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Popular Electronics

WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE AUGUST 1975/75¢

7

BUILD A GIANT-SIZE DIGITAL TIMER-SCOREBOARD FOR ATHLETIC EVENTS

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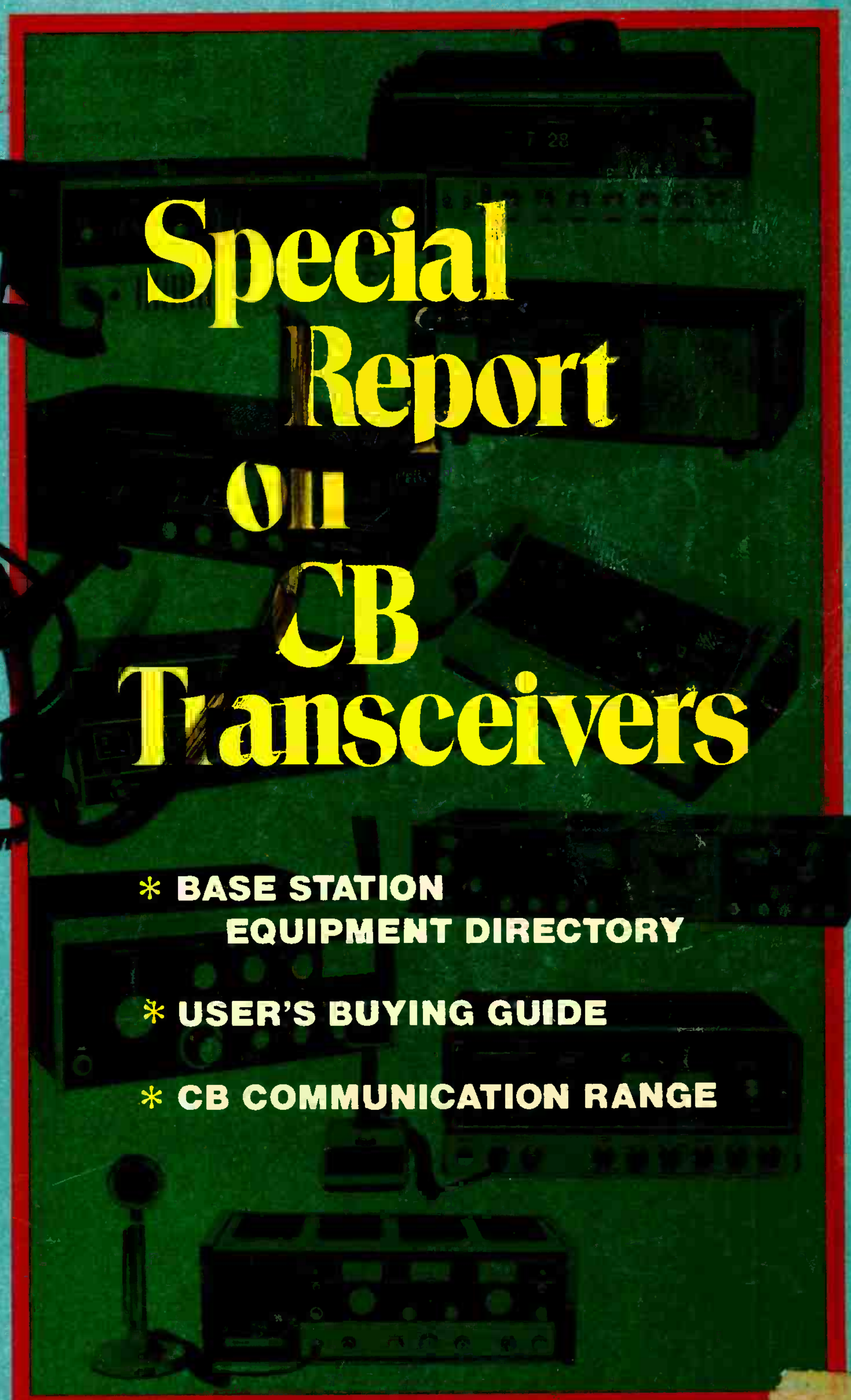

LAB TEST REPORTS

Sherwood S-7310 Stereo Receiver
Stanton 8004-II Turntable/Cartridge
McKay Dymek DA-3 Active AM Antenna
Dynascan Cobra 29 CB Transceiver
Exact 190 & 195 Function Generators

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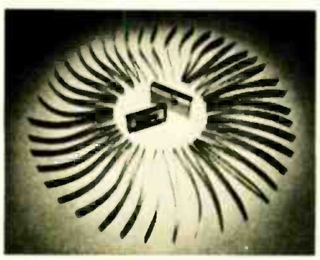

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AUGUST 1975 VOLUME 8, NUMBER 2

Popular Electronics®

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Editorial

NO FROWNS IN DISTRIBUTOR LAND

Electronic parts and equipment wholesalers registered sales of nearly $5 billion in 1974—a record. And expectations are that the figure will be higher for 1975. So it's not surprising that we saw no frowns among exhibitors and attendees at the annual NEWCOM Show (the old distributor parts show) held recently.

The product star of the show was clearly CB radio gear—mobile and base stations, antennas and accessories. There was general agreement among CB suppliers that the best thing to happen to CB was its use by truckers during a strike about two years ago. Since then, with CB impressed on the public's consciousness, the no-test two-way radio system for just about anyone has exhibited a sales explosion. Manufacturers aren't sitting on their hands, though. Many exciting engineering innovations have been introduced to attract new buyers and to induce present CB'ers to upgrade their equipment. As an example, E.F. Johnson had a mobile unit at the show that employs LED readouts in place of the traditional analog S meter; Royce showed a mobile with channel readout incorporated into the microphone; Beltek features a unit especially designed for motorcycles and snowmobiles; Tram's base station had a two-speed vernier tuning arrangement; etc.

A wide array of mobile and base station antennas was displayed, too. An abundance of CB accessories, from mounting kits to CB antenna co-phasers, was shown; GC Electronics introduced a conical bit for drilling infinitely variable diameters when mounting antennas on automobiles. VHF-FM scanners for Public Safety Broadcasts were very much in evidence, as well. SBE's new 10-channel digital scanner employs 2¼" × 4¾" optical programming cards to give users fast, easy selection of about 16,000 frequencies.

CB did not fully dominate the show, however. There were plenty of other products exhibited: test instruments, TV and FM antennas and rotators, commercial sound systems, intercoms, garage door openers, electronic components, cabinets, cordless soldering irons, and so on.

Of special interest to us were products that we had never heard about. For example, Electrosonics exhibited its "Sound See-er", a battery-powered device that quickly indicates, through a red, yellow or green lamp indicator, whether a person using a public address system is producing a satisfactory sound level in the audience; RCA introduced an adapter for converting single-trace scopes to dual-trace; Para Dynamics featured a signal-searching TV color signal antenna rotor system; Datak showed a new photo-etch pc kit; Intra-Fab displayed a line of color-coordinated aluminum cabinets; Fanon boosted its wireless "babysitter" intercom; Sencore demonstrated a yoke and flyback tester; and making its U.S. debut was Italy's Amtron electronic kits.

Naturally there were many products we knew of but never handled: B&K's low-cost frequency counter, Panavise's bench tools, Eico's telephone electronic accessories, etc. So, in all, the show was a most worthwhile expenditure of time, considering the "hands on" opportunities presented under one roof. Further, it was made patently clear that the electronics distributer business is healthier than ever before.

Art Salsberg

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Direct-Reading Logic Probe

Letters

MANUFACTURER CHANGES TYPE NUMBER

In Mac's Service Shop "Lightning Damage Insurance Jobs" (January 1975), reference was made to the General Electric No. 9L15CCB007 home lighting protector. The number for this item has been changed to 9L15DCB002. This device is a 2-pole/3-conductor unit for 120/240-volt grounded metal service.

RICHARD W. BEHNKE
Texas

MANY USES FOR PE

POPULAR ELECTRONICS is a most exciting and easy-to-read magazine. I particularly appreciate the construction projects for CB'ers and SWL's. One needs only a minimum of tools and no specialized knowledge of electronics to build the projects. (My chief hobby interests are CB radio, which I use in Scouting, boating, and shortwave listening.)

It is also very gratifying to see that PE is now using the metric system of measures as well as the so-called British system. Keep up the good work.

JAN STIGELL
Stockholm, Sweden

LENS F NUMBERS

"Experimenting With Light-Beam Communications" (April 1975) appears to contain an error. Author Forrest Mims states that the term f/number is used to define the ratio of diameter to focal length and is expressed as f/no, which is equal to d/fl, where d is the lens diameter and fl is the focal length. This part of the text should read, "The term f-number (this is the proper designation—not f/no) is used to define the ratio of focal length to lens diameter and is expressed as f-no equal to fl/d.

DANIEL J. NETTO
Los Angeles, Calif.

You are correct. The f-no of a lens is equal to the focal length divided by the diameter of the lens. The formula d/fl is the divergence of the projected beam, or receiver field of view, in radians. —*Author*

NOTES ON HEAD ALIGNMENT

I would like to comment on the procedures outlined by Ralph Hodges for tape head alignment in his February 1975 "Stereo Scene." There are two important points Mr. Hodges did not mention. The first is head rotation, which is very important on modern tape decks that do not have pressure pads. Rotation must be set so that the wear pattern is equal on both sides of the head gap and, more important, for maximum output at 15,000 Hz. I am certain that in most decks, any change in one alignment parameter *will* affect the other alignment parameters to some degree.

The second point, in azimuth alignment, is the importance on a multi-channel deck to check the phase relationships of the tracks to each other. It is possible to read maximum level at high frequencies and still be 180° out of phase.

In short, when it comes to a critical alignment procedure, the job is best left to a professional who has the knowledge and equipment to do the job correctly.

HOWARD M. LIEBERMAN
Audio Concepts
Spring Valley, N.Y.

The column was not intended to be a formal discourse on head alignment. It was merely a loose discussion of a few cheap-and-dirty diagnostic tricks that might help one to keep tabs on a deck's variations in performance. I share any reservations Mr. Lieberman has about these procedures being good studio practice. I also agree on the subject of head rotation. However, the head gaps of many consumer decks cannot be seen with the unaided eye. As for adjusting rotation for maximum output at 15,000 Hz, I must confess that I have never tried it, but I agree that it can be worthwhile, particularly if thicker tapes are customarily used on the tape deck.

I realize that track phasing is important in certain professional applications (as when stereo material is mixed for mono broadcasting), but I do not understand why phasing should be of any practical consequence in consumer recorders where mixing is very rarely used. —*Author*

Out of Tune

In "Digital Marine/Auto Tachometer" (June 1975), the connection where the line coming from pin 5 crosses the line between pins 1 and 8 of *IC2* in the schematic should be removed. Also, the IC's are sensitive to the r-f noise from the car's ignition system. To cope with this problem, it may be necessary to install r-f suppression-type spark plug cable in older cars and extensive capacitive bypass techniques in the circuit. Route the coaxial feed cable close to the metalwork on the bottom of the car and locate its grounding point experimentally. In most cases it will be on the car's body or frame, rather than on the engine.

In "How to Design Your Own Power Supplies" (June 1975), Fig. 10, page 39, the polarity of the zener diode should be reversed.

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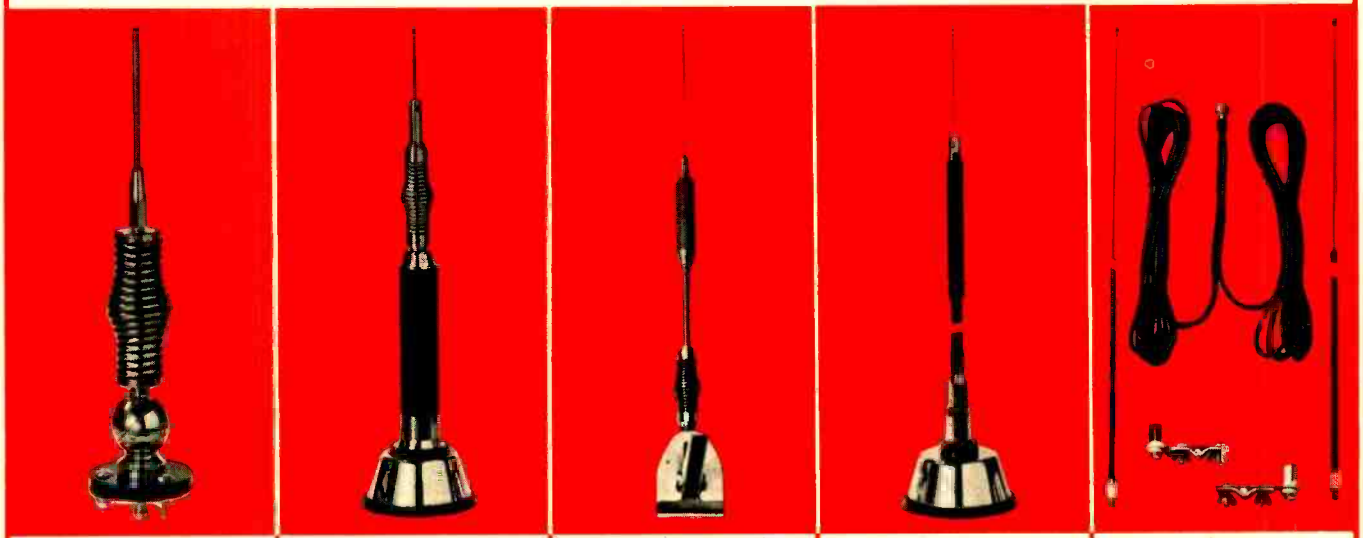

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New Products

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.

TELEQUIPMENT DUAL-TRACE PORTABLE OSCILLOSCOPE

Tektronix's new Telequipment Model D32 oscilloscope is a 10-MHz, dual-trace unit. The scope has a vertical sensitivity ranging from 10 mV/div to 5 V/div in nine calibrated steps, nineteen sweep speeds ranging from 500 ns/div to 500 ms/div, a X5 horizontal magnifier, and flexible triggering. Automatic selection of chopped or alternate modes is incorporated, and the D32 can be run off line current or rechargeable batteries. Up to four hours of continuous operation is possible under battery power. Six rechargeable "D" cells, probes (2 each), and a front-panel protective cover are included as standard equipment. An optional carrying case is also available. The scope measures 11" D × 9" W × 4" H (27.9 × 22.9 × 10.2 cm). $995.

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WALL-LENK SOLDERING PISTOL

Wall-Lenk's new Model 2116 is a lightweight, 30-watt pistol-grip soldering gun. It is UL listed and has a nylon handle that is said to stay cool even during prolonged use. The pistol is balanced for comfort, and its heating element reaches operating temperature in a few seconds, according to the manufacturer.

CIRCLE NO. 71 ON READER SERVICE CARD

RCA PORTABLE SEMICONDUCTOR CHECKER

The new portable, battery-powered Transistor/Diode/FET Checker, Model WC-506B by RCA, permits quick checks of both in- and out-of-circuit devices. The instrument provides four ways to connect a device for relative gain or leakage tests of npn and pnp transistors, p- and n-channel single- and dual-gate FET's, and relative front-to-back ratios of diodes. A conductive foam pad on the front panel is included to discharge FET leads. A special "square-law" meter makes possible one extended range for all tests. Relative gain readings are indicated on a single "good-bad" color-coded scale. Devices can be tested in the panel socket or with color-coded test leads. Extension leads are provided for in-circuit testing. The Checker measures 6¼" × 3¾" × 2" (15.9 × 9.5 × 5.2 cm) and weighs 14 ounces (397 g). $33.

CIRCLE NO. 72 ON READER SERVICE CARD

HIGH-VOLTAGE/CURRENT MEASURING PROBE

Eico's Model HVP-5 is a self-contained, direct-reading high-voltage and current measuring probe. It can read dc voltages up to 40,000 V and dc currents up to 200 mA. The two measuring circuits are independent of each other, and the meter is switched between them by a slide switch mounted on the probe body. The manufacturer claims that the HVP-5 cannot be damaged by placing the function switch in the mA position while measuirng high voltage. $29.95.

CIRCLE NO. 73 ON READER SERVICE CARD

AUDIOANALYST "TOWER OF SOUND"

The Audioanalyst Tower of Sound is a stacked pair of A-100X three-way acoustic suspension loudspeakers. This is done to take advantage of the dispersion characteristics of the high-frequency drivers and mutual coupling between the two 10-inch woofers. It is said that the two low-frequency drivers behave as one 15-inch woofer without the beaming and breakup problems of a larger transducer. The two A-100X systems are wired in parallel, presenting a 4-ohm load to the power amplifier. The Tower of Sound stands about four ft. (1.2 m) tall and occupies a little more than a square foot of floor space.

CIRCLE NO. 74 ON READER SERVICE CARD

CLARION UNDER-DASH CASSETTE PLAYER/RECORDER

The Clarion Model 812 car cassette player features record capability, a microphone with coiled cord and an on/off switch for stop/start operation, and automatic reverse. Also included are fast forward/rewind and volume, tone, and balance controls, automatic or manual program switching, and program indicator lights.

CIRCLE NO. 75 ON READER SERVICE CARD

KENWOOD LUXURY RECEIVER

The new KR-9400 stereo receiver boasts 120 watts rms/channel into 8 ohms between 20 and 20,000 Hz, with no more than 0.1% THD. The amplifier section uses direct-coupled output circuitry, and a pro-

tection circuit combining electronic and relay switching. The KR-9400 tuner section uses a dual-gate MOSFET front end, a multi-function IC, and a phase-locked loop IC. Claimed sensitivity is 1.7 μV, selectivity 80 dB, and capture ratio 1.3 dB. A triple-function meter performs as a signal-strength, multipath, and deviation indicator. Other features are three tone controls, a dual tape system for uninterrupted dubbing, and a new injection circuit which mixes the signal from any program source into the recorded signal, with front panel level control for proper blending.

CIRCLE NO. 76 ON READER SERVICE CARD

AUDIO SWEEP GENERATOR/FREQ. METER

Production Devices' Model 140B is an audio oscillator, sweep generator, and frequency meter in one enclosure. As a sweep generator, it operates over two ranges—from 40 Hz to 1000 Hz, and from 1000 to 20,000 Hz. The frequency meter may be used independently. As an audio oscillator, it provides a sine wave with an adjustable output from 0 to 2.5 V_{pp}, which is constant over the audio range (±0.25 dB). Distortion is said to be less than 1.5%. As a square-wave generator, the Model 140B can produce a fixed 8V_{pp} output. $78.95.

CIRCLE NO. 77 ON READER SERVICE CARD

ESP TESTER

Edmund Scientific's new solid-state portable ESP Tester has a guaranteed random

circuit for accurate testing. When the examiner pushes a button, a light appears above one of four symbols — a star, a square, a triangle, or a circle. If either the examiner or the subject has ESP, the number of correct guesses will average above that indicated by random chance (1 out of 4 or 25%). Four "D" cells are required for power. The ESP Tester (Cat. No. 72,090) comes with instructions and a 50-test experiment pad. Measures 6¼" × 3¾" × 2" (15.9 × 9.5 × 5.1 cm) $29.95 Extra pads for 250 tests (Cat. No. 72,092) are available for $3.50.

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New Literature

ELECTRONIC IGNITION BOOKLET

"A Revolution in Ignition Systems," offered by the Tri-Star Corp, describes the physical operation, advantages, and disadvantages of the conventional (Kettering), transistorized, and capacitive-discharge (CDI) ignition systems. The illustrated publication includes comparative data on the three types of systems, and highlights the company's Tiger line of CDI modules. Also given are the results of a laboratory test comparing six of the most popular CDI products. Address: Tri-Star Corporation, Grand Junction, CO 81501.

ELECTROSTATIC SPEAKER BROCHURE

An Electrostatic Research brochure describes its new ER-139 two- and three-way speaker systems, featuring dynamic bass and electrostatic tweeter drivers. The three-way system uses a dynamic mid-range driver. In both systems, a circular array of eight ES tweeters provides 360-degree horizontal dispersion. Energizing techniques (through either a separate voltage supply or self-energization) is discussed. Address: Electrostatic Research Co., Dept. P, 38 Cabot Street, Beverly, MA 01915.

3-D DISPLAY CATALOG

A new 8-page catalog is available from Optical Electronics, Inc., describing its three-dimensional display system modules for use with conventional XY CRT displays. The catalog illustrates the various capabilities of the 3-D system, including the generation of monocular and binocular images, image magnification, and various depth cues including local field, interposition, movement parallax and perspective. Also described are peripheral modules such as vector generators, background generators, and computer buffer/interfaces. Address: S. Day, Sales Dept., Optical Electronics, Inc., Box 11140, Tucson, AZ 85734.

TRIPLETT TEST EQUIPMENT CATALOG

A new 16-page catalog of its line of test equipment is available from the Triplett Corp. The new 60-T catalog features two new VOM's, as well as Triplett's temperature testers, special feature testers, and general-purpose portable units. The catalog also contains a product selection guide for easy comparison of the manufacturer's various units. Address: Triplett Corporation, Dept. PR, Bluffton, OH 45817.

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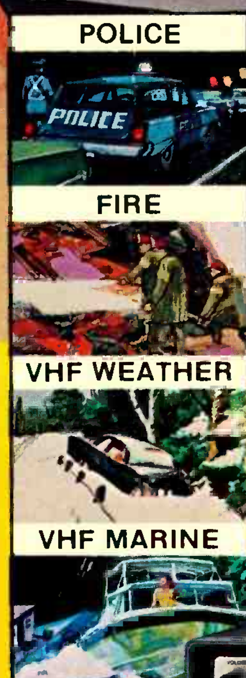

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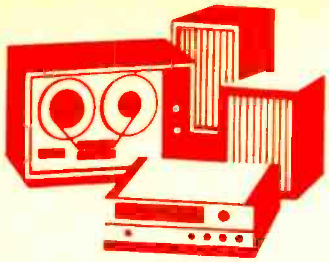

Stereo Scene

By Ralph Hodges

WILL AUDIO GO DIGITAL?

"WHAT'S happening with digital audio?" is a question you hear from time to time. The answer is that it's loping along nicely, with groups as diverse as Bell Telephone Laboratories and the British Broadcasting Company doing serious work on one project or another. Consumers cannot yet find digital tape recorders awaiting them at the local hi-fi emporium, but audio professionals can buy digital delay lines that can do a most effective job enhancing the naturalness of artificial reverberation, particularly when they are used with more conventional studio techniques. Digital techniques have been used to restore the fidelity of old recordings, and these efforts have met with unprecedented success. And, of course, in the area of synthesized music, digital techniques are becoming more established every day.

Digital applications for audio are being pursued in areas such as: signal processing (delay, filtering, etc.) and straight recording. Recording is simpler, at least in theory, except that it must generally be carried out in real time and committed to a medium (most often magnetic tape) which has serious storage-density limitations for this kind of work. Signal processing—or some types of it, anyway—can proceed chunk by chunk at the computer's leisure, and permanent storage of the signal in digitized form may not be involved at all.

Earlier this year the Midwest Acoustics Conference, which takes place annually in Evanston, Illinois, devoted itself to an overview of digital audio, presenting a number of uniquely qualified speakers who explained where we are today and what's coming next. I went there to get a feel for the viability of these techniques in the consumer sphere, and I came away mildly encouraged. Many of the experts foresee digital hardware making its way into the home in the not-too-distant future. (The exact timetable will involve marketing considerations as much as technological advances, so it isn't really worth speculating about right now.) Probably the most attractive product that could be offered the audiophile is a digital program source, especially if it—like a digital tape machine—could also produce digital recordings. For the rest of this column, I'll focus on that sort of product, because it is of demonstrated interest and because its essential functions—conversion from analog to digital and back again—are basic to any digital processor.

Music By Numbers. You are perhaps familiar with the advantages of digital recording. They include virtual immunity to cumulative noise, distortion, and frequency-response degradation. Audible wow and flutter can be wiped out because the signal itself carries with it an unambiguous timing notation, derived from a very stable and accurate electronic clock. This notation can drive a mechanical servo system that regulates the rate at which the recording is scanned (a simple servo-controlled capstan motor on a tape machine, for example). Another scheme might use a matrix of memory locations that "hold" data until they are scanned electronically to regenerate the digitized signal.

Digital comes by these benefits because it substitutes a numerical code for the thing itself, unlike our present-day analog recordings (discs and tapes) which really *are* the musical performance in a sense, frozen in time for our convenience. To construct a rough analogy: any oil painting would not fare too well if preserved for posterity by means of photocopies, whereas an instruction sheet for a paint-by-number kit, even if rendered just barely decipherable, would give rise to the same end product as an undamaged copy. Of course, few paint-by-number kits would fool anyone into believing he was in the presence of a Rembrandt original. But if the instructions were detailed enough—one hundred items per square centimeter of canvas, say—the unaided eye might very well find the reproduction indistinguishable from the original. This is the goal of a practical digital recording system: to provide adequate instructions for an au-

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With this fascinating learn-at-home program, you do a lot more than just read about electronics. You'll conduct dozens of experiments . . . build your own laboratory equipment for testing out electronics principles . . . and also as part of this program you put together a 4-channel amplifier and FM/FM stereo tuner as you delve into advanced audio technology.

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HANNEL AUDIO!

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A wealth of knowledge in digestible chunks.

O.K.! So now you might be thinking, "It sounds really interesting . . . but kind of complicated." And you're right. But that is why we use the "hands on" teaching approach.

We've taken all the material and broken it down into short, simple-to-grasp lessons, so you can master one thing at a time before moving on. And we take you through it step by step. From the basics to advanced theory to applied audio technology. So you actually have an easier time with it.

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How do you convert music to numbers? You could use any number of systems, as long as you're consistent. Figure 1 shows, for example, a musical waveform (such as a microphone output) of perhaps a millisecond's duration applied to a rectangular coordinate system; the t axis is time, and A is amplitude (voltage or current). Any point on the waveform can obviously be expressed in coordinate values of A and t, and that is how the waveform

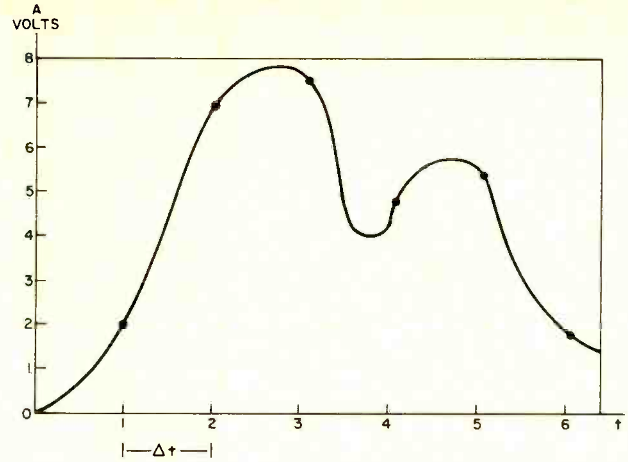

Fig. 1. A typical musical (analog) waveform. The smooth curve is sampled at small time intervals and the amplitudes are converted to digital information.

will be digitized. To establish the t values we'll move along the axis in small fixed increments. The size of the increments is determined by the *sampling rate*, which we'll have to get involved with later. For now, assuming our sampling rate is established, we'll just move along collecting our data: at t=1, A=2; at t=2, A=7; at t=3, A=7.8, etc. We end up with the coordinate values for a series of points (Fig. 2). The numerical values are what we'll record on the tape, in digital form. What we'll get when the recorded tape is played back through a digital-to-analog converter is the points of Fig. 2, obviously not a good reproduction of the original curve. However, if the increments of time and amplitude are made small enough, very good results can be obtained.

1, 2, 3 . . . Digitally. Most computers can't make anything of such abstract symbols as "2," "5.5," and "9," even if they could be fed to them in that form. So, as many of you are aware, computers have their own language for counting, based on the digits 0 and 1, generally corresponding to the open and closed conditions of the numerous switches that are among their principal contents. In this binary system, the digits are arranged in columns with the leftmost expressing the highest values, as in the decimal system. However, the columns are arranged in powers of the base 2 rather than the base 10 (Fig. 3). The first column on the right is the 2^0 column (2^0 equals 1); the second is the 2^1 column (2), the third is 2^2 (4), the fourth is 2^3 (8), and so on. Thus the decimal number 9 is expressed 1001 in binary notation — one 1 plus no 2, no 4, and one 8. Each of the digits in 1001 is called a *bit*. A four-bit system like this can count up to 15 (1111, or 1 plus 2 plus 4 plus 8). To go higher (17, for example), we must add another bit to get 10001 (1 plus 0 plus 0 plus 0 plus 16). Note also that there's no way of expressing fractional parts of integers. We could arrange the system to

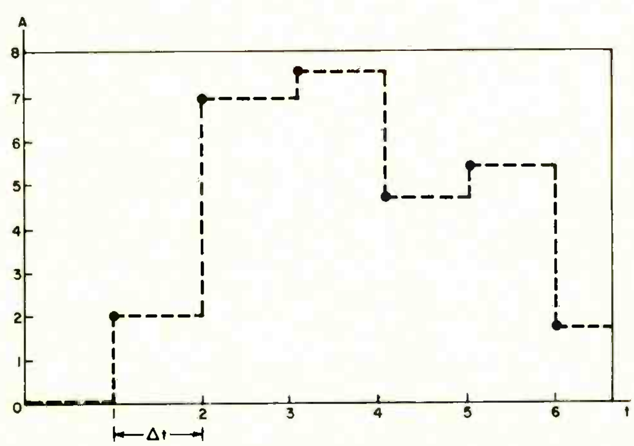

Fig. 2. Reconstructed waveform. In practice, much smaller time increments would be used to obtain a smoother, more detailed replication of waveform.

do so but we would have to add more bits, just as we have to add columns to the right of the decimal point in our own number system.

