. 72 on Reader Service Card

AMERICAN TRADING CB TRANSCEIVER

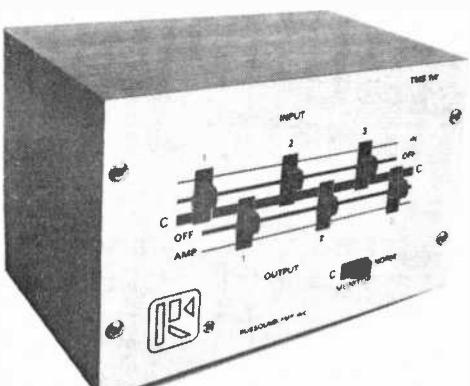
A new Electronic 2000/Contact CB transceiver has just been announced by American Trading Corp. The Model CB-23CH uses a low-noise, double-conversion superhet with a series gate type of noise limiter. Incoming signal strength can be read by means of a combination S-meter/modulation indicator. A local/distance switch is used to allow maximum sensitivity in low noise areas. Power input is rated at 5 watts.

The unit is 6½" wide x 2" high x 7" deep and it weighs about 4 lb. The transceiver is budget-priced.

Circle No. 73 on Reader Service Card

RUSSOUND 3-WAY AUDIO SWITCHER

A new tape recorder selector switch which expands the tape monitor facilities of amplifiers and receivers to accept up to three tape recorders or other line-level audio devices is available from Russound. The TMS-1W connects to



the tape monitor inputs and outputs of the amplifier or receiver and allows three recorders to be used simultaneously for recording, copying or editing. It can also be used to interface graphic equalizers, noise reduction units, synthesizers and other signal processing equipment. The unit makes it possible to conveniently switch equipment in and out without the constant hooking and unhooking of audio cables usually required.

Circle No. 74 on Reader Service Card

TECH SYSTEMS DIGITAL KEY

The Digital Division of Tech Systems has introduced the Model 500 digital key. The key operates when the proper 5-digit code is punched into the unit; the proper sequence must be used or the key will not operate. Over 95,000 code combinations are available. The unit uses the latest IC's to produce a product that operates with any voltage from 5 to 30 volts dc. The entire device fits into a standard 2" x 3" electrical wall box and is available with either maintained or momentary relay contacts rated at 1 amp to provide compatibility with all types of alarm systems and electric door strikes.

Circle No. 75 on Reader Service Card

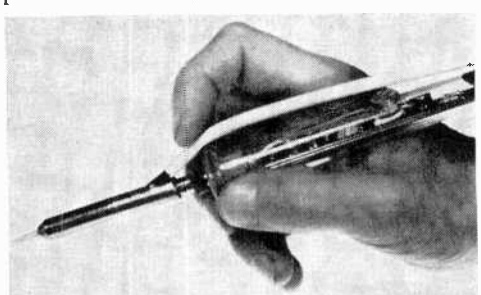
LESLIE PLUS 2 SPEAKER SYSTEM

Electro Music/CBS Musical Instruments has just entered the consumer market with its new Leslie Plus 2 speaker systems. Consisting of a pair of 2-way or 3-way speakers with a built-in pair of 50-watt solid-state power amplifiers, the system has some unique features that are said to eliminate standing wave conditions in the listening room. A mechanical rotor is used with the low-frequency speaker to disperse the acoustic energy produced; another mechanical device which randomly varies the capacitance in the power amplifier input is used to disperse the middle and high-frequency energy to eliminate the standing-wave problem at those frequencies. The purpose of the overall effect is to create sound that is rich in ambiance.

Circle No. 76 on Reader Service Card

EDSYN HOT AIR TIP ATTACHMENT

A hot air tip attachment, Part No. HA120, has been designed for Edsyn's Loner soldering instrument. With the attachment it is possible to produce a narrow jet of heated air that can be



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directed at a small area. The hot air can be used to shrink plastic tubing, for fast drying of small wet areas on a PC board, for localized testing of components by fast heating, and for heat shaping of plastics. Routine soldering can also be done at the same time. To use the hot air attachment the technician merely blows into the mouthpiece supplied or connects it into his shop air supply.

Circle No. 77 on Reader Service Card

ASCOM SPEECH PROCESSOR

A new microphone accessory for both mobile and base applications, the Model M-260 speech processor, is being offered by Ascom Electronic

Products for amateur, CB, public address and similar communications systems. The unit provides high gain as well as effective speech compression to produce full modulation without distortion. The microphone may be held at arm's length or within ½" of the mouth with no change in mike output. For mobile use, it is necessary only to provide 12 volts dc input to the speech processor and replace the microphone plug with the special plug furnished with the unit. Gain is adjustable to match the transceiver gain, and internal adjustment is set initially to provide a wide range of adjustment for the front panel control.

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CHRISTIANSEN "MINI-MOUNT" BREADBOARD

A ground plane card with uncommitted gold-plated fingers is the latest feature in the Christiansen Radio, Inc., "Mini-Mount" breadboarding system. The double-sided, solder-coated cards—when used with the Mini-Mount pads—permit rapid assembly of all electronic components. Ready for testing in minutes, the breadboard can be plugged directly into the card cage. Packing density of the components will equal the final circuit. Pressure-sensitive adhesive on the back of the Mini-Mount holds it in place. The mounts are easily moved about or exchanged, yet will remain firmly in place in the finished assembly. Mini-Mounts come in different configurations to fit 14- and 16-pin DIP's, 6-12 pin TO-5 cans, etc.

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RADIO—T.V. Tubes—36¢ each. Send for free catalog. Cornell, 4213 University, San Diego, Calif. 92105.

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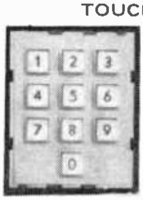

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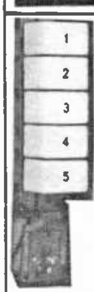

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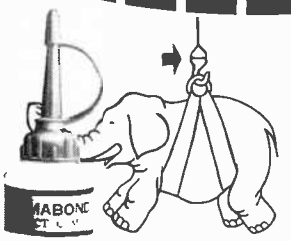

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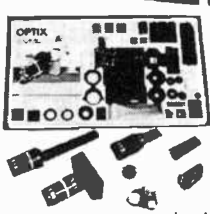

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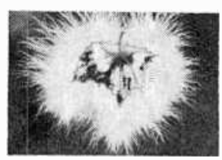

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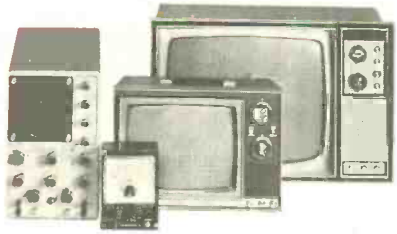

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