The binary code described here lets us put the information we feed to the computer somewhat in a suitable form. Still, we're hard pressed to express the amplitude of the waveform at any instant with only the 15 numbers of a four-bit code. First of all, if the waveform should go below zero, merely to be able to express all the whole numbers will require an additional bit to distinguish between positive and negative values. (A 0, meaning positive, or a 1, meaning negative, preceding the four-bit digital "word" will readily accomplish that function).

Decimal	2^3 (8)	2^2 (4)	2^1 (2)	2^0 (1)
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0

Fig. 3 Table for converting decimal to binary numbers.

But we'd also like to subdivide in order to express fractional values. This needs more bits; the question is, can we afford them? According to Dr. Barry Blesser of MIT, speaking at the Midwest Acoustics Conference, an 8-bit converter (analog-to-digital or digital-to-analog) can be bought for $4 to $8. A 12-bit converter might cost $100 to $500. An 18-bit converter is still blue sky. In short, equipment costs have a highly unfavorable exponential relationship to the number of bits in the system.

Quantization Error. But anyhow, we have our however-many-bit system and we're going to do the best we can. What should we watch out for? First, we should guard against signal levels that exceed the range of our number system because our converter won't be able to express them and will present us with nonsense at the output.

Second, we must worry a lot about values that fall between the numbers we have available. The value 5.5, for example, cannot be expressed by our four-bit system; it will have to write 5 (0101) or 6 (0110) in its place. The difference between 5.5 and the 5 or 6 the converter gets from it is the *quantization error*, and it is something you have to put up with unless you can afford to divide up the values (with more bits) to achieve a closer approximation to the actual value. What quantization error *sounds* like is a subject we'll approach a little later.

If all has gone well up to now, we confront our third problem: the recording medium. Most existing digital systems use magnetic tape, laying down the 1's and 0's as dc pulses and non-pulses, or pulses of opposite polarity, or ac pulses with two discrete frequencies. But whatever the system of recording, tape has a notoriously limited packing density; you're allowed just so many bits per inch. More information per time unit can be recorded by increasing tape speed (sometimes to absurdity), or it is certainly possible to use several tape tracks for one audio channel. However, you're still at the mercy of those imperfections in the tape that cause dropouts. If the bit in the farthest-to-the-right column (the "least significant bit" or LSB) happens to get recorded on a tape dropout hole, the consequences are not likely to be too dire. But if it's the leftmost digit (MSB, or "most significant bit"), the performance of your electronics must be phenomenal if you don't get a distinctly audible pop or other sonic clunker as a result.

Sampling Rate. Leaving for the moment the problem of recording amplitude values, let's take a closer look at the time axis. Our "sampling" of the waveform is done at a uniform rate with samples separated by a more-or-less short space of time. How frequently should we sample? The rule is that the sampling frequency must be at least twice the highest sine wave of frequency of interest—40 kHz for a 20-kHz audio bandwidth, for example. And in fact, we must do everything possible to prevent a signal frequency higher than 20 kHz from reaching a 40-kHz sampler. The reason is simple. A signal frequency above 20 kHz cannot be adequately sampled. When this state of affairs crops up, the signal is modulated by the sampling rate, giving rise to heterodyne (sum and difference) tones of the two frequencies. The difference tone is lower in frequency than either the signal or the sampling rate, and thus it tends to get heard. The sum tone is inaudible. The phenomenon is called *aliasing*. It is equivalent to gross intermodulation distortion.

In front of the input of any digital audio converter there will inevitably be a pretty sharp low-pass filter to forestall such nuisance. The skirt of the filter determines where the sampling rate must be placed to avoid trouble. But unfortunately, not-allowed high frequencies may be generated within the converter itself under certain circumstances, with the same unwholesome effects. This takes us back to quantization error and (again) to Dr. Blesser.

Quantization error results in distortion of the output waveform—distortion that does not strictly correspond to the spurious products we're used to from analog devices, but measurable by HD and IM analyzers nonetheless, and just as audible. In complex, high-level signals, quantization error sounds like hiss (white noise), although it doesn't come from the tape or from thermal noise in the electronics. It is simply (I would guess) the sum of highly randomized mistakes made by the recording system. However, for simpler, low-level signals, the audible character of quantization noise changes.

Consider a sine wave so low in level that its fluctuating value is expressed only by the least significant bit in the system. The device that quantizes the waveform can at best indicate only its maximum values in the positive and negative directions. There are no bits left to chronicle the rate of its rise and fall. To the quantizer, therefore, this sine wave is indistinguishable from a square wave, and a square wave, as we know, possesses an infinite series of odd-order higher harmonics. Some of these harmonics will fall above the highest frequency the sampler can handle, and up come the beat tones again. Of course, no typical audio signal is a simple sine wave, so the usual result is several beat tones, creating a dreadful, whining accompaniment to the music.

The Fix Is In. To diminish the beat tones, which are always much more annoying than the white-noise form of quantization error, there are a couple of elegant ways to cheat on the analog-to-digital converter. One is the "dither" technique, in which a trace of random noise is fed to the converter along with the signal. The noise keeps the least significant bit occupied with things other than the low-level sine wave, so that the process won't produce a series of higher harmonics. The result, of course, is some noise in the output, but this is much more tolerable to most ears than the reedy whine.

Another technique, mentioned specifically by Dr. Blesser, involves little more than compression of the input signal, so that there are *no* low-level signals. The input to the converter is fed by several amplifiers of increasingly higher gain. The lowest-level input signals are switched through the highest-gain amplifier, and when the signal is recovered, there is a complementary amplifier array to undo the compression, controlled by information digitized along with the program. The approach is quite similar to that used by the nonlinear amplifiers in the Dolby system and other analog noise reducers. (In fact, nonlinear compander and coding schemes also turn up in digital systems.) It's most reminiscent of the Dynatrack noise-reduction technique that Mullin devised for 3M: recording high- and low-level signals on separate tape tracks, whilst employing high-gain electronics for the low-level track.

Then Why Digital? According to Blesser, none of the above will succeed in reducing quantization error, but it will convert the offensive noise into a form we can live with. Beyond that, the way to reduce error is to increase the number of bits available—an expensive remedy right now, but surely not for always. In terms of naked semiconductor hardware, a bit cost about 10 cents a few years ago; the price is now more like 1/10 of a cent (figures provided by Mahlon D. Burkhard at the Midwest Acoustics Conference).

Is it worth all the trouble and expense? Again, perhaps not immediately, but it certainly will be someday. Several of the speakers at the conference brought along tapes to demonstrate digital audio at its worst and best. It was obvious, even from a brief listening, that digital's best is very good indeed. So let it come if it will; I'll buy it, if I can afford it. ◈

New 21"(diag.) Heathkit digital-design Color TV

Popular Electronics editors called the digital-design GR-2000 "the color TV of the future." Now you can enjoy the same technology and features in the new GR-2050 with the convenient, popular 21-inch picture tube.

On-screen electronic digital channel numbers—big, bright, bold, and easy to read, even from across the room. **On-screen electronic digital clock time**—low cost insurance against missed programs. In 12 or 24 hour format, 4 or 6 digits. **Silent, electronic, touch-tuning,** thanks to the combination VHF-UHF varactor tuner. No knobs to turn, nothing to wear out. Just touch to tune...on the front panel or the Remote. **Programmable digital counter/channel selector**—a computer-like programming board for you to pre-program any 16 stations, UHF or VHF, or both, in any order, even repeating if you wish. Touch the tune button and the counter silently sweeps up or down through all 16 channels, stopping when you release the button.

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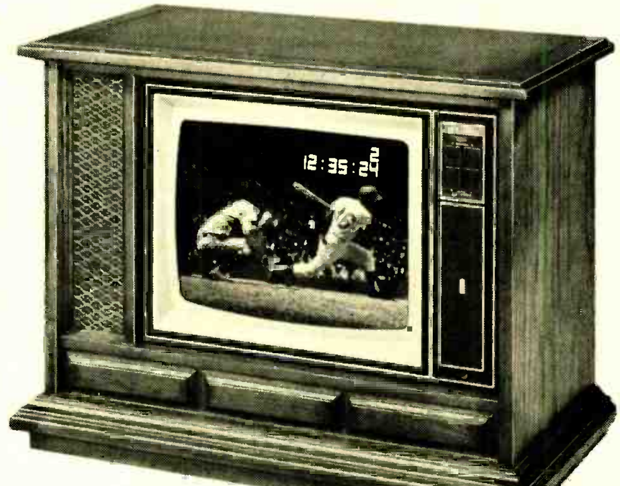

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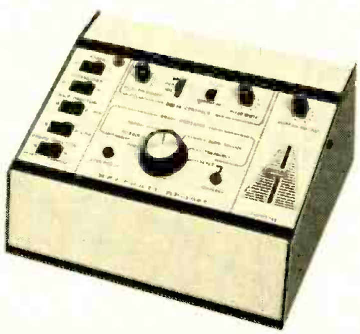

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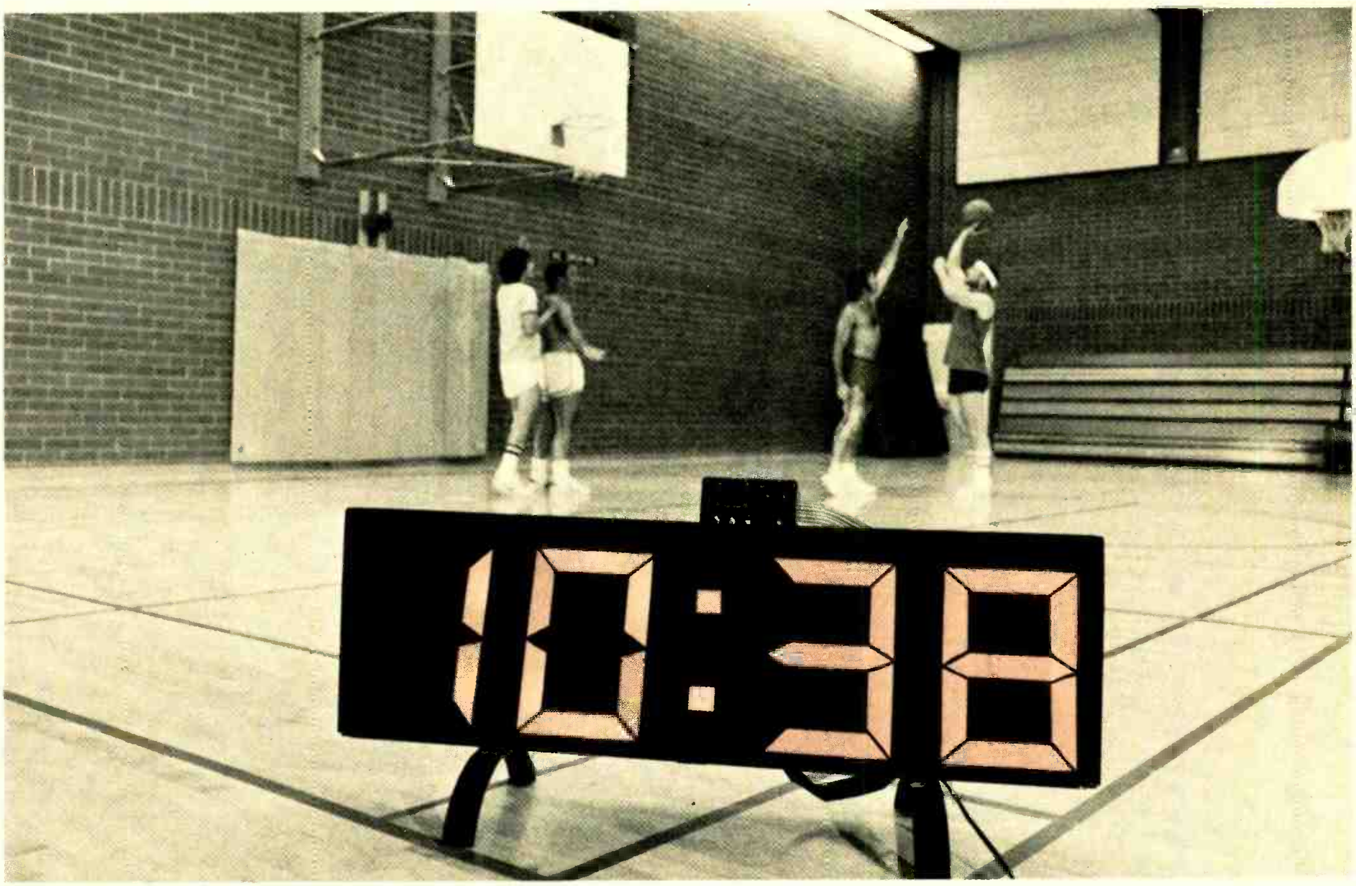


A DIGITAL TIMER-SCOREBOARD FOR ATHLETIC EVENTS

Gymnasium-sized digital readouts simultaneously time up or down and keep score. Ideal for schools and amateur sports groups.

BY PHILIP HARMS

ELECTRONIC timers and scoreboards for athletic events are often too expensive for amateur organizations and small school groups. This is particularly true of a display that can be read across a gymnasium or stadium. The combination timer/scoreboard described here can be built with readily available components (TTL logic), many of which can be obtained from surplus dealers. Though variations on the display are possible, the prototype has four seven-segment digits, each one foot high. It can be built for about $100.

The project has two independent modes of operation — timing and score displaying — both remotely controlled. Usually, the time is displayed, but while the score is being displayed, the internal electronic clock keeps operating so that the time display is always available. In addition, the timing can be made to run backward and the operator can start the timer at any selected time and run the time up or down from that point. If it is desired to stop the timing (for time-outs in basketball or football), this can also be done. The readouts will hold the time and will start to operate (either up or down) when timing is resumed.

The four-digit readout can be set to indicate a preset score. When the time is displayed, a colon is lit between the two sets of digits. For a score, there is no colon. Provision is also made for an instant test of all the display lamps.

The electronic portion of the scoreboard control is easily assembled on printed circuit boards. Though some carpentry is involved in the construction of the display, it is not beyond the capability of a high-school

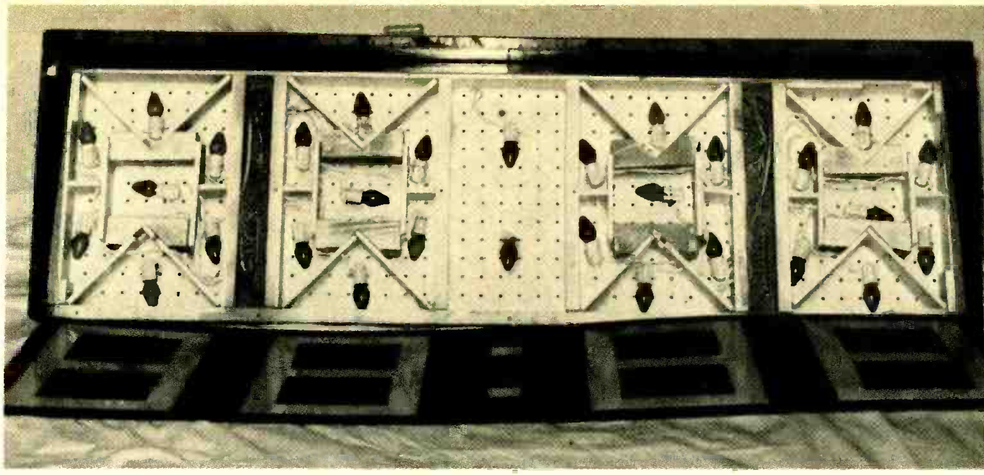


Photo of interior of prototype display board shows how lamps are placed in each segment and for colon. Note plastic front panel with all but figures painted flat black.

student. Ordinary 7½-watt lamps (Christmas-tree type) are used to illuminate the display. The remote control board and the display are connected by a multi-conductor cable.

Circuit Operation. An overall logic diagram is shown in Fig. 1. Portions of the circuit are shown in individual schematics and will be discussed separately.

Control Box. The control switches for the various functions are shown in Fig. 2. All of the circuits to which they are connected are terminated in resistors connected to the +5-volt line.

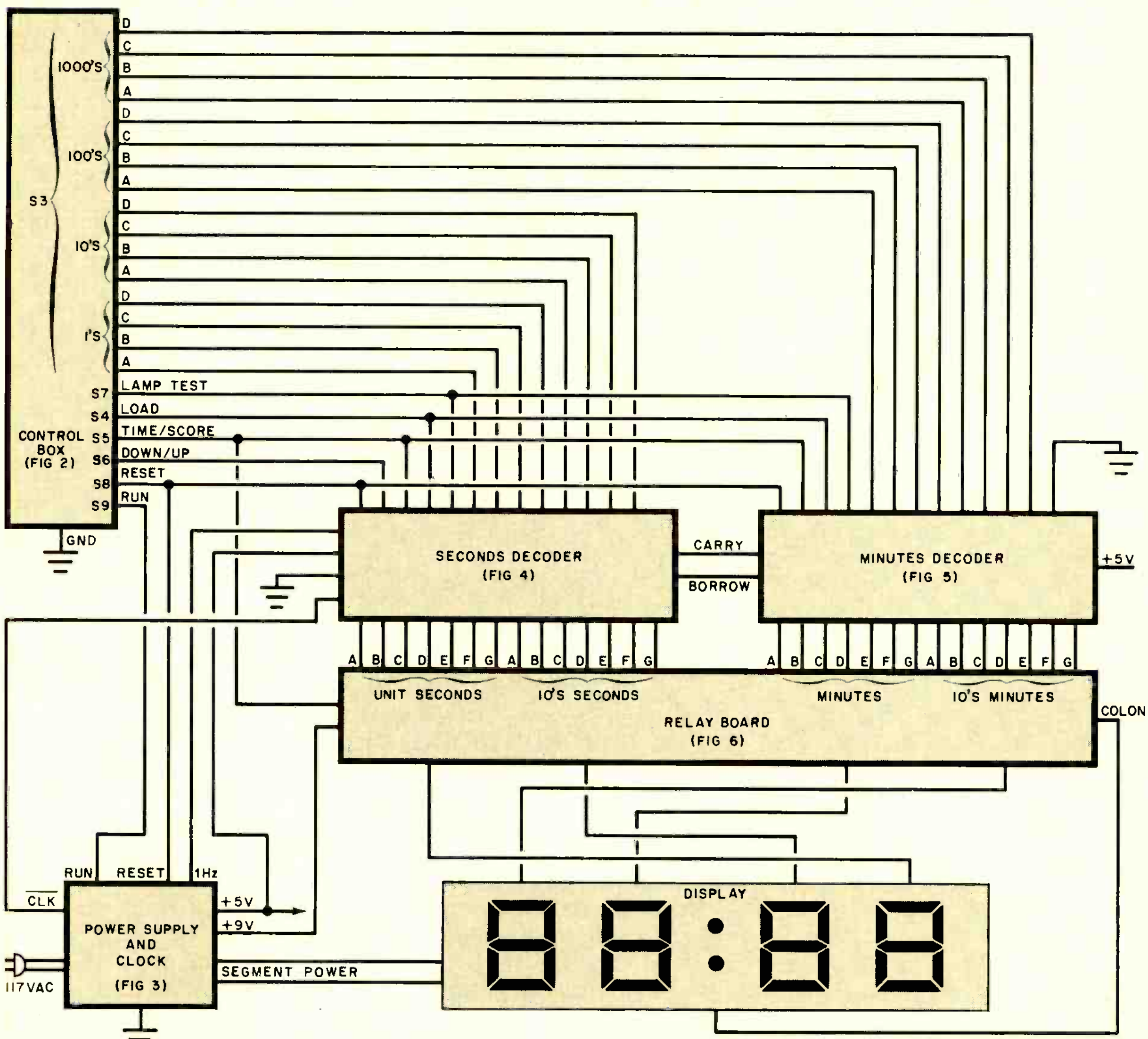
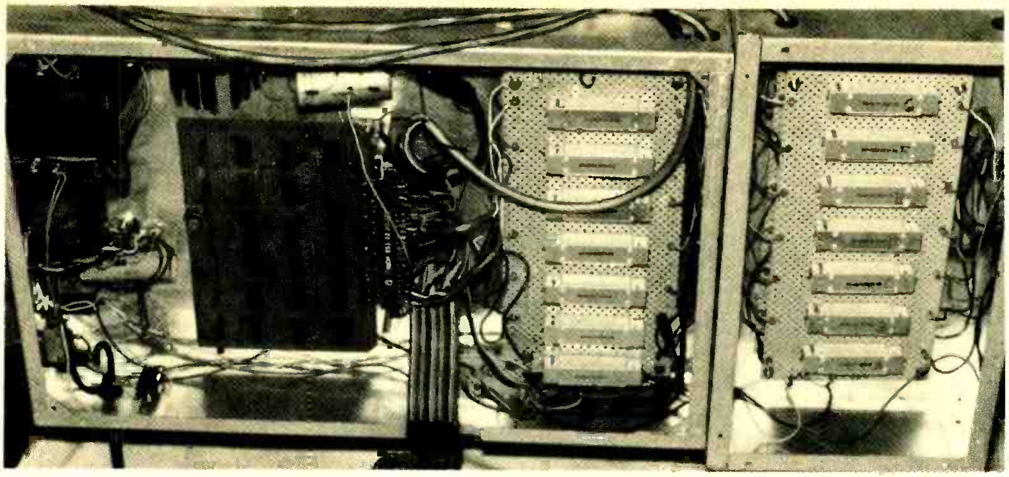


Fig. 1. Overall block diagram of the system. Schematics of individual sections are identified by figure number.



Interior of the two electronic chassis. The power supply, main electronic board, and relay board for two digits are in one chassis. Relay boards for other two digits are in second chassis.

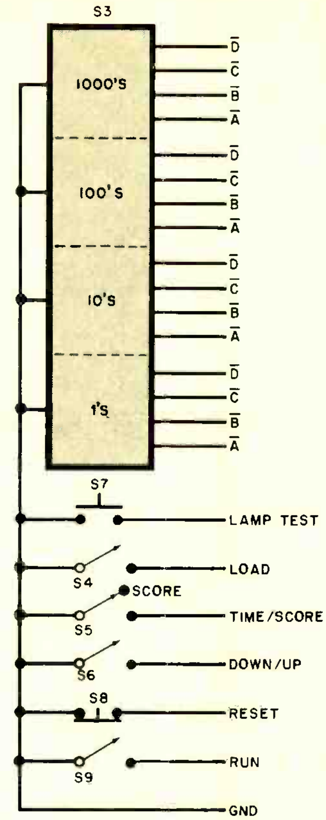


Fig. 2. Control box determines operation of the system. Connection to rest of system is through multiconductor cable.

Thus, when the switches are open, the lines indicate a logic 1 state.

The four sections of thumbwheel switch *S3* have a complementary BCD output. Each section has a common wiper contact and four output lines. System ground is tied to each common line and the selected code is presented at the output terminals. The complementary BCD code is as follows: (C = closed contact; O = open contact)

	D	C	B	A
Digit	8	4	2	1
0	C	C	C	C
1	C	C	C	O
2	C	C	O	C
3	C	C	O	O
4	C	O	C	C
5	C	O	C	O
6	C	O	O	C
7	C	O	O	O
8	O	C	C	C
9	O	C	C	O

Power Supply and Clock. The system requires two power supplies (Fig. 3). One, using a two-transistor regulator, provides +5 volts for the logic. The other is a simple rectifier (*D4*) and filter (*C2*) circuit to provide 9 volts for the segment relays.

The 117-volt ac supply is applied to the display lamps to light each segment. When *S2* is closed, the full ac supply is applied to provide a bright display. With *S2* open, diode *D1* permits only the positive half cycles to be applied to the lamps, producing a dimmer display.

Integrated circuit *IC8* is a one-shot multivibrator which provides a clean 60-Hz pulse from the ac supply so that any noise on the power line can't cause false timing. This pulse is then coupled to *IC9* (a divide-by-six counter). To prevent contact bounce from the *RUN* switch from producing false signals, the switch signal is conditioned by *IC7*. The latter operates *IC10C* (an AND gate) to allow the 60-Hz signal to pass to the countdown circuits.

Seconds Decoder. In this circuit (Fig. 4), *IC12* is an up/down counter whose direction is controlled by *S6* in the control box. Note that the 1-Hz signal is applied to *IC12* through two sections of *IC10*. These gates control the up and down count lines. When the unit is set to time up, the 1-Hz clock is routed to pin 5. For count down, the input is to pin 4.

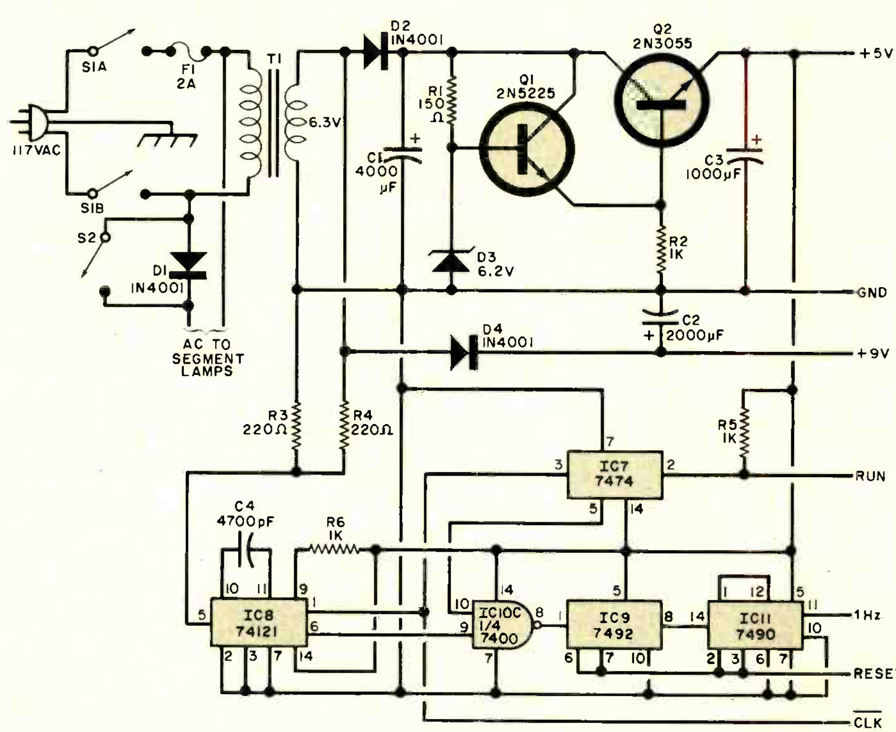


Fig. 3. Regulated 5-volt supply is used for TTL. The 60-Hz is counted down to produce 1-Hz clock pulse for timing.

PARTS LIST

C1—4000-µF, 15-V tantalum capacitor
C2—2000-µF, 15-V tantalum capacitor
C3—1000-µF, 15-V tantalum capacitor
C4—4700-pF, 100-V ceramic capacitor
C5 to C10—0.1-µF, 100-V ceramic capacitor
D1,D2,D4—Diode (1N4001 or similar)
D3—6.2-V zener diode
D5 to D33—1N914 diode
F1—2A fuse and holder
I1 to I30—117-V, 7½-W incandescent lamp
IC1,IC2,IC12,IC17—74192 decade up/down counter
IC3,IC4,IC13,IC18—8233 quad 2-to-1 multiplexer
IC5,IC6,IC14,IC19—7447 BCD-to-7-segment decoder
IC7—7474 dual-D flip-flop
IC8—74121 monostable multivibrator
IC9—7492 divide-by-6/12 counter
IC10—7400 quad 2-input NAND gate
IC11—7490 decade counter
IC15,IC16—74153 dual 4-to-1 multiplexer
IC20—7404 hex inverter
IC21,IC22—74H21 dual 4-input AND gate
IC23—7473 dual JK flip-flop
IC24—7410 triple 3-input NAND gate
K1 to K29—12-V reed relay
Q1,Q3—2N5225 transistor
Q2—2N3055 transistor
R1—150-ohm, ½-W resistor
R2,R5,R6,R11—1000-ohm, ½-W resistor
R3,R4—220-ohm, ½-W resistor
R7 to R10, R12 to R26—2200-ohm, ½-W resistor
R27—4700-ohm, ½-W resistor
S1—Dpst switch
S2,S4,S6,S9—Spst switch
S3—Four-decade thumbwheel switch (EECO 1776 or similar)
S5—Spst switch
S7—Normally open spst pushbutton switch
S8—Normally closed spst pushbutton switch
T1—6.3-V, 2-A filament transformer
Misc.—Heat sink kit for Q2; lamp sockets (30); hookup wire; 1" × 2" wood strips for display frame; pegboard for display back; translucent white plastic for display front, glossy white or silver paint; flat black paint; thin wood or metal strips for segment dividers; suitable metal chassis; multiconductor cable; press-on type; mounting hardware; line cord; perforated board; IC sockets (24); component mounting clips; etc.

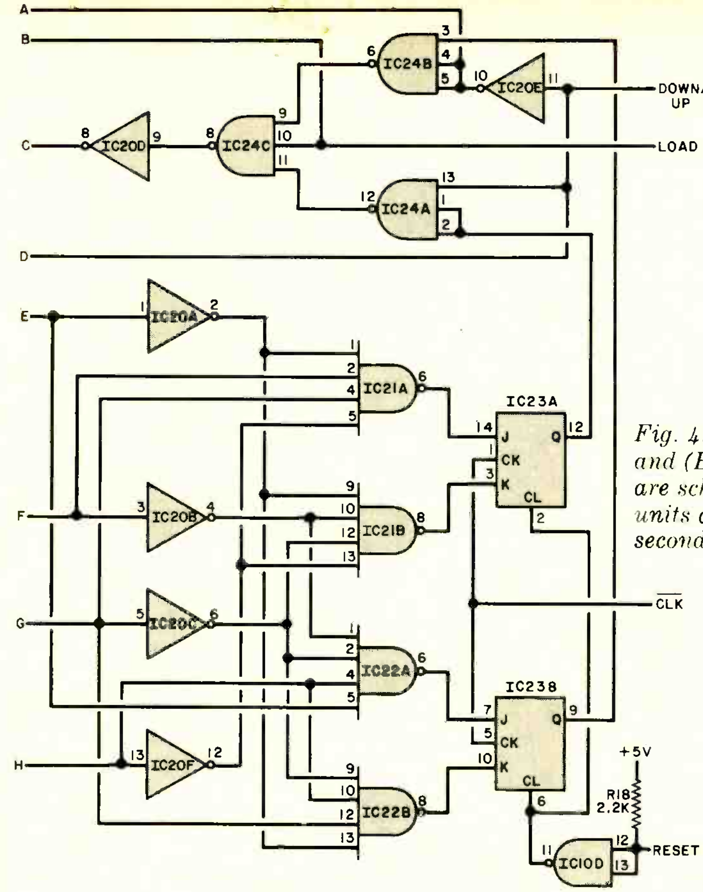
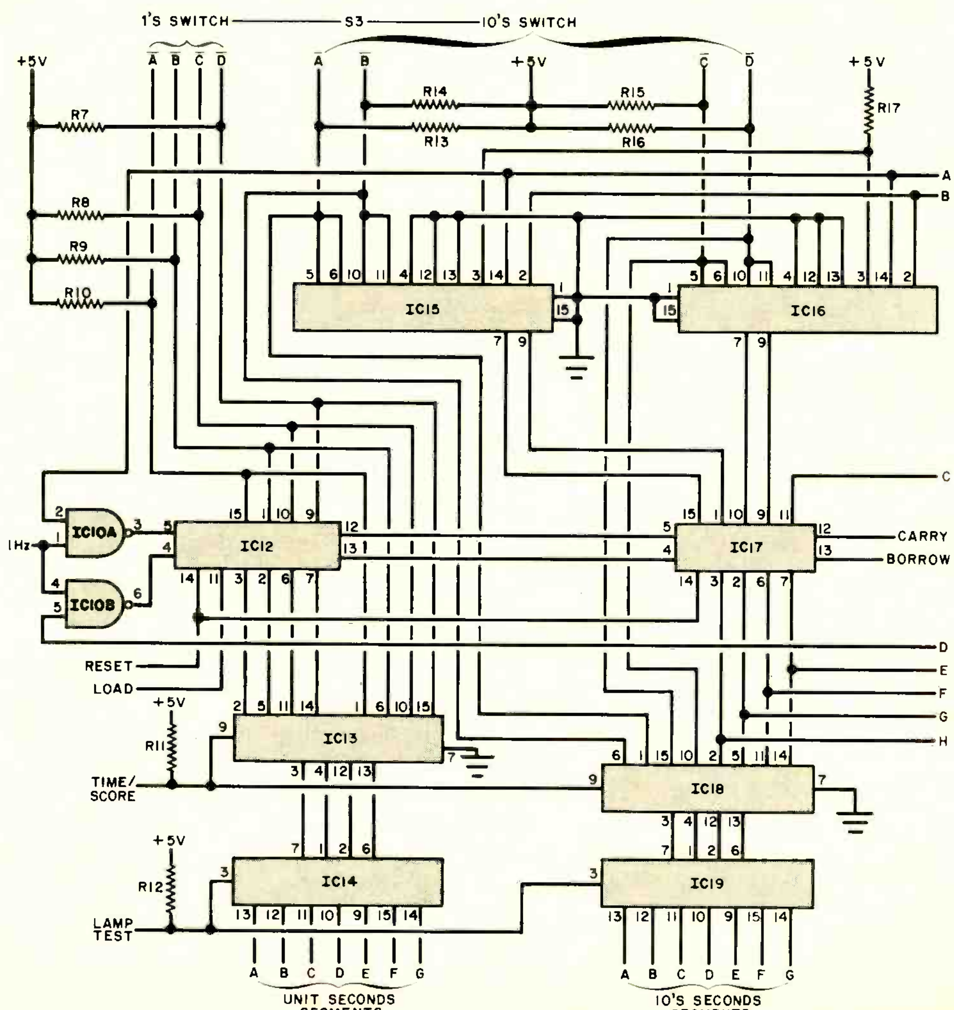


Fig. 4. (A), left, and (B), below, are schematics of units and tens of seconds stages.



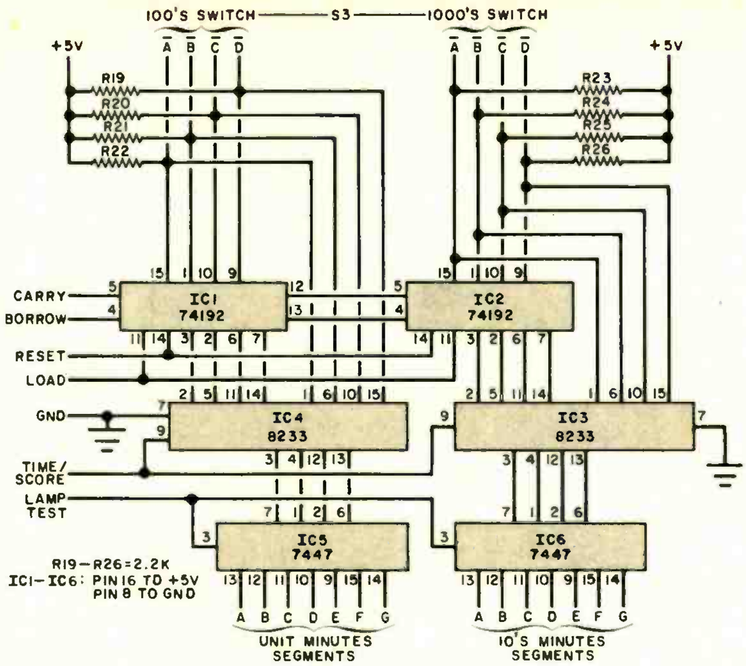


Fig. 5. Schematic of the units and tens of minutes stages. Part of circuit is also used to preset the score.

When pin 11 of *IC12* is low, the BCD present on pins 15, 1, 10, and 9 is loaded into the counter; and when timing begins, it starts from this preset code. The preset code is generated in the applicable thumbwheel switch in the control box.

When the counter is being clocked (up or down), carry and borrow lines cascade *IC12* to *IC17*, another decade up/down counter that forms the 10's of seconds counter. Each time *IC12* reaches a zero on its up count, an output pulse increments *IC17*. Likewise, on a down count, a borrow pulse is generated for every zero transition. Integrated circuit *IC13* acts as a four-pole, two-position switch. When pin 9 is low (indicating a score display), the BCD code from the thumbwheel switch is routed to *IC14*. When pin 9 is high, the BCD from counter *IC12* is routed to *IC13*. Note that changing the display from TIME to SCORE does not affect the timing operation. The selected output from *IC13* is decoded in *IC14* and converted to seven-segment format with the standard segment (A through G) designations.

Decade counters can be cascaded for as many digits as required. However, since a minute consists of 60 seconds (not 100), external circuitry must be added to *IC17* to make it a divide-by-six counter. This is not too much of a problem, except that both up and down counting are involved. For counting, up, the sequence must be 1-2-3-4-5-0-1-2 etc.; while for counting down, the sequence is 5-4-3-2-1-0-5-4 etc.

The feedback to produce this logic is implemented as follows (for the up count; the down count logic is identical). When the counter cycles from 5 to 6, we want it to replace the 6 with a 0. The 6 count from *IC17* is sensed by *IC21A* and the resulting high state presented to the J (pin 14) input of *IC23A* is stored. The high output of *IC23A* causes *IC17* to enter a load condition; and, at the same time, *IC14* and *IC16* (arranged as a four-pole, four-position switch) force a count of 0 into the counter. When this 0 is detected by *IC23A*, the load command is removed and the counter continues to time from the 0 state. While the invalid 6 digit would be displayed, it is only for 1/60 of a second and will not be observed. *IC15* is wired for a code of 0 (used during time up) and a code of 5 (used during time down), with the BCD

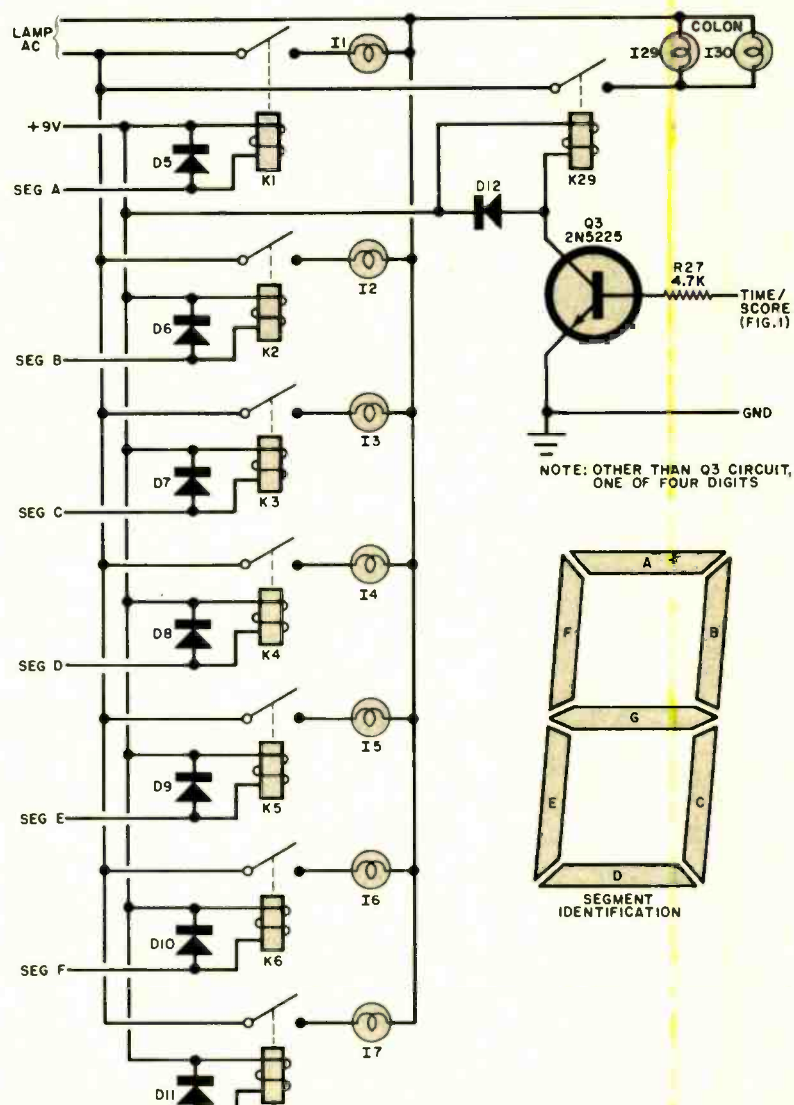


Fig. 6. There is one relay board for each digit in display. Relay circuit for colon display is on only one board.

code from the thumbwheel switch routed into the counter during the normal loading time.

The minutes and tens of minutes decoders are shown in Fig. 5. These are conventional circuits receiving their instructions from the control box.

Relay Board. The outputs of the BCD-to-seven-segment decoders (*IC14, IC19, IC5,* and *IC6*) are connected to their respective reed relay coils shown in Fig. 6. Other than the colon circuit, the reed-relay circuits are duplicated for each digit on the display. One side of each relay coil is connected to the nine-volt supply and the other to the decoder output. The diode across each coil eliminates the inductive spike that is generated when the segment drive voltage is removed. The switching is arranged so that each 117-volt segment lamp is placed in the circuit as its reed relay operates.

Transistor *Q3* saturates when the TIME switch on the control box is operated. This energizes *K29* and *I29* and *I30* to form the colon.

Horn Option. An additional circuit (not included in the prototype) can be used to sound a horn or buzzer at zero time (Fig. 7). The BCD code from each counter is routed to its own four-input NOR gate (7425). When all lines are at a zero level (zero time), the output of four-input NAND gate (7420) goes low causing the SR flip-flop composed of the two 7400 NAND gates to produce a high state. This state is retained until the RESET switch on the control box is operated. The output transistor is used to operate a relay whose switch contacts should have the capability of handling the current demand of the selected horn or buzzer. Any relay that can operate at 9 volts can be used and the transistor should have sufficient collector current (when saturated) to operate the relay coil.

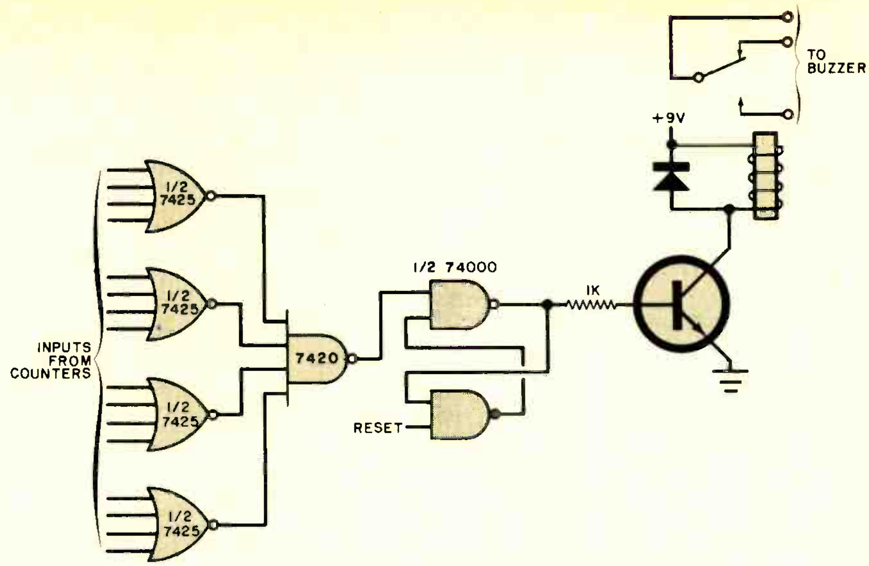


Fig. 7. This optional circuit can take the outputs from the counters and connect power to sound a horn accessory when the time is 00:00.

Construction. The electronic circuits can be wired on perforated boards, using sockets for the IC's. No particular arrangement is required. The circuits can be grouped on boards as shown in the schematics, but separate boards will be required for each relay system (Fig. 6). (Only one colon circuit is needed.) In the prototype, most of the circuits, including two sets of segment lamp drivers, were assembled in one aluminum box (12" × 17" × 3") with the other two segment driver circuits in a smaller box (8" ×12" ×3"). Other, possibly smaller arrangements could be used; but if overall size is not important, the extra room facilitates wiring and maintenance.

Since the logic circuits operate at low frequencies, special layouts are not necessary. However, since there are current spikes flowing in the 5-volt and ground leads, it is a good idea to insert bypass capacitors (0.1 μF) between each 5-volt line and ground. Decoupling all counter IC's is also a good idea.

The control box can be connected to the electronic circuits through a length of multiconductor cable, or the control box can be mounted on the larger package.

The display board can be constructed to fit your needs. The prototype was 48" long and 14" high. A wooden frame was constructed. The front face was made of translucent white plastic (available from most building supply stores) the same size as the frame. The face was prepared by masking out the four digits (seven segments each) and the colon on the back of the face. The back was then sprayed with flat black paint so that only digits and colon remained translucent.

Pegboard was used to mount the lights and provide ventilation. After cutting the board to size, it was painted glossy white (or silver) to add brightness to the lamps. A 7½-watt lamp socket was mounted at the center of each segment and wired as shown in Fig. 6. Pressboard or sheet aluminum was then used to separate the lamps for each segment so that the light did not spill over. Black masking tape can also be used to avoid light spill.

The front face can be secured to the frame in any way that will provide a good overall appearance. Keep in mind that the front may have to be removed to replace lamps. A light shade can be added over the top of the front to make the digits more visible in bright ambient light. It has been found that yellow lamps in the display provide better definition. However, avoid lamps rated at more than 7½ watts, or the reed relays may be damaged. If brighter lamps are needed, an extra driving stage (with SCR's or triacs) will be necessary.

Operation. The controls are as follows:

THUMBWHEEL SWITCH: Used to set in the time and score.

LAMP TEST: Lights all segments of all digits for testing.

LOAD: Timer is forced to time set by thumbwheel switches.

TIME/SCORE: In the TIME position, the display indicates the preset time and the colon is lit. In SCORE, the colon is dark and the display indicates the score preset on the thumbwheel switches.

DOWN: Makes the timer count down from preset time. If switch is not closed, time counts up from preset time.

RESET: Returns timer to all zeroes.

RUN: Starts timer. When opened, the timer stops. (This switch is useful for time-out periods.) ◈

Electronic Crossover Networks FOR HI-FI

What they are, how they work, and how you can design your own.

BY LEONARD FELDMAN

THE FIRST thing you're likely to learn about loudspeaker systems, whether through experience or by reading about them, is that different speakers are needed for different portions of the audio spectrum. You need a woofer to handle deep bass tones and a tweeter to handle the highs. Very often, one or more extra speakers are used to handle the midrange, upper bass range, and the super highs.

The analogy is often made between a multi-driver (speaker) system and a human choral group in which basses, baritones, tenors, mezzo-sopranos, and coloraturas are all needed to cover the spectrum of songs created by composers. The analogy is valid only up to a point. The chorus is "powered" by as many human beings as there are voices, each supplying the acoustic "watts" for his or her range of frequencies. The multi-driver speaker system, on the other hand, is usually powered by a single amplifier, feeding all drivers simultaneously.

The Crossover Network. With a single source of power energizing all of the drivers in a multi-speaker system, a device is needed to direct the proper portions of the audio band to their respective speakers. This device is usually a passive capacitor/inductor network.

In a simple two-driver speaker system, the typical circuit of a crossover network would look like that shown in Fig. 1A. The lower part of the network would deliver to the woofer low frequencies up to some predetermined point based on the values of inductor *L1* and capacitor *C1*. Beyond the

The Crown International Model VFX-2 two-channel crossover network has fixed 18-dB/octave rolloff.

selected point, all higher frequencies would be attenuated, or "rolled off," at a rate of 12 dB/octave by the lower portion of the network.

The upper portion of the network would be designed to pass all frequencies beyond a certain point, determined by the values of *C2* and *L2*. All frequencies below that point would be attenuated at a rate of 12 dB/ octave.

The response curves of both parts of the network are shown in Fig. 1B. The intersection of the curves is called the crossover point or frequency. Most crossover networks are designed so that the crossover point is 3 dB below (half) the levels of the frequencies within the pass band of each part of the network. Theoretically, if the crossover is at 600 Hz, the woofer and the tweeter will each produce sounds that are only half of that required at this frequency. The combined sound power would then equal that required by the original signal (½ + ½ = 1).

When the theory is put into practice, problems often develop. What is seldom mentioned concerning passive crossover networks is that even the best of them introduce time-delay distortion in the region of the crossover frequency. This occurs for a variety of reasons, including unequal phase delays between the two halves of the network, differences in response characteristics, differences in the velocity of the sound coming from the woofer and the tweeter, and many other variables.

Even if an ideal crossover network were designed, the manufacturer would still be faced with the problem of having to fabricate very large value inductances and buying low-loss, low-distortion fixed capacitors of high value. For example, if the speakers to be driven are rated at 8 ohms, *L1* and *L2* would have to be about 2 mH in inductance. Since low-frequency audio current will be flowing through *L1* within the pass band, the inductor must be made from fairly heavy wire so that its dc resistance will be negligible and the power dissipated within it will be minimal. The values for *C1* and *C2* would be greater than 30 μF, and complicating matters would be the fact that these capacitors would have to be nonpolarized.

Power and Harmonics. Modern recorded music has much more dynamic range than was contained in recordings of a few years ago. This means that audio amplifiers must be able to respond to sudden large transient peaks and deliver accurate replicas of high-amplitude signal waveforms without clipping or distorting. To make matters worse, most popular sealed-enclosure speaker systems require much more power for a given amount of sound output than did their large vented predecessors.

Suppose that during a given instant of music the amplifier is called upon to deliver a few cycles of 50-Hz tone at 20 volts rms. Assume that the amplifier will develop and deliver 50 watts of power to the speaker output terminals, to which an 8-ohm speaker system is connected. If the amplifier is rated at 50 watts/channel output power, the signal waveform might appear as shown in Fig. 2A.

Now, suppose that simultaneous with the 50-Hz tone a 1000-Hz burst, also at 20 volts rms, appears at the output of the amplifier. (Its waveform is shown in Fig. 2B.) How much power would the amplifier now have to deliver to the speaker load? If you said 100 watts, you are wrong. The combined 50-Hz and 1000-Hz tone waveform would look like that shown in Fig. 2C. At 40 volts rms, its amplitude would be exactly twice that of either waveform by itself.

Since power varies as the *square* of the voltage ($P = E^2/Z$, where P is power in watts, E is voltage, and Z is the impedance of the speaker load), the amplifier would actually have to deliver 200 watts to the load. An amplifier rated at 50 watts would have clipped the waveform horribly.

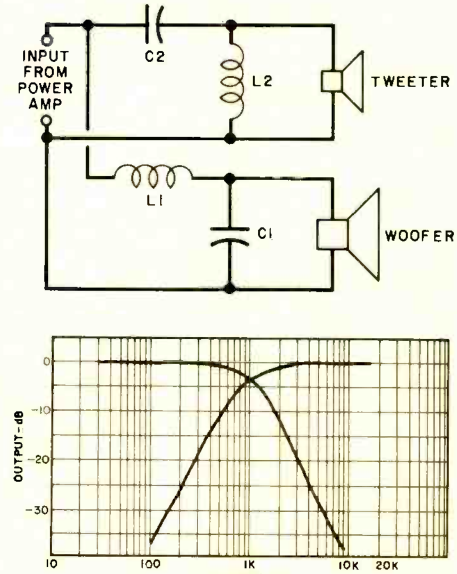
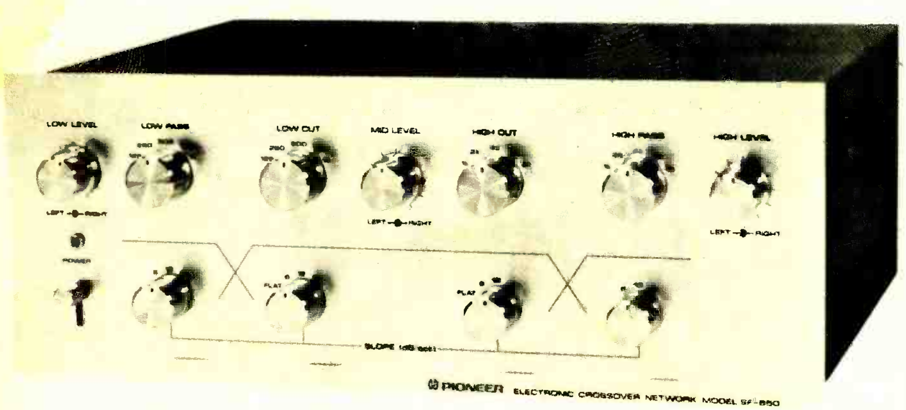


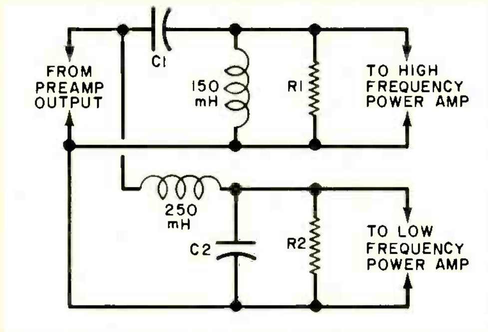
Fig. 1. (A) L/C crossover networks (12 dB/octave) and (B) response.

When an amplifier clips off the tops and bottoms of a musical waveform, it creates unwanted harmonics (multiples of the desired frequencies that were not in the original signal waveform). Worse still, since the harmonics might contain high-energy content and, being at higher and higher frequencies, some harmonics might pass right through the upper filter section of the crossover network and be fed to the tweeter. The network cannot discriminate between the high frequencies that are really part of the music and high frequencies generated by harmonic distortion, but the tweeter can. It is accustomed to accommodating *musical* high frequencies that usually contain much less energy than is ordinarily contained in the middle- and low-frequency registers. Faced with having to handle unnatural amounts of high-frequency energy, the tweeter either distorts badly or it burns out.



U.S. Pioneer Electronics Model SF-850 crossover network provides for selection of 6-, 12-, or 18-dB/octave slopes.

CIRCUIT VALUES FOR LOW-LEVEL NETWORKS



Frequency	C1 (μF)	R1 (ohms)	C2 (μF)	R2 (ohms)
1500 Hz	0.04	1500	0.06	1500
1200 Hz	0.062	1200	0.10	1200
1000 Hz	0.01	1000	0.15	1000
800 Hz	0.20	790	0.25	790
650 Hz	0.25	600	0.40	600

Clipping also causes a great deal of intermodulation (IM) distortion to appear at the output of the amplifier. IM distortion, consisting of the sum and difference between the two desired frequencies, is far more annoying to the average listener than simple harmonic distortion.

Suppose that instead of feeding both tones to the same amplifier we fed each tone to a separate amplifier and connected the woofer to one amplifier and the tweeter to the other amplifier. If each amplifier were rated at 50 watts or more output power, there would be no clipping. The woofer would receive pure 50-Hz energy, while the tweeter would receive the same amplitude 1000-Hz tone.

The sound power delivered to the listener would be exactly the same as if a single 200-watt amplifier, plus the conventional crossover network, had been used, and there would be no harmonic or IM distortion created at the output of either amplifier or driver element. This is the driving force behind the current switch to bi-amplification and tri-amplification, a technique that has been used in professional studio monitoring and other professional sound applications for years. Hi-fi enthusiasts who have recognized the many advantages of multiple-amplifier/speaker systems have also made the switch, usually by fabricating their own low-level filter networks from scratch.

Making your own filter (crossover) network is not a formidable task. The low-level network is introduced ahead of the power amplifiers in a system, usually between preamplifier and power amplifiers, and is therefore fed from a low-impedance source and drives a high-impedance load. As a result, capacitor values become quite low, while inductances—though greater in value—are not required to handle appreciable power and can be quite small in size.

In passive crossover networks that are connected between the amplifier and speaker system, the terminating impedance is the impedance of the speaker elements themselves. So, in such crossover networks, it is difficult to vary crossover frequency without changing the values of both the capacitors and inductors. In the case of low-level crossover networks working into the high-impedance input of an amplifier, an arbitrary resistance can be used to terminate the filter sections. It is, therefore, possible to work out a filter network for specific crossover frequencies using a fixed value of inductance and varying the values of the capacitors and terminating resistors.

Listed in the table are the component values for several popular crossover frequencies. These values apply to the crossover network shown. The resistances have been chosen to be low enough so that the parallel input impedance of the following power amplifiers will have little or no effect on the frequency response characteristic available at the woofer (low-frequency) and tweeter (high-frequency) outputs.

Low-level crossover networks have a further advantage in that the termination is purely resistive and unvarying. Part of the problem with passive networks introduced between the amplifier and speaker system is that they are presumed to terminate in a constant impedance when in fact the impedance of each driver coupled to the network varies widely with frequency. Consequently, the carefully chosen capacitor and inductor values seldom yield the optimized transfer characteristic shown in Fig. 1B. In fact, a typical curve might exhibit a somewhat random transfer characteristic as in Fig. 3.

The situation becomes even more complex when an attempt is made to design an 18-dB/octave passive crossover network such as shown in Fig. 4. The reason is that this filter con-

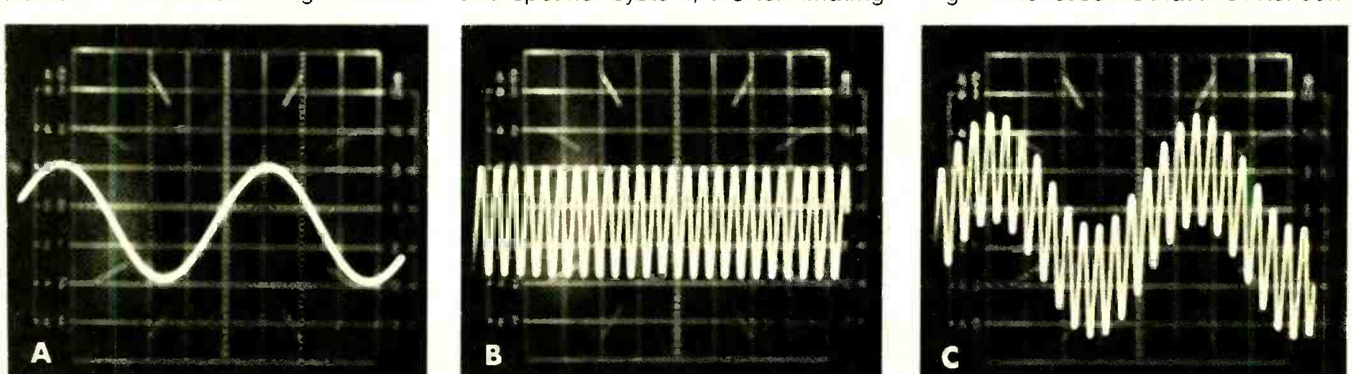


Fig. 2. At (A) is 50-Hz, 20-V amplifier output tone; (B) is 1000-Hz tone at same amplitude; (C) is (A) and (B) combined with twice the voltage and four times the power.

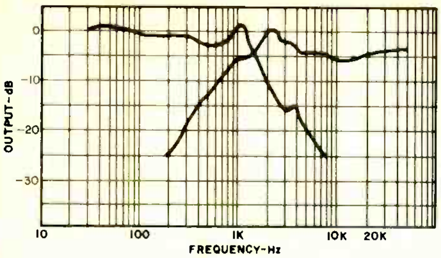


Fig. 3. Idealized response of Fig. 1 may actually be like this.

figuration is also based on the assumption that the termination is a constant-resistance load.

Attempting to make the crossover network variable to compensate for loudspeaker characteristics, listening environments, and listener preferences is an almost hopeless task. Many manufacturers resort to simple L-pad controls that provide a means for adjusting the level of the energy fed to the driver itself, after the crossover network. This further upsets the impedance relationships between the theoretically designed network components and their termination. It is also quite difficult to design a passive crossover network with one slope rate for attenuating the low-frequency signals and another slope rate for attenuating the high-frequency signals. But this is exactly the type of response that is often desirable with certain speaker combinations. For example, we might want to roll off the low frequencies fed to the woofer at an 18-dB/octave rate, while rolling off the middle or high frequencies fed to the midrange driver or tweeter at a more gradual 12-dB/octave rate.

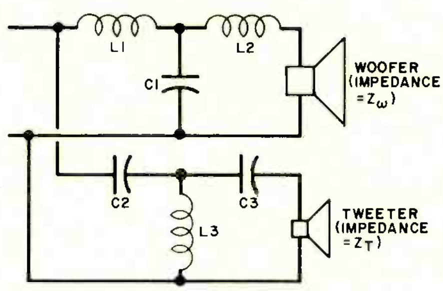
Setting Up a System. It is more difficult to set up a multi-amplifier system than it is to set up a single-amplifier system. Getting the volume-control settings for the woofer, mid-range, and tweeter amplifiers just right for a smooth energy response from the lowest bass to the highest treble requires more care and a sound level meter. (Very few of us can judge absolute sound levels at all frequencies without the aid of some metering device.) Most SLM's sell for hundreds of dollars, but Radio Shack has one — the No. 33-1028 — that retails for only $49.95.

Here is one way you might set up an active-crossover-network/tri-amplifier system using an FM tuner set between stations to serve as a wide-spectrum noise generator and an SLM. First, determine which are the proper crossover frequencies for the particular system and experiment with different slope rates for each of the two crossover points to determine which are the best.

With the other two level controls in the crossover system turned fully down in each case, adjust each level control in turn to obtain a random-noise level reading of about 80 dB on the SLM in each of the three bands. Carefully note the exact setting of each control as it is set.

Next, set all level controls to the noted positions, and play some music through the system. As you listen to the reproduced music, you might have to touch up the setting of one or two of the level controls to make the system response as flat and neutral sounding as possible. Differences in individual speaker efficiencies and gains in the three power amplifiers might require widely different control settings in each band, but this should be of no concern as long as the overall musical response is smooth and flat when you are finished.

Once the system is set up via the controls on the active crossover network, the volume control on the preamplifier then becomes the system's master volume control.



$$L1 = \frac{3Z_\omega}{4\pi f_c} \qquad C2 = \frac{1}{3\pi f_c Z_T}$$

$$L2 = \frac{Z_\omega}{4\pi f_c} \qquad C3 = \frac{1}{\pi f_c Z_T}$$

$$C1 = \frac{2}{3\pi f_c Z_\omega} \qquad L3 = \frac{3Z_T}{8\pi f_c}$$

Fig. 4. An 18-dB/octave network; formulas for calculating values.

The differences between single- and multiple-amplifier systems begin to become very obvious as volume levels are increased. At the level where a single-amplifier system would begin to have audible distortion, the multiple-amplifier system will still sound clean and distortion-free. Further increases in volume will only make the distortion more intolerable in the single-amplifier system, while the multiple-amplifier system will still be going strong.

There is one precaution you should take if you embark on a multiple-amplifier project. Normally, when a manufacturer installs a passive crossover network inside his speaker enclosure, he takes pains to make sure that all drivers are connected in phase. (This is particularly important when connecting woofers and midrange drivers which, if accidentally hooked up out-of-phase, will cause their outputs to cancel.) In the case of an electronic crossover network and assorted power amplifiers, there is no guarantee that the various speakers in a system are wired in accordance with the phasing indicated at the terminals.

Unless you are using identical power amplifiers for each driver—a rather expensive approach since in most cases the tweeter does not need nearly as much power as do the midrange speaker and woofer—different amplifiers might have different numbers of stages. Ordinarily, each stage produces a 180° phase shift of the waveform fed to it. So, you might well have one amplifier with an odd number of stages, with the result that the signals at their outputs will be 180° out-of-phase with each other.

Since you might not be able to interpret the number of stages merely by looking at the amplifier's schematic, the best way to solve the phasing problem is by trial and error. Even in a three-way system, there are only four possible ways to hook up the midrange speaker and tweeter with respect to the woofer. So, establish a connection to the woofer and then try the four combinations of midrange and tweeter connections one by one.

Play only a single (mono) system at one time to avoid confusion, and listen for the combination of connections that gives the fullest, widest-range sound. You will be able to tell when the system is in-phase just by listening to ordinary musical program material.

In Conclusion. Multiple-amplifier systems are not for everyone. In general, the loudspeaker systems chosen for multiple-amplification applications should be relatively efficient, which would make them large and unsuited for bookshelf placement.

If your present speaker systems are of the small bookshelf variety, chances are good that they are also sealed-enclosure units. If they are sealed, you might not want to tear into them—especially if they are expensive and still under warranty. ◈

IMITATING MUSICAL INSTRUMENTS

WITH SYNTHESIZED SOUND

How the sounds of traditional instruments can be produced electronically

BY DON LANCASTER

IN A previous article ("Timbre and Voicing Circuits for Electronic Music," June 1975), we discussed techniques for altering the tonal quality of a basic waveform to produce the desired musical effects. Now, we can consider specific ways of synthesizing the sounds of given traditional musical instruments. Once we know how to accomplish this, we can go on to designing our own "voices" for the instruments. (Imitating an instrument is called "voicing." Proper voicing can make an electronic instrument, while improper voicing will break it.)

As a gross and crude approximation to classes of instruments, you can use sine waves with slight amounts of second-harmonic content to imitate flutes, piccolos, and bland tibia organ pipes. Sawtooth waveforms, with either additional high-pass filtering for brightening or low-pass filtering for softening or mellowing, produce string-like tones. The same sawtooth waveforms passed through a fixed resonant bandpass filter circuit or two will produce a horn-like resonance.

Square waves with some softening and perhaps some even-harmonic content added are useful as a source of "hollow" or "woody" tones, such as those produced by the clarinet and other woodwinds and some stopped organ pipes. Lower piano notes and some organ pipes, or diapasons, have strong second harmonics, obtained by adding extra energy (usually more than is available in an unmodified sawtooth) at twice the fundamental frequency. Filtered noise forms the basis for many of the percussion instruments, particularly drums.

While any of these techniques is a good place to start and can produce a "clarinet-like" or a "trumpet-like" tone, they will all sound less than real. So, let us look at some basic voicing principles to find out what is needed in synthesized voices to make them sound more realistic.

Principles of Voicing. Successful voicing schemes must customize both the envelope and the timbre to the instrument. Having a fixed envelope shape and changing only the timbre is just as bad as having a fixed timbre and changing only the attack, sustain, and decay characteristics of the voice. Admittedly, some instrument limitations are somewhat tolerant of variations in envelope and timbre, but to do the job properly both envelope *and* timbre must be controlled, in addition to adding special effects.

Successful voicing cannot be accomplished with resistors and capacitors alone. Active electronic filters or inductors are usually needed. The formant or fixed-filter method (or a voltage-controlled filter with a fixed input reference) is normally best for synthesizing traditional musical instrument sounds, although a tracking filter or vcf is useful for changing harmonic content during note decay and for sympathetic resonance effects.

Precise control of many harmonics, preferably the first 30 or so involved, is required for successful voicing. Synthesis techniques that use or build up only the first few harmonics are doomed to failure. Harmonics 30 dB and more down from the fundamental can have a significant effect on overall tone quality.

Voicing must be accomplished in register to be successful. If a trumpet has a certain acoustical range, the filtering to imitate that range should handle only those notes a trumpet would normally cover. Extensions out of register on the high or low end will sound too bright or too shallow to be realistic.

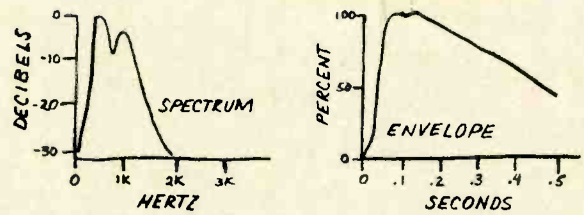
Voicing must not be spread too thin if it is to be successful. With modern low-cost operational-amplifier active filters, there is no reason to use only one active filter for an entire voice register. By customizing the filtering to one-third or one-half octave steps and using multiple filters, a much better

continued on page 40

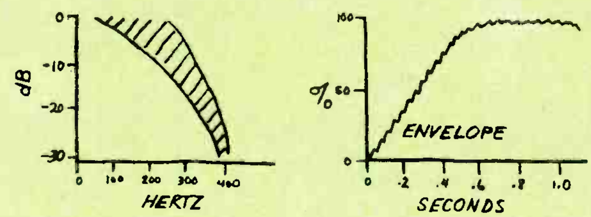
CHARACTERISTICS OF MUSICAL INSTRUMENTS

(Numbers in parentheses give the instrument's range, indicated by note and octave on the piano keyboard.)

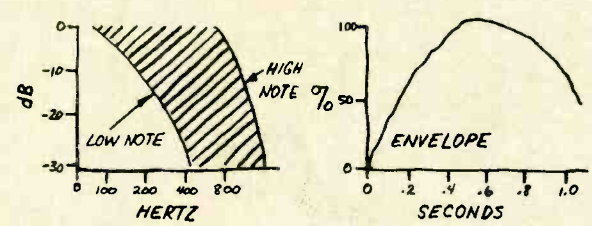
Bassoon (A#1-D#5): Typical of the bassoon are its moderate Q resonances at 550 and 1150 Hz. Dropoff of higher harmonics is very rapid above the second peak. The blip-free attack lasts 50 ms and sustain is 60 ms in duration, followed by a gradual noise-free decay.



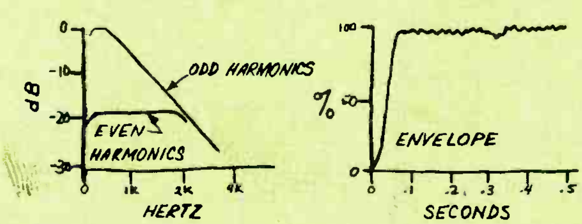
Bass Violin (E1-E3): Characteristic of the bass violin is its range through an almost pure sawtooth wave on the low end (50 Hz) through a steeply low-pass-filtered sawtooth on the high end (250 Hz). The rise and decay times are both 0.5 s in duration. A slight low-frequency noise modulation appears on the envelope.



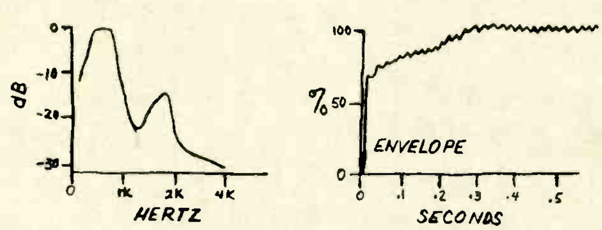
Cello (C2-E3): The sound from the cello is obtained by a predominantly sawtooth waveform that is moderately low-pass-filtered. Filter cut-off becomes steeper and must move up with increasing frequency. Very gradual attack and decay, with decay becoming more abrupt on the higher notes. characterizes the envelope.



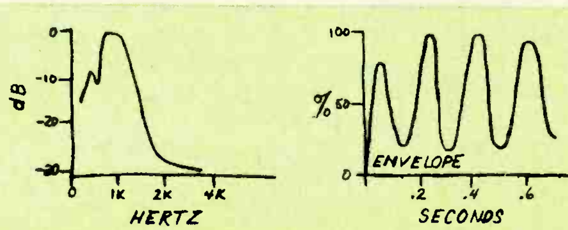
Clarinet (D3-F6): The sound of the clarinet consists predominantly of odd harmonics, although a low level of even-harmonic content must also be provided. Even harmonics are somewhat stronger for the upper notes. The rise time is about 50 ms, and a 10% modulation of low-frequency random noise adds to tone character.



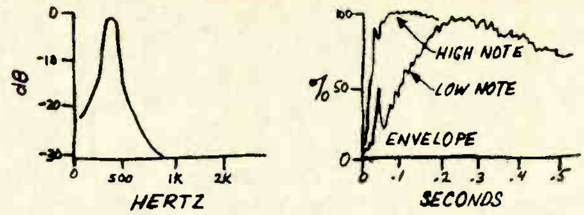
English Horn (G#3-C#6): A high, flat-topped resonance at 600 Hz and a narrower resonance at 1900 Hz are characteristic of the English horn. The dip between the two resonance peaks, located at 1300 Hz is some 26 dB down from the lower-frequency resonance peak. The two-step rise time is 5 ms to 60% amplitude and then more gradually to maximum at 400 ms. The final attack and sustain have a characteristic 10% random-noise amplitude modulation.



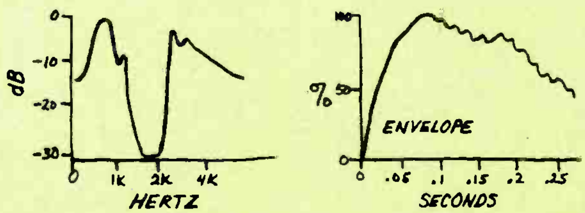
Flute (C4-C7): The flute is another double-resonance instrument with a minor resonance peak located at 300 Hz and a stronger peak at 600 Hz. Harmonics are very weak. The rise time is about 50 ms. A very pronounced (50-75% of maximum) tremolo of 5 to 7 Hz is present.



French Horn (B1-F5): Has a single resonance at 500 Hz and much narrower bandpass than the trombone. Risetime varies between 100 and 20 ms, with an attack blip on lower notes.

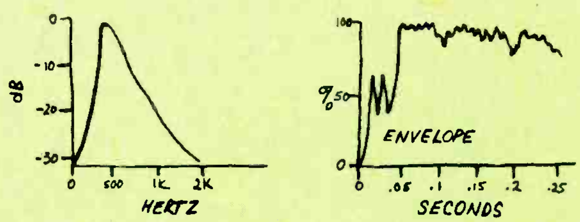


Oboe (A3-G6): A very complex spectrum structure is characteristic of the oboe. It has a 1050-Hz resonance peak, a 30-dB dip at 200 Hz, and a final high-pass resonance at 3000 Hz. Much more harmonic energy is in the oboe's sound than in other instruments. The rise time is 60 ms, sustain time is zero, and decay begins 100 ms after the start of the note. The envelope starts out relatively clean but then takes on a 10% noise modulation during the decay period.

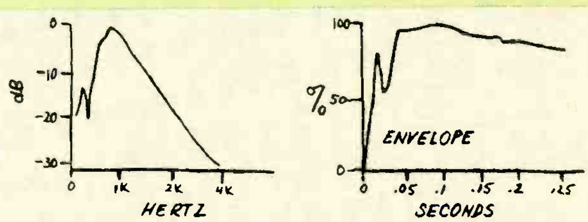


Piano (A0-C8): The absolute minimum needed to create a piano voice is three tone sources with non-harmonic overtones, combined with sympathetic-resonance buildups and interactions of harmonic overtones with time for each note. The waveform structure for the piano note is too complex to be shown here.

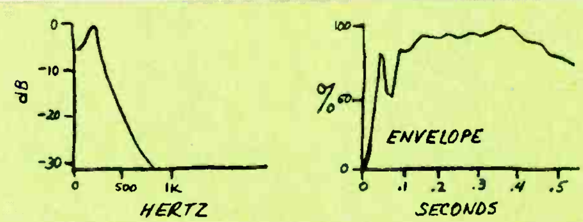
Trombone (E2-B4): The trombone's frequency spectrum curve shows a single resonance peak at 475 Hz whose rise time is on the order of 60 ms. The envelope has a very pronounced double blip on the leading edge. Portamento or frequency modulation is needed for slide effects.



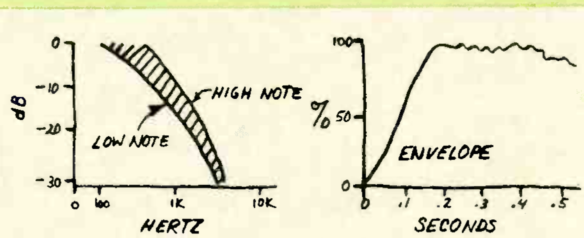
Trumpet (E3-A#5): The trumpet's single resonance peak falls at 1150 Hz. Its envelope displays a characteristic horn blip or impulse change in amplitude. The rise time is 50 ms.



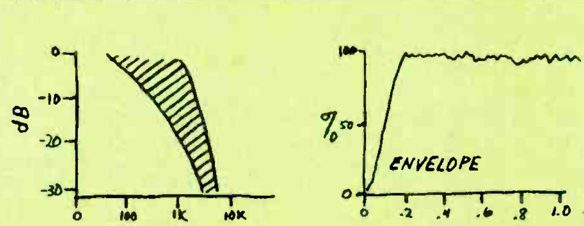
Tuba (F1-F4): The tuba's voice has a single resonance peak located at 275 Hz. A very pronounced horn blip is on the attack edge of the envelope. Rise time is 400 ms.



Viola (C3-E4): The voice of the viola ranges from a brightened, high-pass-emphasized sawtooth on the low end at 140 Hz through a slightly low-pass-filtered sawtooth on the high end at 750 Hz. The attack time is 150 ms, followed by a 150-to-300-ms decay time. The envelope exhibits some low-frequency noise modulation.



Violin (G3-C6); The violin's voice ranges from a brightened high-pass-emphasized sawtooth on the low end at 200 Hz through a slightly low-pass-filtered sawtooth on the high end at 1500 Hz. The attack time varies between 80 and 200 ms, and a 6- to 8-Hz frequency-modulation vibrato is optionally present.



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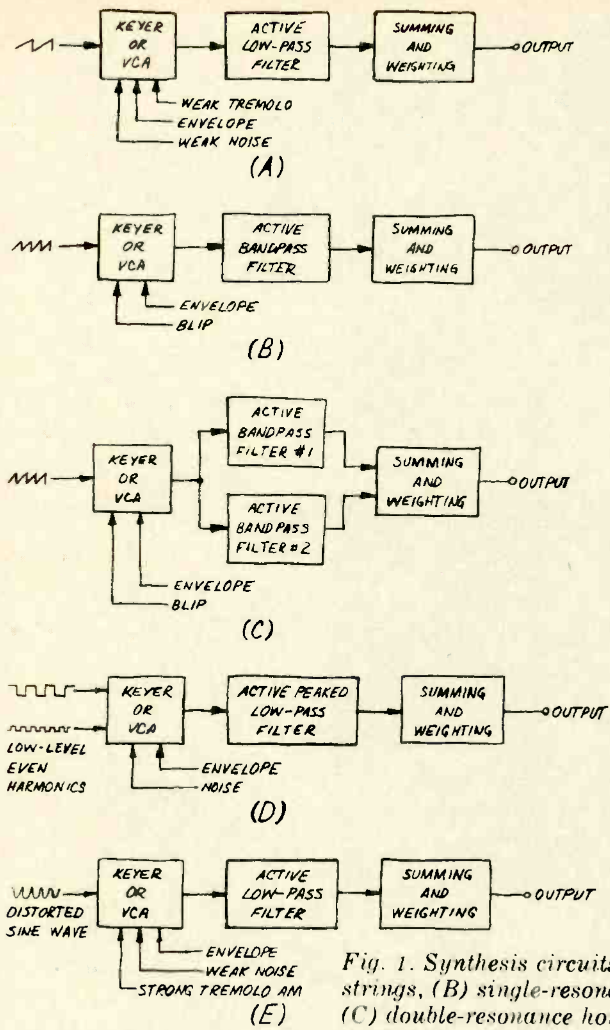


Fig. 1. Synthesis circuits: (A) strings, (B) single-resonance horn, (C) double-resonance horn, (D) woodwind, (E) flute or piccolo.

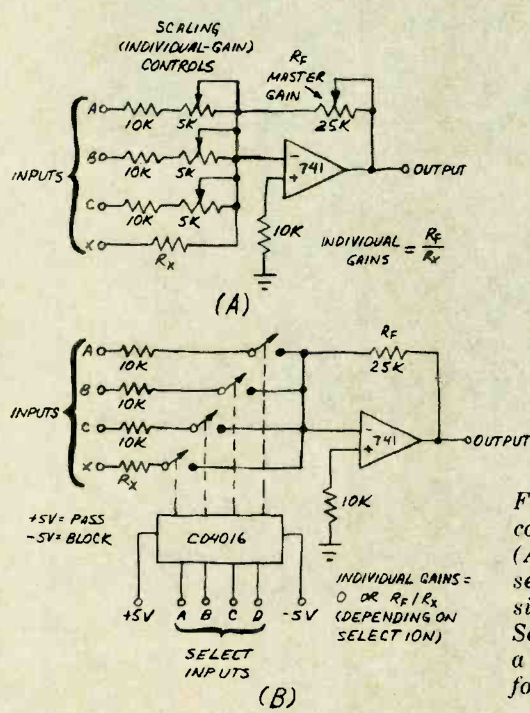


Fig. 2. Mixing and combining voice outputs: (A) Summing and scaling several sources to a single output. (B) Selecting voices with a CMOS analog switch for stops or presets.

job can be done at negligible additional cost. An alternate approach in monophonic instruments is to use a bank of vcf's and shift their parameters as needed to get the desired effect. Multiple or movable filters greatly ease the loudness balancing (scaling) problem from note to note.

One must recognize that instrument sounds are norms and not absolutes. A bass violin sounds quite different when played in a tiled room than it does in a concert hall. It sounds even more different in an anechoic, or acoustically "dead," room. Furthermore, the model and age of the instrument, its quality, the ambient temperature and humidity, mood of the performer, and context in which the instrument is used all combine to produce the final effect of the sound heard.

Finally, successful voicing cannot be accomplished by an engineer alone. Nor can the musician alone do the job properly. It must be done by both people contributing their best efforts.

Instrument Sound Synthesis. The accompanying box illustrates some of the characteristics essential to a number of popular traditional musical instruments. Bear in mind that the information given in the box is only a starting point in designing a system capable of realistic instrument voicing.

For most of the instruments listed, you can use a system setup like one of those shown in Fig. 1. In general, start with a sawtooth waveform and pass the signal through a suitable active filter or two. Use similar circuits for each octave or, better yet, each half- or third-octave increment. This permits each portion of the register to be weighted for optimum voicing and volume level. Where a clarinet voice is needed, a square wave or two sawtooths are used as an input. (A fundamental-frequency and minus one-half of the second harmonic-frequency sawtooths can be summed to obtain a square wave. Filtering then takes over.)

You can combine and mix various instrument voices, either in the preset form of the synthesizer or in the stop-tablet form of an electronic organ, with the aid of one of the circuits shown in Fig. 2. The CMOS analog switch in (B) is ideal for voice switching because it draws essentially zero control-line power. ◈

USER'S BUYING GUIDE TO CB BASE STATIONS

What to look for in terms of specifications and performance.

BY JOHN J. McVEIGH, Assistant Editor

MORE and more people are turning to the "no test" 27-MHz Citizens Band for personal and business communications. Growth of the band has been geometric, with over 6 million two-way CB radios said to be in current use by U.S. citizens.

The majority of CB users with dc-powered mobile transceivers also install ac-powered units in fixed locations—homes, factories, depots, and marinas. These "base stations" differ physically and, in many ways, electronically from mobile transceivers. Additionally, the more sophisticated base station antennas provide extra receiving and transmitting "power" for base station equipment.

Base Station Transceivers. A CB base transceiver is usually larger than a mobile unit, is designed for desk-top operation, and uses ac line power. However, the distinction is not as clear as it once was. Many new models now feature dual power supplies (12 V dc and 117 V ac) and have mid-sized enclosures. They also have other features common to mobile and/or base units.

Base stations, of course, can be used to talk to mobile units, or for communicating with other base stations. There are AM-only and AM/SSB types. The latter are becoming increasingly popular.

Typically, base stations have more complete metering and control facilities. Some have built-in power and/or SWR meters, dummy loads, and peak modulation meters, in addition to the S/r-f (relative) output meters found in most mobile rigs. Many have speech processors to improve intelligibility. These circuits raise the average modulation level of the signal, thereby boosting the rig's "talk power." Others which don't have this feature frequently incorporate it in matching desk microphones.

Base stations often have a battery of controls which make operations easier and more effective. An r-f gain control is one example. It is useful in helping the transceiver cope with very strong signals which overload its automatic gain control (agc). The signal strength is reduced to a level the rest of the transceiver can handle. "Delta tune," also found in the more sophisticate mobiles, allows one to tune the receiving frequency slightly off center-channel to compensate for variations in the transmitting frequency of other transceivers. Tone controls are also found on some base station rigs.

Base stations offer a number of other convenience and performance bonuses not often found in smaller mobile units. For example, some have built-in digital clocks with turn-on alarms, and most have built-in speakers. Another popular feature is the channel 9 priority monitor found in some of the latest crop of transceivers. These units incorporate a separate receiver permanently tuned to channel 9 (the emergency frequency). When an emergency signal is transmitted from a point within the base station's normal range (20 to 30 miles), it interrupts whatever was on, so that the priority message can be heard.

SPECIAL REPORT ON CB TRANSCEIVERS

Some transceiver manufacturers have carried this idea further by building complete vhf Public Service monitors into the CB equipment. For a person active in REACT or working closely with local authorities during emergencies, this feature is invaluable. Another performance extra commonly found in base stations, as well as better mobile transceivers, is the digital noise blanker. This circuit is placed in the r-f portion of the receiver, cutting out any short-duration noise spikes. It works so fast, though, that you don't "miss" any of the desired signal. These r-f noise blankers are much more effective than the common diode-type noise limiters, which can only shave off the top-of-signal noise. Some base station units combine both types of noise reducers.

Voice-operated control (VOX) operation is more commonplace with base station equipment. VOX automatically turns the transmitter on when you start to speak, and then flips back to receive after a short holding period. The VOX DELAY control allows the user to vary this holding period. Operators usually make it long enough so that the switchover relay won't chatter between the words in one phrase or sentence, but short enough so that they'll be back on RECEIVE fairly quickly without missing the first few words of the transmission. The VOX SENSITIVITY control sets the point where the VOX will trip. It is usually adjusted so that the operator's voice activates the system, but fainter background noise or voices will not.

Squelch, found on almost all transceivers, is analogous to VOX, but it works on receive instead of transmit. The SQUELCH SENSITIVITY control allows you to keep the receiver muted except when a signal above a certain threshold appears at the antenna.

If you have any need to talk to a group of people in your immediate vicinity, you'll welcome public address (PA) facilities built into some transceivers. In general, the PA power output of a CB base transceiver is 4 to 4½ watts, which is enough to drive a high-efficiency speaker to reasonable paging levels.

Finally, there are certain cosmetic differences between base and mobile rigs. Some base stations have large "On The Air" signs which light up when the transmitter section is active. Most base stations have larger knobs and dials than mobiles, making operations easier on the eyes. Sleek console designs, attractive anodized panels, and walnut cabinets will often be appreciated by the XYL!

Circuits. Base and mobile transceivers also have internal (circuit) differences. While the trend is toward completely solid-state designs (including IC's and FET's), some hybrid (tube and transistor) and vacuum-tube units are still being manufactured. Although the high-voltage and filament supplies required by tubes are a disadvantage in mobile applications, they are easily derived from base station ac supplies. Tubes, moreover, can offer competitive performance to transistors in r-f circuits, and their mere presence should not detract from an otherwise fine rig, assuming its features, performance and price are attractive.

The front ends of base transceivers are generally not as "hot" as those in mobile units. This is not a drawback, though, because most base antennas are more efficient than mobile whips and thus provide the receiver section with more signal to work with.

SSB. This year you'll find more single-sideband (SSB) transceivers in the marketplace. SSB is a much more efficient mode of communicating. It requires only half of the spectrum space, thereby doubling the number of available channels. SSB rigs with AM (double sideband) provisions provide 69 channel choices. In truth, though, only operation on 23 or 46 channels is possible. If everyone in your area is on SSB, then 46 "subchannels" are available—23 upper sideband (USB) and 23 lower sideband (LSB). Two SSB stations can operate on the same channel without interference if one uses LSB and the other USB. However, if strong AM stations dominate the channels in your area, you'll experience interference from them no matter which sideband you are on.

SSB has a 6-dB efficiency advantage over AM. This means that only one watt of SSB output will do the same job of communicating as four watts of AM. As in all things, you don't get something for nothing. In this case, the extra "talk power" that SSB will deliver is the product of a more complex circuit. The extra engineering required to produce an SSB transceiver will generally be expressed in a higher pricetag. You'll find that the increased performance is well worth the extra investment. Further, there appear to be more serious communicators on SSB, making CB more enjoyable.

Both the transmitting and receiving sections of an SSB rig are more complicated than their AM counterparts. The transmitting circuits must filter out both the unwanted sideband and the carrier before they reach the final amplifier. In most cases, these are "set-and-forget" circuits that need no attention after being adjusted at the factory. In fact, on TRANSMIT, you really can't tell the difference between an AM and SSB transceiver. Both are operated in exactly the same way.

RECEIVE is a different story, however. Tuning in an SSB signal requires a practiced touch. Otherwise, the operator you're listening to will sound like a weird variation on Donald Duck. A "clarifier" or fine-tune control is used to lock-in the voice properly.

In general, you'll find that SSB receiving circuits are more sensitive and more selective than those for AM. Briefly, this means that they can pull in weaker stations even if there are stronger signals on a nearby frequency.

Specifications. Many people who are in the market for a CB base transceiver become very confused by specifications. So, it pays to have an understanding of the key terms. They tell you a good deal about the performance you can expect from a particular transceiver. Here are a few of the more important specifications. (For a more complete overview of CB transceiver ratings, see "CB Specifications Made Easy," POPULAR ELECTRONICS, March 1975.)

Receivers. One of the most important specifications for a receiver is its *sensitivity*. This relates to how strong a signal must be in order to be heard at a given level above the background noise (some of which is generated inside the receiver). Typically, this figure will be 0.5 μV in SSB units and 1 μV in AM rigs, (the lower the better), for a S/N ratio of 10 dB (the higher the better). *Selectivity*, in its broadest sense, tells how well the receiver can differentiate between the desired signal and another one on another frequency. It is given in terms of the receiver's response (in dB) to a signal whose frequency is not on the center of the channel. (A "narrow slot," down to 2.5 kHz, and a greater negative dB number are desirable.)

A typical figure for an AM transceiver is −6 dB at 6 kHz (±3 kHz) and −40 dB at 20 kHz (±10 kHz). This means that a signal 3 kHz away from the frequency to which the receiver is tuned would have to be 4 times stronger than the desired signal to appear equally strong. At 10 kHz, the unwanted signal would have to be 100 times stronger than the desired one. SSB rigs usually have more selective receivers than AM units, since they must reject signals on the other sideband of the channel being used.

There is a whole group of specs related to selectivity, such as adjacent channel rejection, unwanted sideband suppression, image rejection, etc. Each tells how well the receiver can ignore unwanted signals at frequencies removed from the center of the channel.

A final specification of interest is the receiver audio output, expressed in watts at a given level of distortion. Anything up to 1 watt at 10% distortion will be adequate in most cases. Frequency response is limited to the voice band (500 to 3000 Hz) since that is all the range needed.

Transmitter. The primary spec that CB'ers use in judging a transceiver's transmitting section is its *r-f power output*, expressed in watts. Almost all base station transceivers have rated outputs equal to the 4-watt legal limit. Don't look upon this as absolutely necessary to a good rig, though. You won't be able to hear the difference between two transceivers (other things being equal) if one puts out 3 or 3.5 watts and the other runs 4 watts.

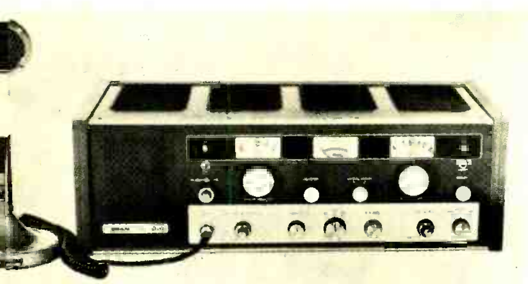
Something that is just as important as the total output is what can be called *undesired products*. This refers to those parts of your transmitted signal at other frequencies than the desired one. They can take the shape of harmonics (high-frequency energies which can get you into trouble with the FCC and/or your neighbors—they are a prime cause of TVI) or in-band components. These signals cause interference to other CB'ers and rob *you* of usable output. All such undesired products, whether they are called splatter, intermodulation distortion products, harmonic distortion, unwanted sidebands or carrier, or harmonics, should be at least 25 to 50 dB below the level of the desired signal.

Frequency stability tells you how close your signal is to where it's supposed to be (the channel center). Almost all rigs are rated a percentage slightly better (lower) than the legal limit of 0.005%. *Modulation percentage* indicates how fully you are putting the carrier to work in conveying intelligence. The optimum figure is 100%, and most rigs will be rated between 90 and 100%. There is no discernable difference between the two figures. It's important not to go over 100%, however, since overmodulation causes splatter interference to other CB'ers, and even TVI!

In Conclusion. Here are some final purchasing considerations. Be sure that the CB rig you buy is *type accepted*. This means that the FCC has approved it for CB service. All transceivers licensed for the first time on or after November 22, 1974 must be type accepted. Those transceivers licensed before this date can be used until November 23, 1978, but must be taken off the air then.

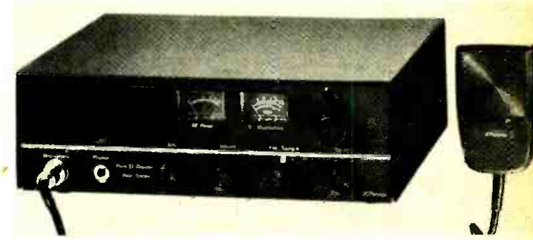
Another area to look into before you buy a rig is its method of frequency generation. If it uses separate crystals for each transmit and receive channel, does it include them for all channels of interest? Sometimes they don't, and it's necessary to shell out roughly $10 for each additional channel ($5 for receive, $5 for transmit crystals). If a frequency synthesizer is used in place of crystals, are all desired channels covered?

Finally, consider the total cost of the rig with all the operating features and conveniences you want—VOX, external speaker (if needed), desk mike, r-f wattmeter, etc. In some cases, these are available only as options, and will raise the final package price considerably. For some, extras are frills; for others, they are most desirable. ◈



Tram Diamond D201 (AM/SSB)

Regency CR-142 (AM)



JC Penney Pinto 23B (AM)

Dynascan Cobra CAM-89 (AM)

Sonar FS-23 (AM)

SBE Trinidad (AM)

BASE STATION EQUIPMENT DIRECTORY

Manufacturer and Model	Retail Price ($)	Dimensions (in.) WxDxH	AM/SSB	Sensitivity (___ μV at ___ dB S/N) AM	Sensitivity SSB	Selectivity (−___ dB at ± ___ kHz) AM	Selectivity SSB	Adj. Channel Rejection (−dB)	Image Response (−dB)	SSB Carrier Suppression (−dB)	Delta Tune Range (± ___ kHz)	Special Features
Browning												
Golden Eagle Mark III SSB/AM	695.00	2 units, each 15.5 x 9.88 x 6.75	Both	0.3 @ 10	0.15 @ 10	70 @ 10	NA	70	56	70	0.7 Tr. 1.5 R.	Spkr. switch, anl, vfo, SWR meter, spot switch, incl. mike.
Dynascan												
Cobra CAM-89	240.00	13 3/8 x 12 5/8 x 5 3/4	AM	1 NA		6 @ 4 40 @ 20		80	30		1.5	Mike gain, anl, noise blanking, PA, mod. & r-f meters, incl. mike & crystals.
Cobra 135	450.00	13 7/8 x 12 x 5 7/8	Both	0.5 NA	0.25 NA	6 @ 5 50 @ 20	6 @ 2.2 60 @ 5.0	80	50	40	0.6	SWR meter, dig. clock, noise blanking, r-f gain cont., mike gain, incl. mike & crystals.
Cobra 139	395.00	13 3/8 x 12 5/8 x 5 3/4	Both	0.75 NA	0.25 NA	6 @ 4.2 60 @ 7.0	6 @ 4.2 60 @ 7.0	80	50	40	0.6	Sep. mod. & r-f meters, switchable nl, noise blanking, mike gain, r-f gain cont., incl. mike & crystals.
E.F. Johson												
Messenger 250	229.95	11 x 9.8 x 5.4	AM	0.5 NA		6 @ 6		50	10			PA, speech compression, S/r-f meter, ext. spkr. provision.
Messenger 132	259.95	13 3/4 x 9 x 5 1/4	AM	0.5 NA		6 @ 6		50	10			Radiotelephone handset, PA, speech compression, S/r-f meter, ext. spkr. provision.
Messenger 124M	339.95	11 x 10 x 5.5	AM	0.5 @ 8		6 @ 7		50	50			Dual receiver for monitoring, 4-way meter, mike gain & nl controls, PA, speech comp.
Fanon/Courier												
Centurion SSB+	550.00	16 3/4 x 16 x 7 1/4	Both	0.25 @ 10	0.15 @ 10	6 @ 2.5	6 @ 2.1	80	55	55	0.6	S/r-f & VSWR meters, clarifier, dig. clock, PA, noise blanking incl. mike & crystals, ac/dc.
Conqueror II	260.00	15 1/2 x 10 1/4 x 5 1/2	AM	0.5 @ 10		6 @ 3		60	50		1.5	S/r-f meter, PA/CB, dig. clock, anl, incl. mike and crystals, ac/dc.
Caravelle II Fanfare 880	230.00	15 1/2 x 10 1/4 x 5 1/2	AM	0.5 @ 10		6 @ 3		60	50		1.5	S/r-f meter, PA/CB, anl, incl. mike & crystals, ac/dc.

Hy-Gain 623A (AM/SSB)

Lafayette Telsat 925 (AM)

Browning Eagle Mark III (AM/SSB)

Teaberry T-Scout (AM)

Royce 1-640 (AM/SSB)

Realistic TRC-57 (AM/SSB)

Pace 1000B (AM/SSB)

Pearce-Simpson
Pussycat 23 (AM)

E. F. Johnson Messenger 132 (AM)

Kris 23+ (AM)

Fanon/Courier Conqueror II (AM)

Midland 13-887 (AM)

PAL Electronics Roadrunner 23 (AM)

Manufacturer and Model	Retail Price ($)	Dimensions (in.) WxDxH	AM/SSB	Sensitivity (___ μ V at ___ dB S/N) AM	Sensitivity SSB	Selectivity (— ___ dB at ± ___ kHz) AM	Selectivity SSB	Adj. Channel Rejection (—dB)	Image Response (—dB)	SSB Carrier Suppression (—dB)	Delta Tune Range (± ___ kHz)	Special Features
Hy-Gain 623A	595.00	11 13/16 x 11 1/4 x 5	Both	0.5 @ 10*	0.25 @ 10*	6 @ 3.5	6 @ 3.5	60	60	45	0.75	SWR/power/S meter, a-f/r-f gain contrs., noise blanking, anl.
673A	239.95	13 1/4 x 11 x 5	AM	0.7 @ 10*		6 @ 6		50	50		1.5	Anl switch, mike preamp, TVI filter, incl. mike, var. tune.
JC Penney 981-6235	169.95	11 7/16 x 8 11/16 x 3 9/16	AM	0.5 @ 10*		NA		100	NA		1.0	R-f & S meters, anl, phone jack, PA & ext. spkr. jacks, ac/dc, synthesizer.
Pinto 23B	319.95	8 7/8 x 10 1/2 x 2 3/4	Both	0.5 @ 10*	0.1 @ 10*	60 @ 10	70 @ 10	80	NA	NA	1.0	S/r-f & mod. meters, anl, PA & ext. spkr. jacks, ac/dc, synthesizer.
Kris 23+	259.95	12 x 8 1/4 x 5	AM	0.8 @ 10		6 @ 6		60	75			NA
Ventura	219.95	12 x 8 x 4 1/2	AM	0.5 @ 10		6 @ 5		45	45		1.0	NA
Lafayette Telsat 925	269.95	16 x 9 1/16 x 5	AM	0.7 @ 10		6 @ 6		45	50		1.0	Dig. clock, ch. 9 monitor, headphone or ext. spkr. jack, S/P-r-f meter, incl. crystals & mike.
Telsat 1023	179.95	13 3/16 x 9 7/16 x 5	AM	1.0 @ 10		40 @ 10		40	55		1.0	Range-boost circ., S/P-r-f meter, anl, PA switch, headphone & spkr. jack, dc power jack, incl. crystals & mike.
Comstat 35	199.95	12 x 8 1/4 x 5	AM	0.8 @ 10		6 @ 6		45	50		1.0	Squelch/standby sw, CB/PA sw., headphone or ext. spkr. jack, range boost circ., ac/dc, incl. crystal & mike.
Com-Phone Mark II	229.95	10 1/4 x 10 x 3 1/2	AM	1.0 @ 10		40 @ 10		40	55			Range boost circ., anl, radio telephone hand-set, PA/CB switch, ext. spkr. jack, ac/dc.
Midland 13-87913	199.95	12 1/8 x 8 5/8 x 4 3/8	AM	0.5 @ 10		6 @ 6		50	NA			S/r-f meter, ext. spkr. jack, incl. crystals & mike, ac/dc.
13-863	244.95	12 1/8 x 8 9/16 x 4 5/16	AM	0.7 @ 10		6 @ 3.5		50	NA		1.0	PA & ext. spkr. jacks, anl, PA/CB switch, ac/dc, S/r-f meter, incl. crystals & mike.

13-887	296.95	16 x 10 x 5	AM	0.7 @ 10		6 @ 7		45	NA		1.0	Dig. clock, S and power/SWR meters, ac/dc, anl, earphone, PA & recording output jacks, incl. crystals and PTT mike.
13-898B	489.95	15 x 10 x 5 1/4	Both	0.5 @ 10	0.25 @ 10	6 @ 7	6 @ 2.4	NA	NA	35	1.5	Dig. clock, S and power/SWR meters, ac/dc, anl, PA, r-f gain, incl. crystals.
Pace 1000B	449.95	14 1/4 x 11 x 5	Both	0.5 NA	0.25 NA	NA		90	60	40	0.6	PA, noise blanking, r-f gain cont., r-f/SWR/S meter, dig. clock, incl. mike.
CB76	219.95	13 3/4 x 9 x 3 3/4	AM	0.35 @ 10		NA		50	NA			Loc./dist. switch, ext. spkr. jack, S meter incl. mike.
DX2300B	249.95	13 3/4 x 9 x 3 3/4	AM	0.35 @ 10		NA		50	NA			Loc./dist./PA switch, PA & ext. spkr. jacks, S meter.
PAL Electronics Roadrunner 23	189.95	7 x 9 x 2 1/2	AM	1.0 @ 10		6 @ 5		55	45		1.5	PA, anl, ext. and PA spkr. jacks, S/power meter, incl. crystals & mike.
Pearce-Simpson Guardian	349.97	11 1/2 x 4 3/4 x 10 1/2	AM	0.4 @ 10*		6 @ 6 60 @ 21		60	70			Ext. spkr. jack, r-f gain & tone conts.
Pussycat 23	179.95	10 3/4 x 3 3/4 x 9 1/4	AM	0.7 @ 10*		6 @ 6		50	50			S/r-f meter, anl, PA & ext. spkr. jacks, ac/dc.
Lynx	209.95	11 5/8 x 4 3/8 x 8	AM	0.5 @ 10*		6 @ 5		50	50		0.6	S/r-f/mod. meter, ceramic filter, anl, ac/dc.
Bearcat 23C	319.95	14 7/8 x 5 x 11 1/4	AM	0.5 @ 10*		6 @ 5		50	50		0.6	Dig. clock, PA, S/r-f/mod. and SWR meters, noise blanking, ext. spkr., PA and headset jacks, ac/dc.
Super Lynx	269.95	13 3/8 x 5 1/4 x 10 3/4	AM	0.5 @ 10*		6 @ 5		50	50		0.6	Dig. clock, anl, ext. spkr., PA and headset jacks, ac/dc.
Bengal SSB	399.95	4 7/8 x 9 7/8 x 12 1/4	Both	0.5 @ 10*	0.3 @ 10*	6 @ 5 50 @ 20	6 @ 2.0 60 @ 5.5	50	50	40	0.6	Noise blanking, ext. spkr. and PA jacks, S/r-f/mod. meter, ac/dc.
Simba SSB	529.95	7 3/8 x 12 x 15	Both	0.5 @ 10*	0.2 @ 10*	6 @ 5 50 @ 20	6 @ 2.1 60 @ 5.5	50	50	40	0.6	Dig. clock, ext. spkr, PA & headphone jacks, S/r-f/mod. and SWR meters, ac/dc.
Realistic TRC-57	399.95	15 x 10 1/2 x 5 1/4	Both	0.5 @ 10	0.2 @ 10	6 @ 4	6 @ 2.1	60	NA	40	1.5	Dig. clock, PLL freq. synth, PA, noise blanking, anl, SWR & r-f meters, PTT mike.
TRC-48	329.95	8 7/8 x 10 1/2 x 2 3/4	Both	0.5 @ 10	0.2 @ 10	6 @ 5	6 @ 2.1	80/100	NA	40	0.6	Dual power suppy, PA, S/r-f meter, freq. synth.
TRC-55	229.95	14 3/4 x 9 x 5	AM	0.5 @ 10		6 @ 6		55	NA		1.5	S/r-f & SWR meters, dig. clock, PA, anl, noise blanking, synthesizer, PTT mike.
TRC-30A	159.95	11 1/2 x 9 x 4	AM	0.5 @ 10		6 @ 6		55	NA		1.5	Dual power suppy, S/r-f meter, PTT mike, ac/dc, synthesizer.
Regency CR-142	199.00	12 3/8 x 9 3/4 x 5 1/2	AM	0.5 @ 10		6 @ 5.5		50	NA		1.0	S/r-f meter, mike gain, anl, PA, ext. spkr. jack, ac/dc, incl. mike.

Manufacturer and Model	Retail Price ($)	Dimensions (in.) WxDxH	AM/SSB	Sensitivity (___ μV at ___ dB S/N) AM	Sensitivity SSB	Selectivity (–___ dB at ± ___ kHz) AM	Selectivity SSB	Adj. Channel Rejection (–dB)	Image Response (–dB)	SSB Carrier Suppression (–dB)	Delta Tune Range (± ___ kHz)	Special Features
CR-123B	399.00	12 13/16 x 9 13/16 x 5 1/2	Both	0.5 @ 10	0.15 @ 10	6 @ 7	6 @ 2.2	50	NA	50	0.6	S/r-f meter, clarifier, mike gain, PA, ext. spkr. jack, ac/dc, incl. mike.
Royce												
1-620	199.95	12 x 4 1/2 x 8	AM	0.5 @ 10		6 @ 5		45	40		1.5	S/r-f meter, on-the-air light, mod. light, anl, variable tone, dual powersupply, PA, tape rec. jack, incl. crystals & mike.
1-640	449.95	15 x 4 3/4 x 10 1/2	Both	0.5 @ 10	0.2 @ 10	6 @ 5	6 @ 2.2	70	50	40	0.6	Dig. clock, Tx. light, S/r-f meter, SWR meter, PA, noise blanker, r-f gain, dual power supply, headphone and tape rec. jacks, MOSFET r-f amp.
SBE												
Trinidad	239.95	17 3/4 x 8 3/4 x 5 3/4	AM	1.0 @ 10		6 @ 2.5 40 @ 10		NA	NA		1.0	S & r-f meters, anl, earphone jack.
Trinidad II	199.95	9 1/2 x 8 3/4 x 3 3/4	AM	1.0 @ 10		6 @ 2.5 40 @ 10		NA	NA			S & r-f meters, PA, ac/dc.
Console II	454.95	12 x 10 1/4 x 5	Both	1.0 @ 10	0.5 @ 15	6 @ 2.0 50 @ 5.5	6 @ 2.4	NA	NA	40		SWR/S & r-f meters, noise blanking.
Console IV	429.95	17 3/4 x 8 3/4 x 5 3/4	Both	1.0 @ 10	0.5 @ 15	6 @ 2.0 50 @ 5.5	6 @ 2.4	NA	NA	40		Clarifier, PA, noise blanking, r-f & SWR/S meters, ext. spkr. jack, anl.
Sonar												
FS-23	360.00	11 3/4 x 11 3/4 x 5 3/4	AM	0.5 @ 10		10 @ 4		60	50		1.75	Dual power supply, S meter, r-f gain, synthesizer, incl. crystals & mike, two power cords, ac/dc.
Teaberry												
T-Scout	119.95	7 1/2 x 5 3/4 x 2 1/4	AM	0.5 @ 10		40 @ 10		45	30			S meter, anl, mod. light.
Tram Diamond												
D201	798.00	29 9/16 x 13 1/2 x 8	Both	0.35 @ 10	0.1 @ 10	6 @ 6	6 @ 2.1	75	80	45	0.8	S/r-f meter, clarifier, tunable receiver, trans. & rec. tone contrs., r-f & mike gain contrs., SWR bridge, incl. crystals & Astatic crystal mike, VOX, noise blanker.

Notes: All have built-in speakers. Most have squelch and agc circuits. NA indicates information not supplied by manufacturer. Asterisk indicates (S+N)/N.

CB COMMUNICATION RANGE

Several factors affect the "talk power" you get from your station. Some are under your control, while others depend on surroundings

BY LEO SANDS

"HOW far will I be able to talk?" is the question most often asked by a prospective CB'er, when shopping for equipment. The dealer will usually reply "it depends" since it does depend on a lot of factors he can't control. However, if he knows the neighborhood where you live and you tell him how high your house is, he should be able to make an educated guess.

The hedges regarding the base station include the altitude of your property, density and proximity to vegetation, type of structure on which the antenna can be mounted, and possible interference sources. With a mobile unit, it is the severity of electrical noise generated by the vehicle.

Range is determined by: (1) transmitter output power which is limited by the FCC to 4 watts on AM or 12 watts peak envelope power (pep) on SSB; (2) antenna system gain or loss; (3) effective antenna elevation (eae); (4) proximity to dense vegetation; (5) receiver sensitivity; and (6) noise level in vicinity of antenna.

Signals at 27-MHz travel outward and upward. The outward-going energy reaches somewhat farther than 1.2 times the distance from the antenna to the horizon with strong intensity and farther with reduced intensity. The upward-going energy is wasted except when "skip" conditions prevail. Then the energy is reflected by the ionosphere to points hundreds or thousands of miles away. The signals generated by a 4-watt (output) CB transceiver might be heard only 5 to 25 miles away under normal conditions and thousands of miles away when skip propagation conditions exist. The latter is prohibited by the FCC, limiting communication to 150 miles.

But, it is not the skip range that is important. It's the useful local range which is governed by erp, eae, effective receiver sensitivity (ers), and plane earth propagation loss, terrain loss, and diffraction loss.

Propagation Losses. Every radio transmitter sends power through space, but very little of the power reaches the receiver. At a distance of seven miles from the antenna of a 50,000-watt station, the power level at the terminals of a dipole antenna would be 0.5 microwatt. Thus if a CB antenna system radiates 4 watts of power, only 1/100-billionth of it is present at a receiving antenna seven miles away—but it is plenty, considering how sensitive most of the receivers are today.

The plane earth propagation losses for various distances are listed in Table 1 with respect to effective antenna elevation above the earth or surrounding terrain. It can be seen that, as distance is doubled, propagation losses increase 12 dB, which represents a power loss of 16 times. It can also be seen that, when effective antenna elevation is tripled from 30 feet to 90 feet, propagation losses decrease 10 dB. This indicates that power is ten times greater at the same distances. And, if antenna elevation is increased nine times, from 30 feet to 270 feet, propagation losses decrease 20 db which means a 100 times increase in received power (Fig. 1).

When an antenna extends 20 feet above a 10-foot-high building, its elevation is 30 feet or when an antenna extends 20 feet above a 20-foot-high building on top of a 230-foot-high hill, the elevation is 270 feet.

The figures in Table 1 are approximate and subject to local variations. They include antenna height gain and 10 dB allowance for terrain loss. Table 2 lists the approximate signal levels at the receiving antenna from a station whose effective radiated power is 4 watts, which is equal to +36 dB above 1 milliwatt.

When the propagation losses are only 90 dB (a 1-billion times power loss), received power is down 54 dBm (0.025 μW) and the signal voltage level at the terminals of a 50-ohm, unity-gain receiving antenna is 1400 μV (all microvolt figures are rounded off). When propagation loss is 140 dB, received signal level is −104 dBm or approximately 1.4 microvolts.

If you are not familiar with decibels, remember 3 dB represents a power ratio of 2, a voltage ratio of 1.4; 10 dB, 10 and 3.16; and 20 dB, 100 and 10. To

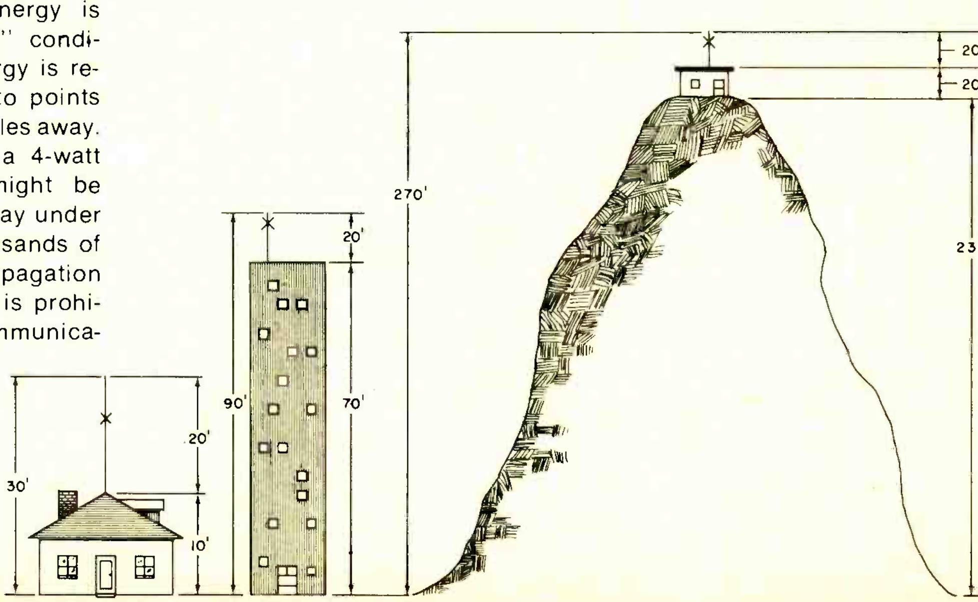
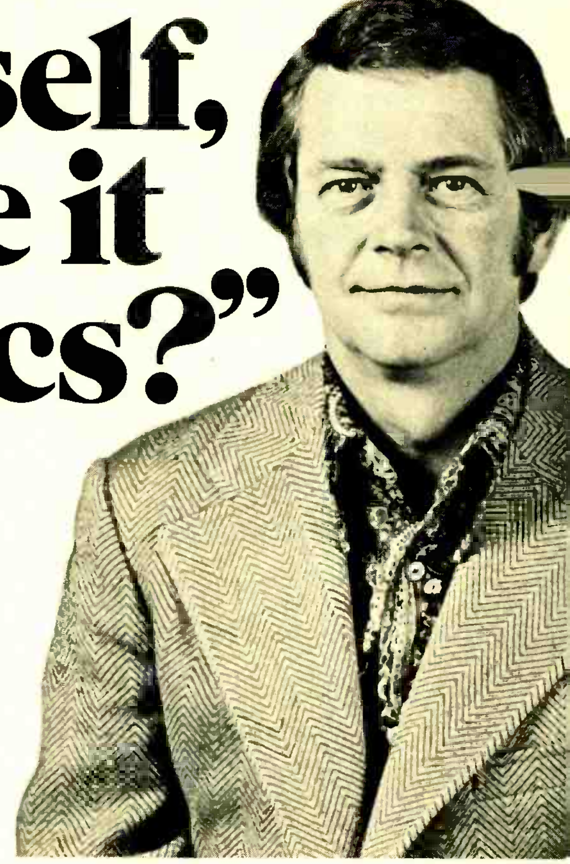


Fig. 1. Examples of effective antenna elevation for a typical CB base station.

Have you ever asked yourself, "Can I make it in Electronics?"



CIE may be the answer if you have a technical aptitude and a serious desire to get ahead.

Right now, you're reading a technical magazine with articles that require a certain amount of electronics know-how. And that says a couple of things about you.

First, you're involved in Electronics . . . on the job, or as a hobby.

Second, you obviously realize the importance of staying up-to-date on the latest technical applications and developments. Reading a technical magazine *helps*, but it takes more than that to get you where *you* want to be . . . if you're serious about Electronics.

How can you afford

. . . *not* to continue with your electronics training?

You know the answer to that as well as we do.

To achieve continuing success, you have to keep building more knowledge into the Electronics background and experience you already have. You have to sharpen the tech skills you've already got and add new ones.

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How can you afford

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use dB, simply add them. For example, 26 dB represents a power ratio of 400 (20 dB = 100, 6 dB = 4, 100 × 4 = 400), and a voltage ratio of 20 (20 dB = 10, 6 dB = 2, 10 × 2 = 20).

Antenna Gain. An antenna can act as an amplifier when it provides "power gain." An omnidirectional antenna compresses the radiated energy toward the earth so that less escapes upward and is wasted; a unidirectional antenna compresses the energy in one horizontal direction; while a bi-directional antenna (such as a co-phased pair of omnidirectional antennas) radiates maximum energy toward the front and back or to the sides.

Antenna gain increases erp. If 3.2 watts of energy is applied to and radiated by a unity (0 dB) gain antenna, erp is 3.2 watts. But, if antenna gain is 4 dB, for example, erp is increased 2.5 times to 8 watts, and a 10-dB gain beam will increase erp to 32 watts—legally.

Transmission Lines. A CB antenna is fed through a 50-ohm coaxial-cable transmission line. Since coax introduces losses, the full output power of the transmitter does not reach the antenna. If you use 50 feet of RG-58A/U cable, 1 dB loss is caused by the cable. If transmitter output is 4 watts, 80% (3.2 watts) of the power reaches the antenna, a small part (about 4%) of which is reflected back to the transmitter by a well-matched antenna with an SWR rating of 1.5. The antenna absorbs about 3 watts. The coax cable loss can be offset by using a gain-type antenna.

Table 3 lists the losses for various types of coax and the maximum length that can be used in order to limit losses to 1 and 1.5 dB. Type RG-58A/U is satisfactory for runs of 50 feet (20% power loss) to 70 feet (30% power loss). For runs up to 150 feet, use RG-8/U cable and for longer runs, use foam-filled coax which has much lower losses.

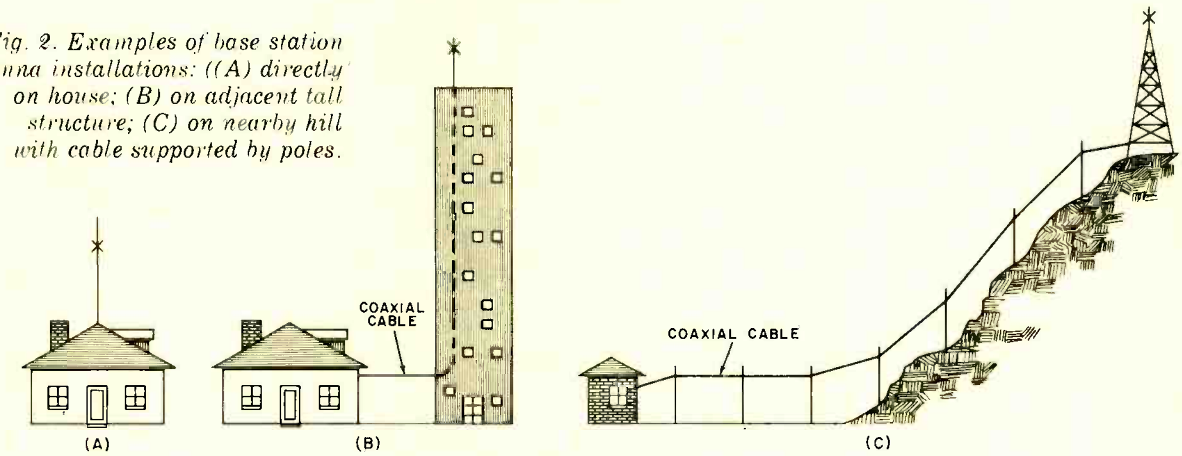
Propagation-Loss Calculations. Although most CB transceivers have better than 0.5-μV sensitivity ratings, noise usually makes it necessary to receive much stronger signals. An S9 indication (very strong signal) on an S meter usually indicates that received signal level is 50 or 100 μV depending on the reference used by the designer.

Table 4 lists the loss calculations for base-to-base, base-to-mobile and mobile-to-mobile transmission over a distance of 14 miles. These calculations assume a 30-foot base antenna elevation, the use of 4-dB gain base antennas, and unity gain mobile antennas in typical terrain. It can be seen that received signal level is almost 22 times higher for base-to-base communication than for mobile-to-mobile. When a 3.3-microvolt signal is acceptable, it would appear that base-to-mobile range would be more than doubled and base-to-base range more than quadrupled. But, in most cases it wouldn't because at 28 miles and at 56 miles, beyond the radio horizon, absorption losses could be very high.

Base Antenna Installation. A base station antenna is usually installed in much the same way as a TV antenna, using the same types of mounting hardware. Most often, the base station antenna is mounted on top or at one end of a house, as shown in Fig. 2A. When a tall building, water tank, or other tall structure is adjacent to the house, the antenna could be mounted on top of the taller structure if permission can be obtained, as in Figure 2B. Low-loss coax should be used.

Many rural residents and farmers living in a valley in hilly country, as in Washington and Oregon, have complained about inadequate CB range. When a hill is within a few hundred feet of the house, the antenna can be mounted there, as shown in Figure 2C. If as much as 1200 feet of coax is required, ⅞-inch foam cable should be used. It can be supported on wooden poles or buried if it has a polyethylene jacket. Since this cable comes in maximum lengths of 300 feet, splicing connectors must be used.

Fig. 2. Examples of base station antenna installations: ((A) directly on house; (B) on adjacent tall structure; (C) on nearby hill with cable supported by poles.



Although the 2.7-dB loss introduced by 1200 feet of ⅞-inch foam cable will allow only 54% of the transmitter power to reach the antenna, the loss can be made up by using a gain-type antenna.

Mobile Antennas. A quarter-wave (approx. 104 inches) stainless steel antenna is an efficient radiator. But, when its mount is attached to the bumper, fender, or cowl of a car, its radiation pattern will be distorted. A much shorter, but less efficient base- or center-loaded whip or helical fiberglass antenna mounted in the center of the car roof will usually work better since the car body won't distort the radiation pattern.

Noise Affects Range. Communicating range can be seriously affected by ignition noise (a popping sound), even at base stations. The electrical noise generated by a car can often be picked up by a CB rig more than 100 feet away. If your home is close to a street, you can minimize ignition noise pickup by installing your antenna as far from the street as feasible — like on the garage at the back.

TABLE 1—PROPAGATION LOSSES

Distance	Effective Antenna Elevation		
(miles)	(30 ft)	(90 ft)	(270 ft)
7	110 dB	100 dB	90 dB
14	122 dB	112 dB	102 dB
28	134 dB	124 dB	114 dB

TABLE 2—RECEIVED SIGNAL LEVELS (4-W ERP)

Propagation	Level at Receiving Antenna	
(loss in dB)	(dBm)	(microvolts)
90	−54	1400
100	−64	440
110	−74	140
120	−84	44
130	−94	14
140	−104	4

TABLE 3—CABLE ATTENUATION LOSSES

Cable Type	dB/100 ft
RG-58A/U	2.2
RG-58 foam	1.7
RG-8/A-AU	0.98
RG-8 foam	0.90

TABLE 4—TYPICAL LOSS CALCULATIONS

	Base-to-Base	Base-to-Mobile	Mobile-to-Mobile
Transmitter output (4 W)	+36 dBm	+36 dBm	+36 dBm
Coaxial cable loss	(−1 dB)	(−1 dB)	(−0.4 dB)
Antenna gain	+4 dB	+4 dB	0
Eff. radiated power (8 W)	+39 dBm	+39 dBm	+35.6 dBm
Propagation loss (14 miles)	(−122 dB)	(−122 dB)	(−122 dB)
Antenna height gain (30 ft)	+20 dB)	+10 dB)	0
Terrain factor loss	(−10 dB)	(−10 dB)	(−10 dB)
Power at receiving antenna	−73 dBm	−83 dBm	−96.4 dBm
Receiving antenna gain	+4 dB	0	0
Coaxial cable loss	(−1 dB)	(−0.4 dB)	(−0.4 dB)
Power at receiver input	−70 dBm	−83.4 dBm	−96.8 dBm
Voltage at receiver input	71.2 µV	15.2 µV	3.3 µV

At a base station, interference can be caused by a nearby TV set, fluorescent lamps, sewing-machine motors, aquarium heaters, thermostats, and other electrical devices with moving contacts. To avoid radiated interference, place the transceiver as far as possible from appliances, particularly TV sets, and not under a fluorescent light fixture. Connect a powerline filter between the ac outlet and the offending appliance. To minimize feedthrough from the power line to the transceiver, install a line filter in series with the power cord and to the nearest earth ground.

Transmitter-Caused Interference. If a nearby CB'er's transmissions can be heard when your rig is not set to the channel on which he or she is transmitting, your antennas may be too close together. Move yours farther away and place it higher or lower than the other antenna. Although modern CB rigs are usually very selective, don't expect to escape channel bleedover when another CB'er pumps thousands of microvolts into your antenna.

When another CB'er or a ham can be heard on all channels, or your receiver is so desensitized that you can't use it, chances are that the CB'er (unlawfully) or ham (lawfully) is using a high-power linear amplifier. If it is the CB'er, the FCC should be happy to hear about it.

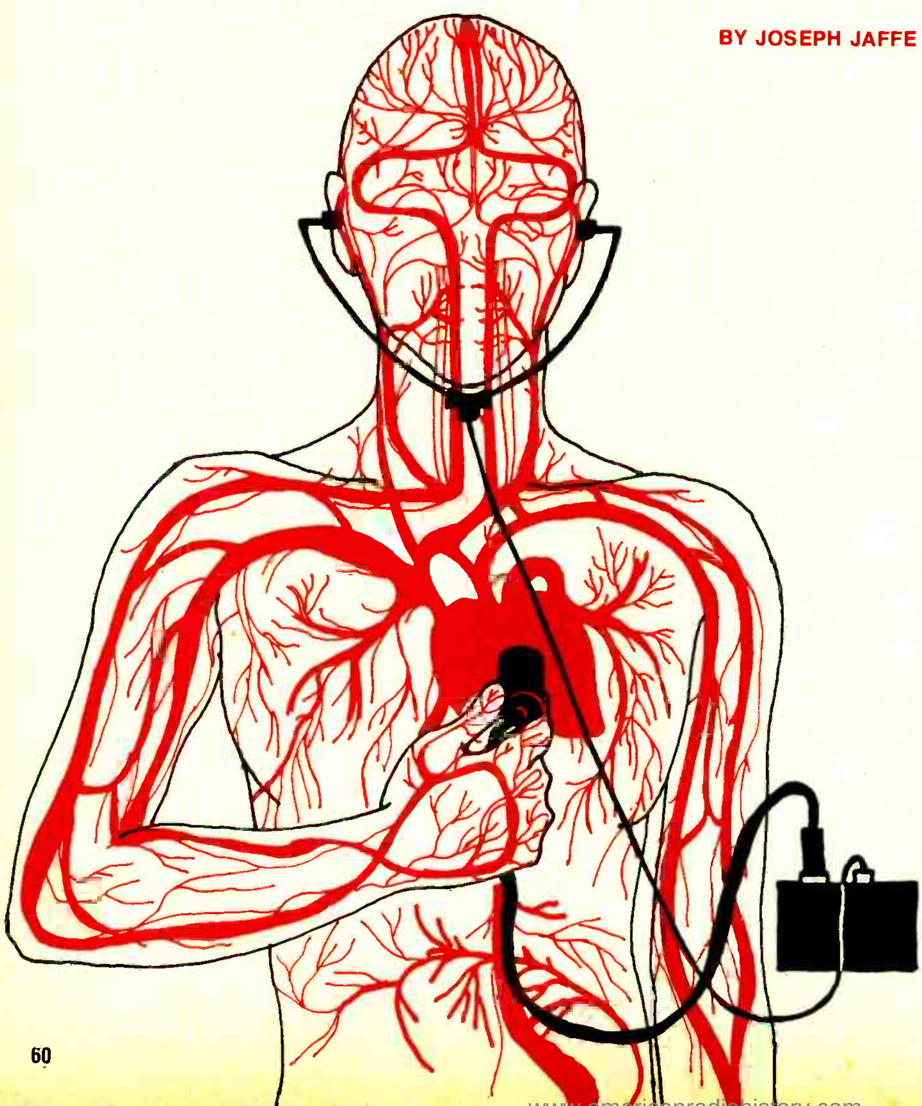
On the other hand, if your receiver is desensitized by a nearby FM or TV broadcast station or land-mobile system FM base station, install a low-pass filter between the antenna connector of the transceiver and the antenna transmission line.

Summary. Transmitting range depends on effective radiated power, effective antenna elevation, and modulation level. Receiving range depends on effective receiver sensitivity, which is affected by antenna gain and capture area, noise level, and nearness to other transmitters which might or might not desensitize the receiver. Range, either way, is affected by power-source voltage. ◈

Listen to your Heart with Doppler Ultrasound

Ultrasonic stethoscope lets you hear snapping of heart valves and blood-flow sounds.

BY JOSEPH JAFFE



ABOUT 15 years ago, it was discovered that, when ultrasonic energy in the low-megahertz range is beamed into the body, the energy is reflected back to the surface by certain internal structures. If the structures move, the frequency of the reflected energy is changed in proportion to the velocity of the movement due to the Doppler effect. Development of this principle has given the medical profession a valuable and completely harmless tool for the noninvasive examination of movements inside the body—especially of the heart, its valves, and the flow of blood within the heart. All of the movements cause characteristic sounds which can be heard with the aid of an easily constructed ultrasonic stethoscope.

The basic elements in the stethoscope are two lead zirconate-lead titanate piezoelectric crystals. One of the crystals is energized by a signal from a 2-MHz oscillator so that it expands and contracts setting up pressure or sound waves that are transmitted into the body. When this wave (which is very directional) passes from one medium to another in the body, a portion is reflected back to the second crystal, which generates an electrical signal. If the reflecting surface is stationary, the signal generated in the receiving crystal is 2 MHz. If the reflecting surface is moving away from the transducer, the frequency is lower than the transmitted wave. Similarly, if the surface is moving toward the transducer, the reflected frequency is higher. By mixing a portion of the transmitted frequency with the received frequency and detecting the difference, we get a frequency in the audio range that is proportional to the velocity of the reflecting surface.

Circuit Operation. In the transmitter circuit (Fig. 1) *Q1* operates as a 2-MHz oscillator. Positive feedback is

Editor's Note. Experiments have shown that beaming high-frequency sound into the body is not harmful. The technique has even been used successfully in listening to the hearts of unborn babies in the mothers' wombs.

It should be remembered, however, that this project is for experimentation and entertainment. Do not attempt to interpret the sounds diagnostically for yourself or for others. Only a physician can do this by correlating the sounds with other medical information.

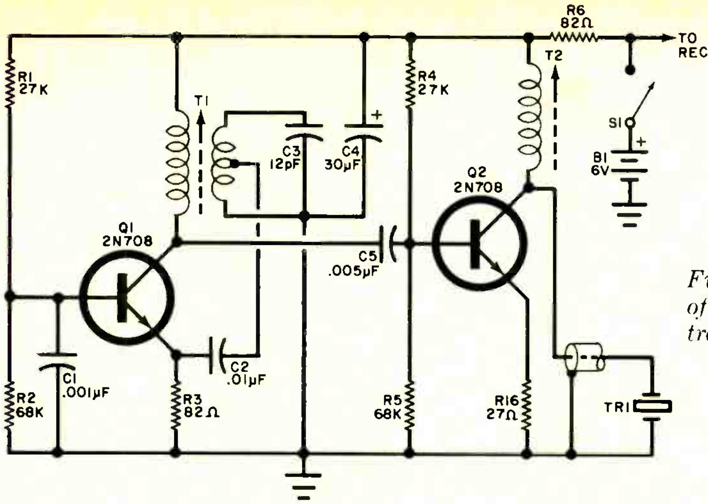


Fig. 1. Schematic of the stethoscope transmitter circuit.

The detected audio signal is amplified by *IC1*.

Construction. The circuits are assembled on a single pc board, using the foil pattern and component installation shown in Fig. 3. Since *IC1* is in a round, TO-type package, you must bend its leads to conform to the in-line pads on the board.

Construction of the transducer assembly is shown in Fig. 4. The two transducers are made by carefully cutting in half a 1-inch diameter PZT crystal (1/32" thick) to make two D-shaped devices. Fine wire, such as #36 or smaller, should be soldered to each side of the crystal using silver-bearing solder to avoid lifting the silver electrode. Use a low-power soldering iron (25 W or less) and a minimum of solder.

Maximum efficiency of power conversion is achieved when the transducers are "air-backed" so that most of the ultrasonic energy is radiated from the front of the crystal. Most of the ultrasonic energy reaching the air-backed surface is reflected to the front because of the poor acoustic matching. As shown in Fig. 4, a porous material such as cork or foam is suitable for mounting the crystals to achieve the air backing. The two crystals are secured to the backing material with small amounts of adhesive, with the two flat edges of the D shapes about 1/16" apart. The thin wires soldered to the crystals are threaded through the backing material.

A 4' or 5' length of two-conductor, individually shielded cable is soldered to the thin wires, making sure the solder joints don't touch any other connection or metal. The entire assembly is then encapsulated with epoxy. The active faces of the transducers should

PARTS LIST

B1—6-volt battery (4 AA cells)
C1—0.001-μF polystyrene capacitor
C2,C6,C13,C14—0.01-μF polystyrene capacitor
C3—12-pF ceramic disc capacitor
C4,C15—30-μF, 15-V electrolytic capacitor
C5,C8—0.005-μF polystyrene capacitor
C7,C9,C11—0.05-μF polystyrene capacitor
C10—0.04-μF polystyrene capacitor
C12—10-μF, 15-V electrolytic capacitor
D1—Diode (1N295 or 1N4148)
IC1—Audio amplifier (RCA CA3020)
J1—Phone jack
Q1 to Q3—Transistor (2N708, 2N5134)
Unless otherwise noted, following are ¼-watt, 10% resistors:
R1,R4—27,000 ohms
R2,R5—68,000 ohms
R3,R6,R9—82 ohms
R7—33,000 ohms
R8—10,000 ohms
R10—100,000 ohms
R11—680,000 ohms
R12 to R14—4700 ohms
R15—10,000-ohm potentiometer
R16—27 ohms
S1—Spst switch (on R15)
T1 to T4—Transformer (Lafayette #99-6300)
TR1,TR2—PZT-5 Vernitron Piezoelectric 16035 disc (see text and note)
Misc.—2-conductor individually spiral-shielded cable, plastic or metal tube (1¼" ID × 2"), cork or foam, epoxy, silver-bearing solder, Telex HMY-2 or #799 2000-ohm headset, knob, mounting hardware, etc.
Note—The following are available from Products and Processes, P.O. Box 380066, Miami, FL 33138: PZT-5 disc at $22, complete transducer and cable at $49.50, pc board at $4.50, cassette recorded with typical sounds at $2.50. All prices postpaid. Florida residents please include 4% sales tax.

provided from the secondary of *T1* through *C2*. The frequency is determined by the value of *C3* and the tuning of *T1*. The oscillator is coupled through *C5* to *Q2*, an amplifier whose output is tuned by *T2*. The amplified signal is then coupled to the transmitter transducer *TR1* through a length of shielded cable. The transmitter generates about 25 milliwatts per square centimeter of transducer surface.

In the receiver (Fig 2), the voltage generated across *TR2* by the reflected ultrasonic signal is coupled to *Q3*, a tuned amplifier with a gain of approximately 300. The signal is detected by *D1*. Though it might appear that an FM detector would be used here, the AM detector provides better sensitivity and is simpler to construct. It also requires no alignment. Amplitude detection can be used because a portion of the transmitted pressure wave is directly coupled to the receiver transducer at the surface of the body. The mixing of the direct wave with the reflected wave causes amplitude modulation at a frequency determined by the Doppler effect.

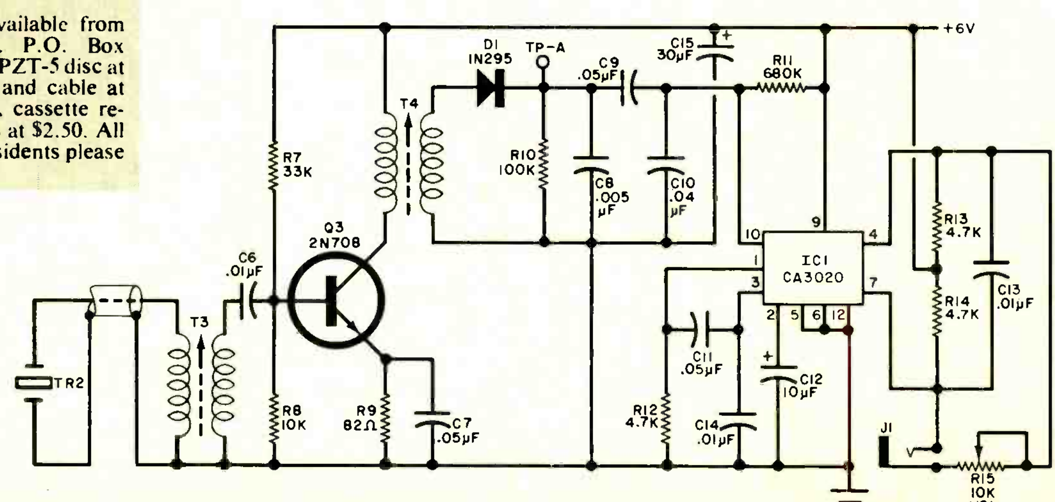


Fig. 2. Receiver uses the same type of transducer as the transmitter.

be slightly below the edge of the tube and covered with epoxy for insulation. Be sure there are no air bubbles in this coating.

Connect the transducer cable to the pc board as shown in Fig. 3, with each shield connected to ground.

The pc board and batteries, with *S1*, *R15* and *J1*, can be mounted in any suitable enclosure.

When assembly is complete and the circuit is energized, you should hear a low-level hiss coming from the stethoscope. Connect a 20,000-ohms/volt meter across the diode load resistor (test point A to ground) and tune the oscillator transformer (*T1*) and amplifier transformer (*T4*) for maximum voltage. If you don't have a voltmeter, fill a water glass half full and immerse the transducer about one inch into the water. Keeping the face of the transducer under water, oscillate it rapidly up and down, listening for the Doppler effect as the sound is reflected from the bottom of the glass. Tune the transformers for maximum volume and best signal-to-noise ratio.

Testing and Use. To get good results, the acoustical impedance of the transducer must be matched to that of the body so that the pressure waves are transmitted into the body rather than reflected back at the skin surface. To obtain an impedance match, use a liquid or a liquid-gel between the transducer and the skin. Water, olive oil, or mineral oil will work; but better results will be obtained with a liquid-gel such as Aquasonic or Sonigel, which are specifically made for this purpose and are available in medical supply stores.

Apply a small amount of liquid or liquid-gel to the active transducer surface and place the transducer firmly against the bare chest several inches to the left of center and about 10 inches below the shoulder (Fig. 5). Place the transducer so that the ultrasonic beam passes between two ribs, for best transmission. You should be able to hear the movement of the heart. Remember that, as you change the direction in which the transducer faces (always keeping it firmly against the chest), the sounds you hear will change, depending on what surfaces are in the path of the beam. When you take a deep breath, the sound may disappear because the lung fills with air, covering a portion of the heart; and air is a poor conductor of high-frequency sound.

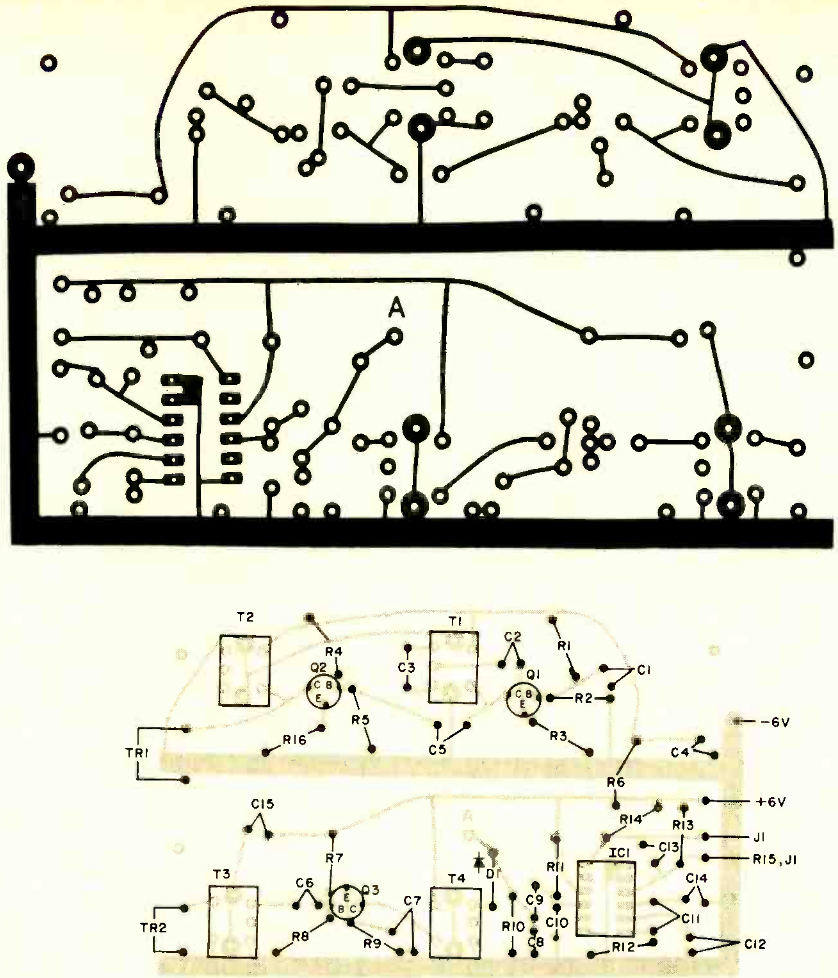


Fig. 3. Etching and drilling guide for printed circuit board is at top. Component layout below.

Typical sounds are the low-pitched "harrumph-oomph" of the heart wall, the snapping sounds of the heart valves, and the "shushing" of blood flow. These sounds occur briefly during each heart beat, and you will quickly learn to recognize the distinctive sounds. You will be able to study the effects of slow or fast breathing on your heart rate, as well as the effect of exercise.

If you are interested in biofeedback training, you may want to try to control your heart rate by meditation or other means. You will be able to hear the changes if you are successful.

Because there is attenuation of the sound wave as it passes through the body, those with a heavy build may find it necessary to try alternate body positions to bring the heart closer to the chest wall and the transducer. Two suggested positions are lying on the left side or leaning forward in a sitting position.

After you have successfully heard the Doppler sounds in one area, you can move the transducer to other

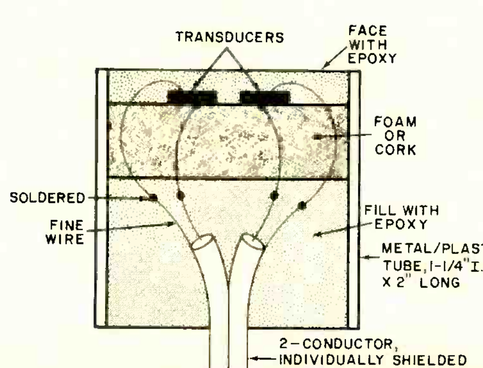


Fig. 4. Diagram shows how to assemble transducers for transmitter and receiver in stethoscope.

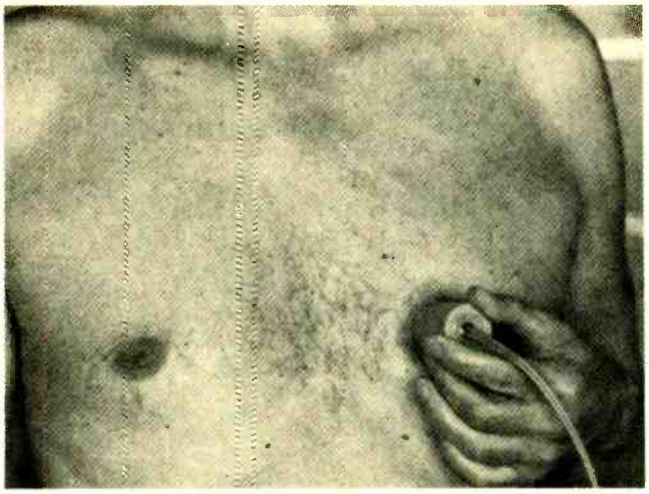


Fig. 5. To hear heart sounds, place the transducer about 10 inches below shoulde

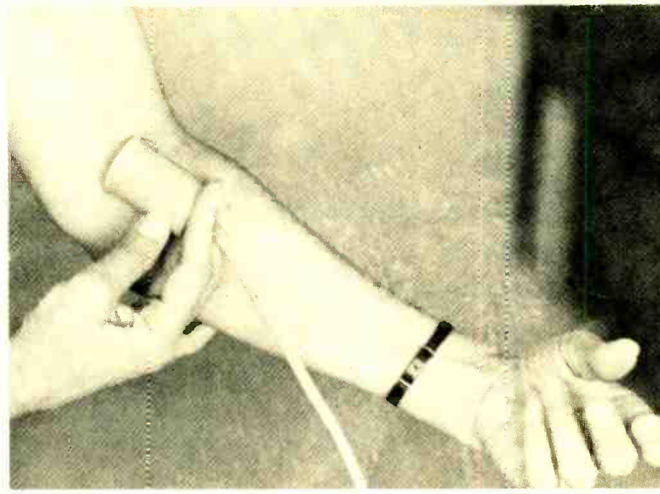


Fig. 6. To hear blood in arm vein, the transducer must point up toward shoulder.

areas to compare the sounds. Rocking the transducer back and forth in one position will also change the sound as the direction of the beam changes. This helps bring in the valve and blood-flow sounds. If loud scratchy sounds are heard when moving the transducer around, turn off the stethoscope while moving it.

It is sometimes possible to hear the flow of blood in the main (brachial) artery in the arm along the inside of the elbow (Fig. 6). In this case, the transducer is not placed flat against the arm but is oriented so that the beam points along the arm in the direction of the blood flow (toward the shoulder). The beam is then reflected from the red blood cells; and when you have located the artery correctly, you will hear a short "pshhh" sound with each heart beat. For this experiment, use enough liquid-gel to fill the space between the tilted transducer face and the arm. It will also be necessary to use an external amplifier and speaker to get better sensitivity. ◈

Product Test Reports

ABOUT THIS MONTH'S HI-FI REPORTS

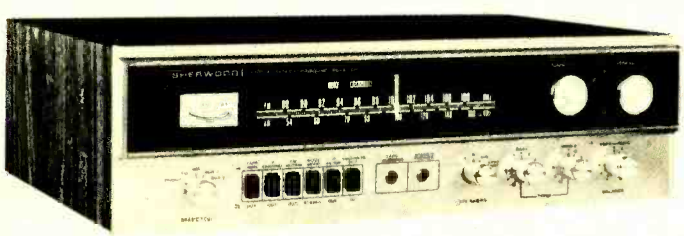
This month we are reporting on two products that provide top value for the buyer's money. Sherwood's S-7310 stereo receiver, for example, is a well-conceived, competently engineered unit where even the AM tuner section performs exceptionally well. It clearly offers better than average performance at a moderate price.

Another long-established company, Stanton Magnetics, has revived (with modifications) a unique single-play manual turntable and tonearm which they first introduced several years ago. Supplied with its excellent 681EEE calibrated cartridge, the new Stanton 8004 stereo record player (a four-channel version is also available) eliminates all the problems often associated with record player installations. The integrated system enables one to just plug it in and use it.

—Julian D. Hirsch

SHERWOOD MODEL S-7310 AM/STEREO FM RECEIVER

High performance, medium power, has simulated 4-channel sound.



HIRSCH-HOUCK LABS REPORT

Some of today's better medium-priced stereo receivers offer a high level of performance and operating flexibility. The Sherwood Model S-7310 is an excellent example of such a receiver. Its FM tuner section employs a state-of-the-art phase-locked-loop (PLL) integrated circuit for stereo demodulation with outstanding channel separation and low distortion. Another IC is used in the final i-f-amplifier/limiter section of the FM tuner. Four transistors and nine diodes are used in the interstation muting system to provide a smooth, noise-free transition between the system's on and off states.

Built into the AM/stereo FM receiver is a Dynaquad ambience-recovery system that derives the rear-channel signals from two-channel sources for a simulated 4-channel sound. There is also a 4CH FM output jack on the receiver's rear apron for use with a discrete quadraphonic FM decoding system should the FCC approve this scheme in the future.

The receiver measures 17½"W × 13¼"D × 5¼"H (44.5 × 33.7 × 13.3 cm) and weighs 24 pounds (10.9 kg). It comes in a wooden walnut-finished cabinet and retails for $369.95.

General Description. The receiver's direct-coupled audio amplifier system is rated at 38 watts/channel continuous output power into 8-ohm loads over a frequency range of 20 Hz to 20,000 Hz and with less than 0.5% harmonic and IM distortion. The preamplifier section has inputs for the receiver's AM and FM tuners, a magnetic phono cartridge, and two high-level AUX sources. There are also two sets of tape recording input/output jacks, with monitoring provisions, although one set is labelled as 4 CHANNEL and is suggested for use with an external quadraphonic adapter if the system is to be converted to 4-channel operation.

The outputs of the power amplifiers can be switched to either of two pairs of speaker systems or to both pairs simultaneously, and can be shut off for private headphone listening. In the DYNAQUAD mode, the second pair of speaker systems (they should be located in the rear of the listening room) is connected into the system in the ambience-recovery scheme for simulated 4-channel sound reproduction with stereo program sources.

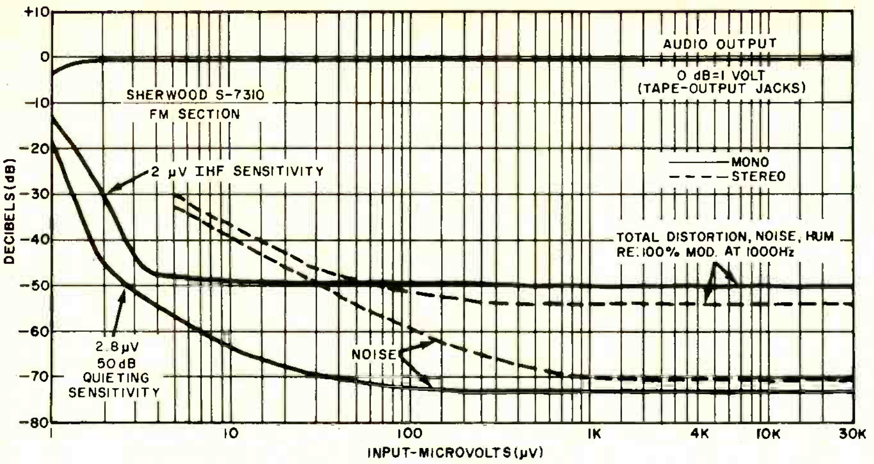
The tuning dial occupies the upper portion of the front panel, along with a single tuning meter and large TUNING and LOUDNESS control knobs. The window is faced with a filter that blacks out the logging scales and meters when the receiver is switched off or is on and neither tuner section is being used. The meter operates as a zero-center indicator for FM tuning and a peak indicator for AM tuning.

All remaining controls and switches are located along the lower portion of the front panel. Six pushbuttons are for switching in and out the TAPE MON, 4 CHANNEL (or second tape monitoring system), FM MUTING, MONO/STEREO mode, HI FILTER, and LOUDNESS compensation.

Two jacks on the front panel are labelled HEADPHONE and TAPE DUBBING. The latter jack duplicates the functions of the rear-apron tape recorder inputs and outputs.

All remaining inputs and outputs are located on the rear apron of the receiver. Also included is an external AM antenna input, as well as a hinged and pivoted ferrite-rod AM antenna.

Laboratory Measurements. The audio amplifiers in the receiver surpassed all of their published specifications by a wide margin. At the rated output of 38 watts/channel into 8 ohms, the THD was less than 0.1% from 20 to 20,000 Hz. Below 1000 Hz, where the THD measurements included small amounts of power supply ripple, our instrument readings were typically about 0.05% at full power, half power, and one-tenth power. When we used a filter in the distortion analyzer to remove the power frequency components, the THD above 1000 Hz measured between 0.01% and 0.02% up to about 10,000 Hz and 0.05% to 0.1% 10 to 20 kHz.

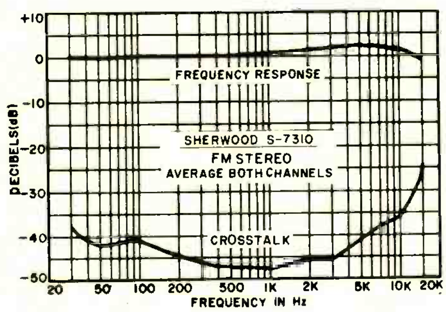


The 1000-Hz THD was below the receiver's noise level until the output power reached 10 watts, where it measured 0.01%. It was only 0.02% at 45 watts. (The output clipped at 46 watts.) The IM distortion was about 0.05% at 0.1 watt, decreased to 0.02% between 5 and 10 watts, and measured 0.06% at 50 watts.

Into 4- and 16-ohm loads, the 1000-Hz clipping power was 52.6 and 29.4 watts, respectively. The IM distortion at very low power levels remained less than 0.1% down to about 20 mW and rose to 0.47% at about 1.3 mW.

The amplifiers required an input of 76 mV on AUX and 0.9 mV on PHONO to produce a 10-watt reference output power. The respective noise levels measured −86 and −73.5 dB. The phono input overloaded at a very good 95 mV. The tone controls had an exceedingly wide range, considerably exceeding the rated ±10 dB. At 30Hz, for example, a boost or cut exceeding 20 dB was available, while at 20,000 Hz, the range was ±15 dB.

The loudness compensation circuit boosted only the low frequencies as the volume setting was reduced. The HI FILTER had a 6-dB/octave slope, with the −3-dB point at 5000 Hz. The RIAA phono equalization was as accurate as our test instruments can measure, varying by less than 0.25 dB from 20 to 20,000 Hz. The equalization was virtually unaffected by cartridge inductance, with a response change of less



than 1 dB in the range between 10,000 and 20,000 Hz.

The FM tuner had an IHF usable sensitivity of 2.0 μV in mono, with 50 dB of quieting achieved at a very low 2.8 μV. The muting and automatic stereo switching thresholds were essentially the same at about 4.5 μV. In stereo, the usable sensitivity was 5 μV and the 50-dB quieting sensitivity was 32 μV. The ultimate quieting was very good in both modes, measuring 72.5 dB in mono and 70 dB in stereo. FM distortion was 0.32% in mono and, at 0.2%, was surprisingly lower in stereo.

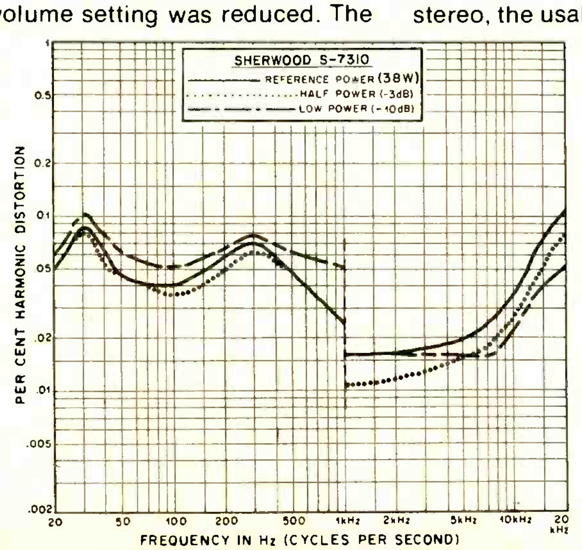
The FM capture ratio was 1.8 dB at 1000 μV. AM rejection was a very good 64 dB, and image rejection was 73 dB. The alternate-channel selectivity, which was essentially the same above and below the signal frequency (unlike most tuners), measured 68 dB. The 19-kHz pilot carrier leakage into the audio outputs was 59 dB below 100% modulation.

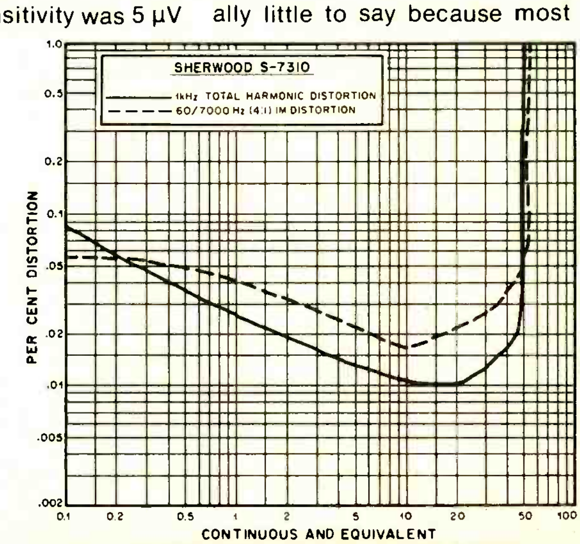
The stereo FM response was ±1.8 dB from 30 to 15,000 Hz, with a slightly elevated output between 2000 and 10,000 Hz. Channel separation was better than 40 dB from 35 to 6000 Hz and was about 48 dB throughout much of the midrange. It reduced to 24.5 dB at 15,000 Hz. The AM frequency response was relatively flat throughout its useful range. It was down 6 dB at 30 and 4500 Hz.

User Comment. The performance of the audio section of this receiver speaks for itself. Except for greater output power, it is difficult to imagine how the audio section could be improved upon without a very large increase in price. Similarly, the FM tuner cannot be surpassed in most respects without a substantial increase in price.

The dial scales on this receiver, in spite of being calibrated at unusually wide 2-MHz intervals, are so linear and accurate that one has no difficulty in interpolating readings and pre-tuning to any desired channel.

The receiver's FM muting is completely free of noise bursts. Even the AM tuner, about which there's generally little to say because most man-





ufacturers skimp in this area, had a dead-silent background, low distortion, and excellent overall quality.

Finally, the Dynaquad feature gives as pleasing a 4-channel effect as any quadraphonic receiver with a *basic* matrix decoder.

In conclusion, the Sherwood Model S-7310 is an excellent receiver that is demonstrably better than the vast majority of lower-priced receivers and, in many respects, the peer of a number of deluxe stereo units costing substantially more.

CIRCLE NO. 65 ON READER SERVICE CARD

STANTON MODEL 8004-II RECORD PLAYING SYSTEM

Single-play, belt-driven manual with arm and cartridge.

The Stanton "Gyropoise", Model 8004 record playing system consists of a two-speed belt-driven turntable, low-mass tonearm, and high-quality cartridge. The whole is set into a wood base that has a removable hinged plastic dust cover. The system comes completely assembled and ready for playing discs.

The Model 8004 record playing system is available in two forms. The Model 8004-II (which we tested) for stereo records is fitted with a Stanton TT681 cartridge, while the Model 8004-IV for discrete 4-channel records has a Stanton TT-780 cartridge.

The record playing system measures 14¾"W × 13"D × 7"H (37.5 × 33 × 17.8 cm) with dust cover in place and weighs 10¾ pounds (4.9 kg). It retails for $199.95 as the Model 8004-II and $224.95 as the Model 8004-IV.

General Description. The turntable platter is driven by a low-speed (300-rpm), 24-pole synchronous motor. The operating speeds are $33^1/_3$ and 45 rpm, selected by a control that shifts the neoprene belt from a pulley of one diameter to a pulley of another diameter. The nonferrous cast platter, weighing 2¾ pounds (1.25 kg), is supported vertically by the magnetic repulsion that exists between two ring magnets, one of which is on the rotating platter and the other on the cast T bar that links the tonearm with the turntable. The entire tonearm / turntable structure, in turn, "floats" on a soft suspension from the mounting plate, to which the motor is rigidly fastened for isolation.

The "Unipoise" tonearm is pivoted on a single point bearing. The cartridge plugs into a slim plastic shell that is fixed to the tonearm's tubular body. The finger lift extends upward from the cartridge shell instead of to the right side of the shell as is the case with most tonearm assemblies.

The tonearm is balanced by a counterweight. The desired tracking force is user set by sliding a small weight on the arm's tube. Tracking-force calibration marks are at 0.5-g intervals that cover a range of 0 to 4 grams. The anti-skating adjustment ring around the base of the tonearm support has separate scales for conical and elliptical styli.

The system is controlled by three sliding plastic plates located on the motorboard. At the left front is the speed selector. It should be operated only when the turntable is stationary. To the right of the platter are the on/off switch and the cueing lift control for the tonearm. Both the lift and the descent of the tonearm are viscous damped. There is no automatic arm lift or system shut-off. Hence, the tonearm must be returned to its rest post and the motor must be shut off manually at the end of play.

Laboratory Measurements. The calibration marks on the tracking force scale were accurate to within 0.1 gram at all points. Unlike most anti-skating devices, the calibrations on this system's dial were exactly correct, with or without the brush installed. Except for a measurement of tonearm resonance, no tests were made of the cartridge's performance. (The TT681 cartridge is identical, except for the width of its mounting flange, to the 681EEE cartridge reported on in this column in April 1975.) The low-frequency tonearm/cartridge resonance was at about 8 to 9 Hz at a 5-dB amplitude peak.

The tonearm tracked warped records considerably better than most arms we have used, suggesting that its low mass and balanced symmetrical pivot design provide a direct benefit to the user. The total wiring and cable capacitance measured 90 pF/channel, which would be ideal for proper operation of the CD-4 version of the system. Although the capacitance is considerably lower than is normal for the 681 cartridge, it appeared to have no undesirable effects on cartridge performance. The lateral tracking error of the tonearm was less than 0.7°/in. over the entire record surface and was typically about 0.6°/in. of radius.

The turntable speeds were exact. They did not change with line-voltage variations of 95 to 135 volts. At both speeds, the wow was 0.1% and the flutter was 0.035% (unweighted rms). The unweighted rumble, including both lateral and vertical components, was 31 dB down. With RRLL audibility weighting, this figure became 55 dB down, which is typical for a high-quality record playing system.

User Comment. This is a very compact record playing system, with a base that is barely larger than the 12" (30.5-cm) diameter of an LP disc and a weight that is far less than that of most contemporary turntables. It does a first-class job of playing records, and the cartridge has been effectively integrated into the 8004 system.

The controls could hardly be simpler or smoother to operate. The easy-to-use cueing system has no tendency to jar the pickup and no lateral drift during tonearm descent.

Once you become accustomed to the rather unusual tonearm finger lift, it is convenient to use. The design of the cartridge and the open face of the mounting shell give an unobstructed view of the stylus when cueing the pickup.

The lack of automatic tonearm pick-up and return and shut-off is a minor inconvenience in a manual record playing system. Also minor is our one criticism. There is barely 1/32" (0.79 mm) of clearance between the left side of the dust cover and a 12" disc on the platter. If the dust cover is not lowered carefully while playing the disc, the edge of the record can rub against the dust cover and cause a momentary "wow." Other than this, the system performed flawlessly.

CIRCLE NO. 66 ON READER SERVICE CARD

DYNASCAN COBRA MODEL 29 MOBILE AM CB TRANSCEIVER

Has switches for automatic noise limiter and noise blanker.

MICROPHONE and r-f gain controls, a switchable automatic noise limiter (anl), and a separately switched noise blanker—all rarely found on mobile rigs—are among the features you'll find in the Dynascan Cobra Model 29 AM CB transceiver. This FCC type-accepted rig uses crystal synthesis for coverage of all 23 Class-D CB channels. Among the more or less standard features you'll find on most mobile rigs, are: adjustable squelch, delta tune, and PA circuits; external-speaker jacks; an S-unit/power-output meter; and transmitter-on and modulation lamps.

The transceiver is designed primarily for mobile service. It can be powered by any nominal 13.8-volt, positive or negative ground source through a doubly filtered, polarity-protected supply line. Zener diode regulation is built into the power supply for critical circuits.

The 5½-pound (2.5-kg) transceiver measures 8½"D × 6⅞"W × 2¼"H (21.6 × 17.2 × 5.7 cm). It comes with a detachable push-to-talk dynamic microphone and mobile mounting hardware. It retails for $185.

The Receiver. Double conversion is employed in the receiver section. The r-f input stage is protected by diodes. A diode-type variable attenuator at the antenna input serves as the r-f gain control.

The first conversion is made to an 11.275-MHz i-f by heterodyning the incoming signal with a signal in the range from 38.240 to 38.530 MHz, obtained from the crystal synthesizer. The synthesizer produces the sum frequency of one of six crystals in the 23.290-to-23.540-MHz range and one of four crystals in the 14.950-to-14.990-MHz range. Heterodyning the resulting i-f at the second mixer with an 11.730-MHz crystal-controlled signal frequency brings the i-f down to 455 kHz. (A ceramic filter provides the selectivity.)

The rest of the receiver system consists of two i-f stages, diode detector, series-gate anl, and a three-stage audio section that ends in a push-pull output configuration. The noise blanker gate, located after the second mixer, is a balanced configuration that minimizes switching-transient noise during gating.

Our measurements revealed a receiver sensitivity of 0.6 µV (better than the rated 1-µV figure) for 10 dB (S + N)/N at 30% modulation and 1000 Hz. The image rejection measured 74 dB, while i-f signal rejection was 52 dB and spurious responses were down a minimum of 40 dB.

Selectivity provided an adjacent-channel rejection and desensitization of 40 dB, with an overall nominal receiver response in the audio section of 450 to 3500 Hz for crisp voice quality. The agc held the audio output to within 12 dB with an 80-dB r-f signal change at 1 to 10,000 µV. A 100-µV signal was required to yield an S9 indication on the meter.

The squelch threshold range was 0.35 to 250 µV. The maximum receiving output was 4 watts at 5% distortion with a 1000-Hz test signal, but on PA it dropped to 3 watts at 10% distortion, both into 8 ohms.

The Transmitter. On transmit, the output of the synthesizer is mixed with an 11.275-MHz crystal signal to generate the carrier. The driver and power output stages of the transmitter are conventionally collector modulated by the receiver's output stage. A sample of the modulating voltage is fed back to a separate microphone amplifier stage, where it is used to provide automatic modulation control.

A multi-section network in the power amplifier stage provides matching to 50-ohm loads. A TVI trap and a filter in the transmitter mixer's output minimizes spurious responses. Receiver/transmitter switching is accomplished with an all-electronic system that employs diode switches.

Using a 13.8-volt dc power supply, we measured 3.5 watts of carrier output, with 100% sine-wave modulation at 1000 Hz at 2.4% distortion. With a 6-dB increase in audio level, the distortion rose to 8%, and some negative-peak crossover resulted. Under normal voice operation, however, adjacent-channel splatter at this point was 55 to 60 dB down. The audio response of the transmitter was nominally 500 to 2800 Hz at the 6-dB points. The radio-frequency tolerance fell between −65 and −775 Hz, depending on the channel in use.

User Comment. This is an attractive transceiver, with its satin-finished silver-colored front panel accented by a chromed bezel and chromed control knobs. The knobs themselves are rather small. The channel-selector knob, owing to its small size, could do with some knurling to improve its "grip."

Miniature toggle switches are provided for switching the PA/CB, ANL, and NB (noise blanker) functions. The delta control is detented at its center-of-rotation position for convenience. Although the transceiver uses an edgewise movement, the meter is larger and easier to read than is usually the case in mobile rigs.

The anl system is extremely effective on many types of low- and high-level noises. On the other hand, the noise blanker was not effective until impulse noise exceeded 1000 µV.

The transmitter's output was a bit lower in power than is usually the case, amounting to a neglible 0.75 dB. What is more important is the fact that the transmitter easily maintained a clean, fully modulated signal.

As is common where a microphone gain control is furnished, this transceiver has no built-in means for accurately determining the proper gain control setting for a given degree of modulation. However, most users would probably crank the gain up all the way anyway, which might not cause undue overmodulation or splatter with this transceiver, as we noted in tests with a number of different voices.

CIRCLE NO. 67 ON READER SERVICE CARD

McKAY DYMEK MODEL DA-3 ACTIVE AM ANTENNA

Improves AM reception, captures hard-to-receive stations.

FM HAS almost completely displaced AM as a serious listening medium for standard broadcast fare. There are certainly cogent reasons for this, but AM still has some attractive attributes: programs not broadcast on FM, some stations that maintain good-quality transmissions (to 10 kHz), and DX'ing opportunities.

The McKay Dymek Model DA-3 AM "active" antenna makes it possible for one to enjoy all of the foregoing by capturing more AM stations than normally received and by reducing interference from stations that are not desired.

General Description. The ac-powered DA-3 couples a shielded ferrite-rod directional antenna with a two-stage transistor preamplifier, which includes a FET front end. The user adjusts r-f tuned circuits by setting a frequency control to approximately the desired station frequency. The circular dial is calibrated in nine AM frequencies broadly spaced across the standard broadcast band range of 540 kHz to 1600 kHz. A front-panel sensitivity potentiometer allows the user to adjust desired preamplification to his AM receiver. The non-electronic section, the ferrite rod, rests on a post above the base. It can be rotated and tilted for best reception, and it has a set knob to secure its position.

A power on-off switch and a power indicating lamp round out the front panel features, while the rear panel has a slow-blow fuse receptacle, an external antenna pin jack and an r-f output pin jack. (A 35" shielded cable with an RCA-type phono plug on one end and tinned, bare wire on the other is included.) Manufacturer's stated sensitivity is one microvolt.

Overall dimensions are 13⅜"W × 9 1/16"D × 11"H (34.9 × 23 × 27.9 cm). Weight is 6½ lb (2.9 kg), and the antenna is priced at $155.00.

User Comment. Attaching the DA-3's output to the antenna terminals of an inexpensive transistor radio brought in a number of AM stations that were not previously received, including a few powerful distant ones. Sound quality of newly received stations was fair. Connecting the output to a hi-fi receiver's external AM antenna terminals produced feedback howls at some frequencies and interference at others. However, the DA-3's manufacturer notes that the antenna is designed for normal use with AM receivers not having a built-in antenna. This was verified by disconnecting the receiver's built-in loopstick. The result was a dramatic improvement in AM reception, which, with the original loopstick, was rather poor. In addition to capturing all the AM broadcasts that one expects, quality of sound was improved in many instances and a bevy of distant stations was brought in.

Our most interesting results were obtained by connecting the DA-3 to a communications receiver (Hammarlund HQ-180A). Here, a great number of distant AM stations, including some foreign ones, were brought in. Sound quality ranged from poor to fairly good. The latter is about the best the communications receiver can produce since audio is down 6 dB at 400 Hz and 8 kHz, while speaker quality is certainly not "hi-fi."

As an example of what we received with the DA-3 connected to this sensitive, highly selective receiver, the following stations were received with maximum clarity at midday at a Long Island, NY, location: WBZ (50 kW), Boston; WTOP (50 kW), Washington, DC; and WCAU (50 kW), Philadelphia, which was broadcasting an exhibition baseball game. We also got fairly good reception of WYAU (10 kW), Tampa, FL; and WBT (50 kW), Charlotte, NC. Additionally, a number of foreign broadcasts were picked up, though none in English at the daytime hours we were listening. (Foreign broadcasts are frequently not spaced 10 kHz apart, so one can often hear them, though weak, by tuning in on the dial "cracks" between 10-kHz divisions.)

Clearly, the DA-3 operates admirably. There was no problem in hitting an S9 on the receiver's S meter, though at busy times of the day, it's difficult on some frequencies to lift out a distant station.

The unit is handsomely designed with walnut wood endplates, high-quality escutcheon and smooth frequency tuning, ferrite-rod rotation, and tilt operation. It's suited for persons who want to DX the mediumwave band or substantially improve AM reception quality on a well-designed AM receiver. Since the DA-3 is an indoor antenna and strikingly attractive, it should have wide appeal.

CIRCLE NO. 68 ON READER SERVICE CARD

EXACT MODEL 190 FUNCTION AND MODEL 195 SWEEP/FUNCTION GENERATORS

Compact instruments provide sine, square, and triangle waveforms.

RECENTLY, we tested a pair of function generators from Exact Electronics, Inc. (a subsidiary of Danalab). The Model 190 is a "deluxe" function generator that retails for $245. The other instrument was the lower-cost Model 195 sweep/function generator, priced at $149.50. Both instruments weigh the same at 2 pounds (0.9 kg) and are housed in 8½"D × 7⅜"W × 2⅞"H (21.6 × 20 × 7.3 cm) enclosures, which makes them very lightweight and compact.

The two instruments share some

electrical similarities. Both offer the user sine, square, and triangle test waveforms, for example. They differ in frequency range (the Model 190 goes from 0.1 Hz to 1 MHz, whereas the Model 195 goes from 2 Hz to 200 kHz) and the types of test conditions they offer. Also, the Model 195 is battery-powered for portability (an optional battery eliminator is available), while the Model 190 is line powered. (The Model 190 is also available in a battery-powered version, Model 196 for $350.)

General Description. The low-cost Model 195 is a special type of precision function generator that takes most of the work out of plotting frequency responses. The instrument has a built-in sweep generator that sweeps 1000: 1 (three decades) on any of the three main frequency ranges. The sweep can be either linear or logarithmic, simply by pressing a pushbutton switch. There are also three fixed 1000:1 sweep rates to select from: SLOW (25 s), MED (250 ms) and FAST (2.5 ms). The sweep covers 20 Hz to 20 kHz in one range for fast audio-equipment response checks, and can be internally or externally controlled.

The generator can also be used at a fixed frequency anywhere within its range. Coarse frequency control is selected by three pushbutton switches labelled 2K, 20K, and 200K, while exact frequency control is via a calibrated control. Separate calibrations for both the linear and logarithmic mode are on this control. Frequency accuracy in the sweep mode is ±2% of full range.

The output signal level at the HIGH and LOW sine jacks is continuously variable via a SINE AMPLITUDE control to 1 volt rms and 10 mV rms, respectively, open circuit. Output impedance is 600 ohms.

Arranged across the bottom of the front panel are six banana-type output jacks. Starting at the left, they deliver triangle, no-legend, square, LOW-sine, no-legend, and HIGH-sine waveforms. The jacks without legends are common to all of the legended jacks. This arrangement permits banana-jack-pair cables to be plugged directly into the instrument for any desired waveform without the need for an adapter.

The costlier Model 190 function generator does not have built-in sweep circuits. However, in addition to sine, square, and triangle waveforms, it also provides pulse and ramp waveforms. It has provisions for a voltage-control frequency input (VCF), dc offset control, and a TTL pulse output.

This is a high-performance function generator that has been designed to meet the demands of the audio, digital, and servo engineer. It offers continuously variable signal level outputs on all waveforms, variable time symmetry, and a floating output. The output is substantially higher than the 195's, being variable from zero to 20 volts peak-to-peak open circuit (10 volts peak-to-peak into 600 ohms). The TTL-compatible output has a fast 25-ns rise time and will sink 20 TTL loads.

Frequency selection is more precise than with the Model 195. Seven pushbutton switches provide the means for selecting the desired frequency range in decade steps from 1 Hz to 1 MHz full-range. Then the specific frequency can be dialed in via a calibrated rotary control.

Input and output connectors are five-way binding posts on plugpair centers that eliminate the need for special adapters. The ramp and pulse modes have their own separate amplitude control and can be instantly inverted simply by pushing a switch. Frequency accuracy of the Model 190 generator is ±5% of full scale. The 10,000-ohm VCF input can accommodate a 0-to-10-volt input to produce a 1000:1 (three decade) ratio. The dc offset is variable from −10 to +10 volts open circuit (−5 to +5 volts into 600 ohms).

Performance Results. Both instruments met or exceeded (exceeded, mostly) all of their published specifications. We were not equipped to run a full battery of tests, but those we were able to perform convinced us that the results obtained would be repeated on those we couldn't perform.

To begin with, the frequency ranges we obtained were greater than specified, which was no surprise. The Model 195's output signal levels were exactly as specified for the fixed outputs at slightly less than +3 volts on the PULSE (square) waveform output and 1 volt peak-to-peak on the triangle output. The HIGH sine-wave output at maximum amplitude into 600 ohms measured closer to 1.3 volts than the published 1.0 volt. The sine-wave distortion was indeed less than 2%; in fact, it barely hit the 1% mark.

The Model 190's bench performance bore out the fact that this is a precision instrument. Its frequency accuracy was well within the 5% specified, and its response topped 1.1 MHz on the top end with the frequency dial beyond its calibrated markings. Sine-wave distortion was about 0.4% over most of the instrument's range.

User Comment. From performance test results and having used these instruments for several months, we feel that both instruments are good investments. We particularly liked the ease of operation provided by a well-designed panel control and jack arrangement. All controls operated flawlessly, and electrical performance was excellent.

With a price differential of almost $100, how does one choose between these two excellent instruments? The low-cost Model 195 is ideal for service shops, particularly those concerned with general audio repair and maintenance. The built-in sweep generator is very handy for overall frequency response checks, while its battery power enables it to be moved easily around the shop. In conjunction with a good scope, the Model 195 would more than earn its keep.

The Model 190 (more expensive) should be useful in engineering and top-grade service shops. Its wider frequency span, plus its TTL-level function output enables its use in all kinds of analog and digital circuitry. Other features (such as the external vco capability) make this a very versatile instrument for original circuit design and critical repair of sophisticated equipment.

CIRCLE NO. 69 ON READER SERVICE CARD

MAC'S SERVICE SHOP

A Simple On-Board Tester

By John T. Frye, W9EGV

"BARNEY," Mac called out the back door of the service shop to his assistant, who was blowing the dirt out of a TV chassis, "come in here a minute. I want to show you something."

"*Con mucho gusto!*" Barney answered, dropping the air hose with alacrity. "Wait till I wash my hands. Wherever did we get that cruddy set?"

"From Harry's Bar and Grill. The set's mounted behind the bar up near the ceiling where it gets all the smoke from the customers and the greasy fumes from the grill. But here's a little gadget I want to demonstrate. Your South American friends would call it a 'gray-bearded novelty' because of its actual age and its recent popularity. I first ran across it in John F. Rider's *The Cathode Ray Tube at Work,* published in 1935. In the past few months, it has been discussed in military and amateur publications. In Navy circles, it's called the 'Octopus.'

"The device (Fig. 1) can be used with any type of oscilloscope and consists of a 6.3-VCT filament transformer, three ½-watt resistors, and two test probes. Half the filament voltage is applied to a voltage divider consisting of *R1* and *R2*, yielding 1 volt ac at the top of *R3*. This voltage can be applied to any component or combination of components across which the test leads are placed. The current is limited to 1 ampere by *R3*. The voltage across the probes is applied to the horizontal input of a scope, while the voltage across *R3* as a result of the current through it is applied to the vertical input. What we see on the scope is actually a display of the *voltage across* a component under test versus the *current through* that component."

"If you put the leads across a capacitor or an inductor, you actually have a phase-shifting network, huh?"

"Precisely. That's how Rider used the circuit. Now let's hook it to the scope. With an open circuit between the test leads, I adjust the horizontal gain for a 2" trace on the 5" tube (Fig. 2A). Under these open-circuit conditions, the full 1-volt ac appears across the horizontal input. Since no current is being drawn through *R3*, no voltage appears across it or the vertical input. Now I short the test leads together, and the trace flips to a vertical line (Fig. 2B). The vertical amplifier gain is adjusted to give a 2" trace. The shorted test leads short out the horizontal input and cause the full 1 volt of ac to appear across *R3* and so across the vertical input. Now we're ready to do some testing.

"First let's hook a resistance substitution box across the test leads. With the resistance in the megohm range, the trace is that of an open circuit: a horizontal line. As the resistance value drops to about 50,000 ohms, the horizontal line starts rotating counterclockwise so that, with 10,000 ohms between the test leads, it is almost 10° from the horizontal; at 1000 ohms, it is 45°; and at 100 ohms, it is a little less than 10° from the vertical (Fig. 2C). When the ac voltage is increasing in a positive direction at the vertical input and deflecting the spot upward, it is increasing in a negative direction at the horizontal input and deflecting the spot to the right. (This particular scope deflects to the left with a positive voltage at the amplifier input.) The resultant of the two synchronized equal right-angle forces on the spot is the straight line lying halfway between the vertical and the horizontal. The angle of this line with respect to the horizontal is a function of the ratio of the resistance of *R3* to the resistance being tested."

"Neat!" Barney approved. "With a little practice you could estimate at a glance the value of any resistance between 50 and 25,000 ohms—the values found most often in transistor work."

"Right. Now let's see what happens with a capacitance between the test

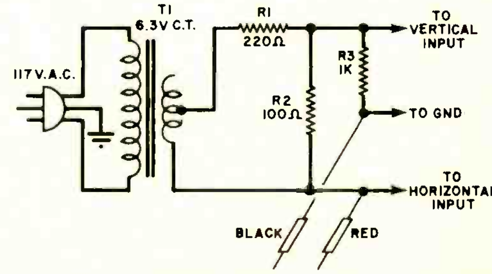


Fig. 1. Schematic of the testing device.

leads. With 0.1 μF, the horizontal trace opens slightly to form a skinny horizontal ellipse (Fig. 2D); but with a combination of parallel capacitors that totals 2.6 μF, we get a pretty fair circle (Fig. 2E). Finally, with 50 μF across the probes we get a skinny vertical ellipse (Fig. 2F). Keep in mind that current leads voltage by 90° in a capacitor and that capacitive reactance goes down as capacitance goes up. The reactance of 2.6 μF at 60 Hz is very close to the 1000 ohms of *R3*; so the voltages across the two are equal but 90° out of phase, a situation that produces the circular trace. Lower values of capacitance produce less current through *R3* and flatten the circle. Higher values of capacitance result in more current through *R3* and less voltage across the capacitor, with a resultant pulling in of the sides of the circle to form a vertical ellipse. Again, with a little practice, you can make a shrewd estimate of the value of any capacitor from 0.1 to 50 μF."

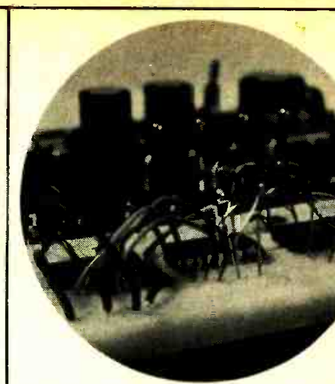
Inductances. "Wouldn't inductances do the same thing?"

"Yes. Unfortunately we have no calibrated inductor in the range we need for demonstrating, but we know that current lags voltage by 90° across an inductance and that the reactance value goes up with increasing inductance—just the opposite of the case with capacitance. When I place the primary of this transformer across the leads, we get a fairly fat ellipse slanted about 15-20° from the vertical (Fig. 2G). Watch what happens when I short the output of the transformer: the sides of the ellipse pull in, indicating that the shorted secondary has lowered the inductance of the primary. Inductances, unlike capacitors, have fairly low values of dc resistance, and this resistance accounts for the canting of the ellipse. When I open the secondary and put 4 μF of capacitance in series with the transformer primary across the test leads, the ellipse collapses to a straight line still about 15 to 20° from the vertical (Fig. 2H). The reactance of the capacitor cancels the inductance of the transformer primary, leaving only the dc resistance of the winding, about 200 ohms, between the leads. If I short the secondary, I need 50 μF of series capacitance to produce the straight line. This tells me the unshorted winding has a reactance at 60 Hz equal to that of 4 μF of capacitance, or about 660 ohms. With the output shorted, this drops to the

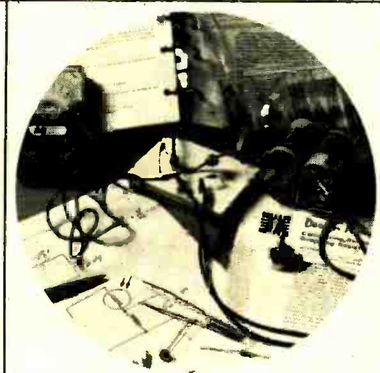
Communications Engineering

Aeronautical & Navigational

Television Engineering



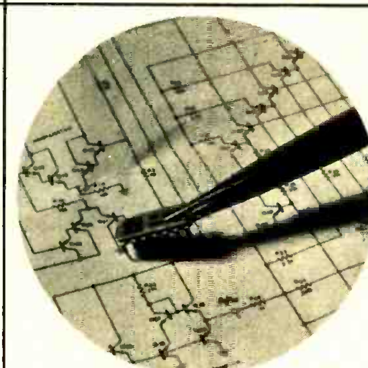
Automatic Control Engineering



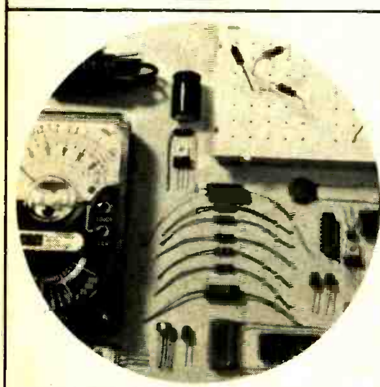
Missile & Spacecraft Guidance

Radar & Sonar Engineering

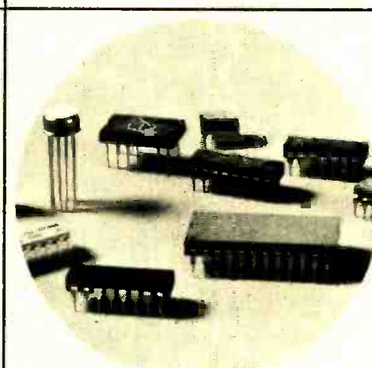
Digital Communications



Industrial Electronics



Microwave Engineering



Satellite Communications

Cable Television Engineering

Electronic Engineering Technology

Nuclear Instrumentation & Control

Special Programs for Electronic Engineers

reactance of the 50-μF capacitor, or about 50 ohms."

"I'm beginning to grasp the possibilities of that thing," Barney said.

"There's more. Watch what happens when I put the leads across this germanium diode with the red lead connected to the cathode and the black to the anode. We get a right angle (Fig 2I). Reversing the test leads reverses the position of the angle (Fig. 2J). See the difference in similar tests with a silicon diode? In either case the horizontal portion is longer than the vertical portion (Fig. 2K and 2L). Can you guess why?"

"Sure. The vertical side of the angle represents the conducting portion of the cycle. A germanium diode conducts practically from zero voltage, but a silicon diode doesn't start to conduct until 0.4 to 0.7 volts in the forward direction appears across it."

"Right on! Now let's simulate a leaky diode by paralleling it with different values of resistance. Note decreasing resistance values cause the horizontal side of the right angle to move so as to open up the angle (Fig. 2M). At very low values of parallel resistance, we get the vertical line that indicates a direct short. Series resistance, on the other hand, causes the vertical side of the angle to pivot so as to open up the angle (Fig. 2N). At high values of series resistance, we have only the straight horizontal line of an open circuit."

"What happens if you put a small capacitor across the diode?"

"Let's try it and see. With a 0.1-μF capacitor across the germanium diode, the vertical portion stays the same but the horizontal line opens to form a fat 'foot' (Fig. 2O). Increasing the value of the capacitor causes this foot to get fatter and fatter. At 2 μF, its influence dominates the pattern, leaving only a little vertical stub to show the diode is still getting in some feeble licks (Fig. 2P). At higher values of capacitance, the diode action is swamped out entirely."

Transistors. "How about transistors? Can it test them?"

"Yes. You treat a transistor junction as if it were a diode—which it really is. If you put the red lead on the base of a pnp transistor and the black lead on either the emitter or collector, you get the pattern in either Fig. 2I or 2K, depending on whether it is a germanium or a silicon transistor. The same tests with npn transistors produce Fig. 2J for a germanium transistor or Fig. 2L for a silicon transistor. A leaky transistor junction opens up the angle of the pattern just as with a leaky diode. Resistance or capacitance across a junction has exactly the same effect that it has across a diode."

"What if the transistor isn't marked and you don't know which is the base?"

"You touch the red lead to a transistor terminal and touch the black lead alternately to the other terminals.

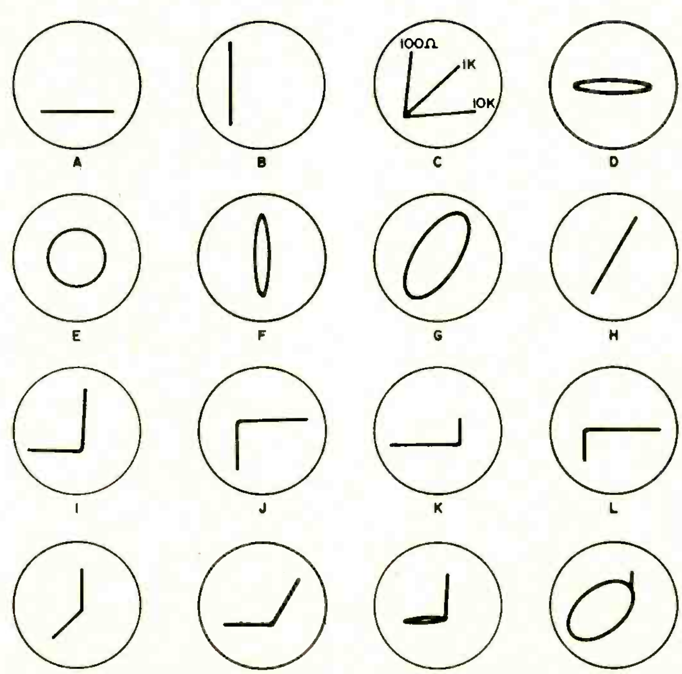


Fig. 2. Traces obtained on a scope using the testing device on various components.

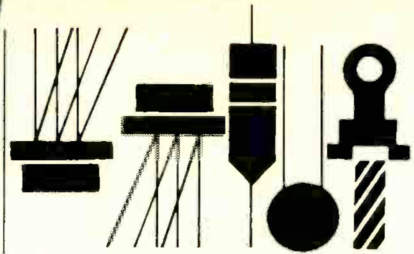
Only when the red lead is on the base will you get almost identical traces when the black lead is touched to the other two."

"I think I see where you're heading. You've been showing me all these individual traces so I can recognize them when I'm probing combinations of components on a printed circuit board. Right?"

"Right. This little gadget which you can build for only a few dollars has the potential of being one of the fastest, most informative, most versatile, and most reliable troubleshooting instruments you ever used. Its uses are limited only by the imagination and technical savvy of the user. The one volt at a maximum of one mA that it puts out is completely safe to use on all transistors and low-voltage diodes and capacitors. You don't have to worry about bending meter pointers. You use it without any power applied to the equipment being tested, so there's no danger of a test prod slipping, shorting something out and blowing a transistor. Since it is a dynamic test, exposing the unit being tested to a continuously varying voltage, each readout yields a wealth of information that would require dozens of separate static tests to duplicate.

"Just consider what it will tell you: it indicates shorts, open circuits, approximate resistance and capacitance values, inductance, and the quality of diodes and transistor junctions. It separates germanium from silicon diodes, indicates the polarity of such diodes and separates germanium from silicon transistors and npn from pnp types. It will pick out the base of an unmarked transistor. It will reveal the presence of resistance or capacitance across a diode or transistor junction. You can also use it to phase transformer windings—but there's no point in my going on and on. The more familiar you become with the device, the more uses you will find for it.

"But make it a habit to understand thoroughly the *why* of every trace you see. Letter the peaks and zero-crossings of a sine wave and then letter each trace to correlate the spot positions with the instantaneous voltage and polarity of the applied 60 Hz sine wave. If you see a puzzling trace, try to duplicate it with a diode, a resistance or capacitance box, and possibly an inductance. Doing this will make an excellent teaching instrument of the little unit." ◈



Solid State

By Lou Garner

AUDIO AMPLIFIERS FOR HOBBYISTS

WITHOUT question, audio amplifier projects, as a class, are the most popular of all among hobbyists. This is easy to understand, since amplifiers are used in a myriad of ways: headphone boosters, hearing aids, radio receivers, r-f transmitters (as modulators), TV receivers, electronic stethoscopes, portable phonographs, controls, tape recorders and playbacks, intercoms, PA systems, paging installations, and test instruments (such as signal tracers and metal detectors).

In contrast to the vacuum tube era, today's builder has a broad range of options. He can still use vacuum tubes, or he can choose an all-IC or an all-discrete solid-state design, or a combination of both discrete devices and IC's. A builder might select a circuit using an output transformer or one using any of a variety of OTL configurations, including direct single-ended drive, quasi-complementary, or full complementary-symmetry output stages. He can assemble a low-power amplifier smaller than a watch and with minimal battery drain or, at the other extreme, he can design an amplifier with sufficient power to shake the walls while running as cool as a cucumber.

Along with a broad range of circuit options, today's hobbyists can reasonably expect improved performance, high efficiency, and relatively modest costs. Old timers may remember the days when a "Hi-Fi" amplifier was one with a reasonably flat response from 50 Hz to, say, 15 kHz ±2dB, where a total harmonic distortion (THD) rating of 5% was considered acceptable, and an amplifier with a rated output of 25 watts was "high power." The parts to assemble, say, a 2-watt phonograph amplifier might have cost as much as ten or twelve dollars, even though average salaries hovered around $60/week.

We've come a long way, baby! Today's hobbyist expects an amplifier intended for high-quality reproduction to have a frequency response of at least 20 Hz to 20 kHz ± 1 dB, while 10 Hz to 40 kHz ±0.5 dB is not uncommon. And while THD might be tolerated in a general-purpose design, one would expect a THD of 1% *or less* in a high-fidelity instrument. Finally, despite inflation and an overall higher standard of living, the average experimenter would hesitate to pay much more than five or six dollars for the components to assemble a general-purpose, medium-power amplifier.

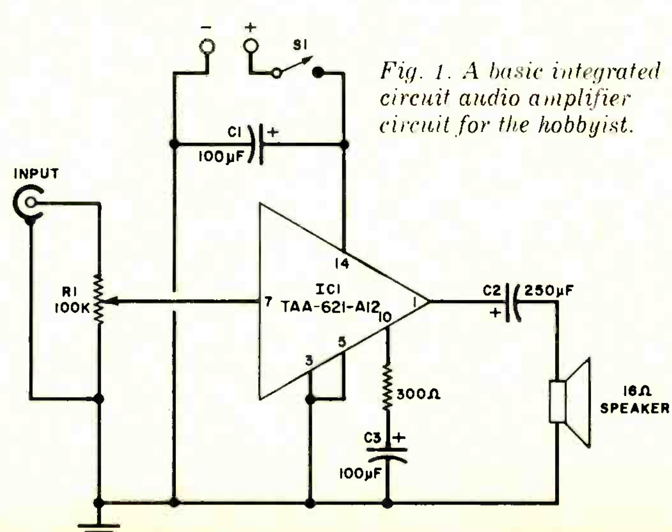


Fig. 1. A basic integrated circuit audio amplifier circuit for the hobbyist.

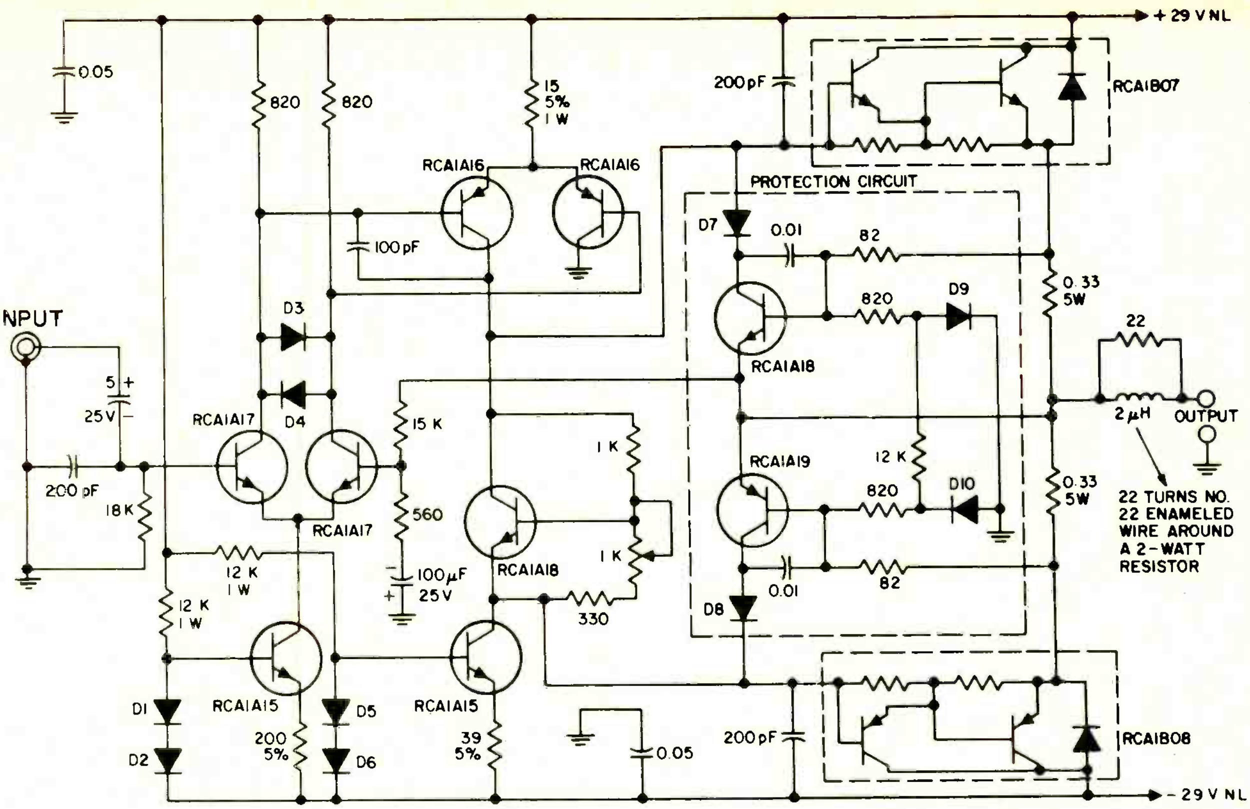


Fig. 2. RCA's 40-watt audio amplifier has full complementary-symmetry Darlington output. 92CM-24144

Except for single-transistor circuits used, typically, in headphone boosters, the simplest design today is one using a complete audio amplifier IC. Monolithic and hybrid devices are available furnishing outputs of from a fraction of a watt to a hundred or more watts and requiring a minimum of external components. A typical general-purpose audio amplifier featuring a single IC is illustrated in Fig. 1. One of several designs presented in a booklet published by the IC's manufacturer, SGS-ATES Semiconductor Corp. (435 Newtonville Ave., Newtonville, MA 02160), this circuit is suitable for a variety of projects ranging from a phonograph to a signal tracer. The rated power output is 2.2 W with an 18-volt dc power source and 4.0 W if a 24-volt source is used. The −3 dB bandwidth, exclusive of speaker, is 300 kHz and the voltage gain is 34 dB.

In operation, *R1* (audio taper) serves as the gain control and input bias return. Low frequency roll-off is determined by series resistor *R2* in conjunction with capacitor *C3*. The loudspeaker is coupled to the IC's output terminal through dc blocking capacitor *C2*. Circuit power is supplied by an external source, either batteries or a line-operated supply, controlled by *S1*, with additional filtering provided by *C1*.

Commercially available components are specified for the circuit. The IC is an SGS-ATES type TAA 621 A12, comprising seventeen transistors and seven integral resistors.

Priced at less than two dollars each, net, in unit quantities, the TAA 621 A12 is supplied in a 14-pin quad in-line (staggered terminal) package.

Turning from the simple to the sophisticated, the high-fidelity power amplifier circuit shown in Fig. 2 should appeal to more experienced hobbyists. Featuring discrete components and a full complementary-symmetry output stage using a pair of high-gain npn (RCA 1B07) and pnp (RCA 1B08) Darlington transistors, the circuit was abstracted from RCA Technical Specification Bulletin 791. The amplifier is designed to deliver 40 watts to a 4-ohm loudspeaker or 30 watts to an 8-ohm load. With a sensitivity of 500 mV, it is suitable for use with virtually all standard preamps. According to RCA (Solid State Division, Somerville, NJ 08876), the amplifier has a THD specification of only 0.5%, an IM distortion level (at 10 dB below continuous power output at 60 Hz and 7 kHz, 4:1 ratio) of less than 0.2%, and an IHF power bandwidth at 3 dB below rated power of 5 Hz to 50 kHz. At a 1-W output, the bandwidth is 5 Hz to 100 kHz. Other performance specifications are an input impedance of 18,000 ohms, and a hum/noise rating 100 dB below the continuous power output with the input shorted.

A pair of npn transistors in conjunction with diodes *D3* and *D4* form an input differential amplifier, supplied by a third npn device which, in conjunction with *D1* and *D2*, forms a current source. The input amplifier is direct-coupled to a pair of pnp transistors serving as a class-A differential pre-driver. An npn multiplier balances the drive to the complementary-symmetry output stage, which consists of a pair of npn and pnp high-gain Darlingtons. Another npn transistor, with *D5* and *D6*, serves as a current source for the multiplier and part of the pre-driver stage. Drive overload protection is provided by an npn and pnp complementary pair in conjunction with *D7* through *D10*. Feedback is applied to one side of the input differential amplifier stage through a frequency conscious network consisting of a 15,000-ohm resistor in series with a 560-ohm resistor and 100-μF capacitor. Finally, the loudspeaker

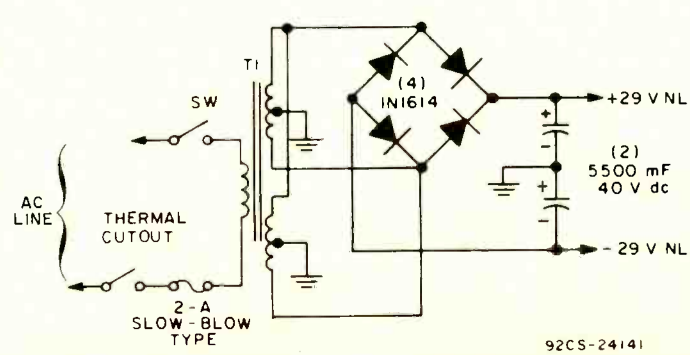


Fig. 3. Suggested power supply for circuit in Fig. 2.

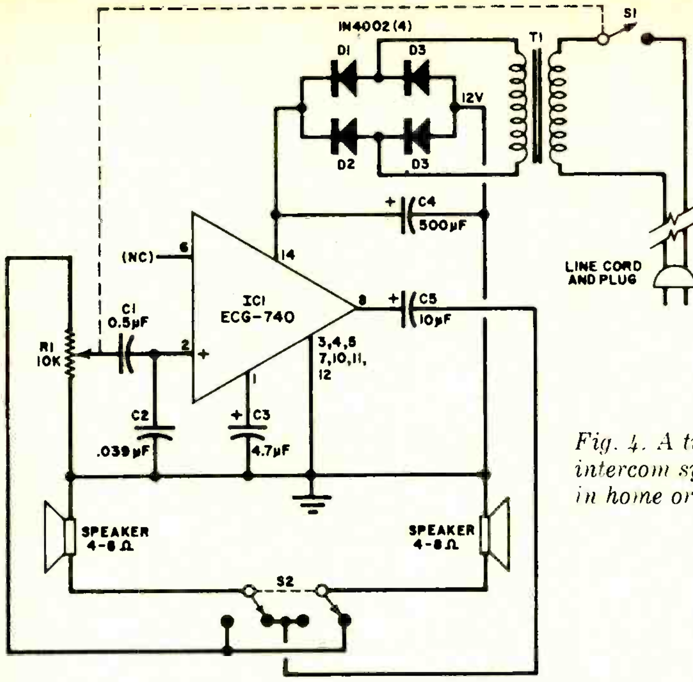


Fig. 4. A two-station intercom system for use in home or office.

load is driven through a 22-ohm resistor shunted by a 2-µH coil.

The Darlington output transistors featured in the amplifier are silicon devices packaged in type TO-3 cases. Both have a maximum V_{CBO} rating of 80 volts, maximum collector current ratings of 10 amperes, and device dissipation ratings (up to 25°C) of 100 watts. Their dc beta (gain) values are specified at not less than 1000 nor more than 15,000.

A line-operated dc power supply circuit suitable for the amplifier is illustrated in Fig. 3.

RCA has specified standard components for the design. All resistors should be noninductive and, except where indicated, ½-watt, 10% tolerance types. Except for the power supply, where type 1N1614 is used, all diodes are type 1N5391. The thermal cutout should be rated to open at 90°C. The power supply transformer is a Signal Model 80-4 (Signal Transformer Co., 1 Junius St., Brooklyn, NY 11212).

Because of the power and gain levels involved, good audio layout and wiring practice should be observed. An adequate common heat sink should be provided for the Darlington output transistors.

Reader's Circuit. Mistakes can happen. A slip of a typewriter key, and Craig K. Sellen (48 Briarwood Road, Wayne, NJ 07470), who contributed the slow-sweep wiper control circuit featured in our April column, became Craig S. Kellem. Apparently all is forgiven, however, for Craig has submitted another circuit which, I feel, is especially appropriate to our discussion of audio amplifiers—the two station intercom illustrated in Fig. 4. Suitable for use in a home, small office or store, the project is inexpensive, requiring relatively few components, and could be assembled by most hobbyists in two or three evenings or on a weekend.

Small PM loudspeakers are used interchangeably as both microphones and output devices, while a single 2.5-watt IC serves as the complete amplifier. Potentiometer *R1* acts as the unit's gain (volume) control, *C1* as the input coupling capacitor, *C5* as the output dc blocking capacitor, and *C2* and *C3* as the input and amplifier bypass capacitors, respectively. A dpdt switch, *S2*, interchanges the loudspeaker input and output connections, providing a *"talk-listen"* capability. Operating power is furnished by a line-operated dc power supply, comprising power switch *S1*, step-down transformer *T1*, bridge rectifier *D1* through *D4*, and ripple filter capacitor *C4*.

Craig has specified readily available components for his project. The integrated circuit, *IC1*, is a Sylvania type ECG-740, while the gain control is an audio-taper potentiometer with an attached spst rotary switch, *S1*. Input capacitor *C1* and high-frequency bypass capacitor *C2* are small ceramic or plastic film types, while the remaining capacitors, *C3*, *C4* and *C5*, are 20-volt electrolytics.

Layout and lead dress are not overly critical but good wiring practice should be observed. One loudspeaker is mounted in the cabinet with the amplifier, power supply and controls, while the second is mounted in a separate cabinet for the remote location and connected to the amplifier using a length of two-conductor intercom wire or ordinary lamp cord.

Device/Product News. A unique device suitable for use in active filters, tone generators, selective audio amplifiers, medical electronic instruments and signal processing equipment has been introduced by Amperex Electronic Corp. (Solid State and Active Devices Division, Slatersville, RI 02876). Designated type ATF431, Amperex's new device is the industry's first practical audio frequency IC *gyrator*. In case you've forgotten, a gyrator is a circuit configuration which is inherently capable of inverting impedances. When terminated by a capacitive load, it presents a corresponding inductive input impedance. Thus, a gyrator may be used to obtain relatively high inductance values in comparatively small volumes. For example, the ATF-431 and a 0.1-µF capacitor combine to produce 5.625 H. Circuit Q's of over 500 can be realized in practice. A thin-film hybrid device consisting of dual monolithic wideband differential amplifiers and four 0.1% film resistors, the ATF431 is supplied in a 10-lead hermetically sealed TO-100 package.

Two new series of 8-ampere npn silicon Darlington transistors have been announced by RCA's Solid State Division. Consisting of eight devices, type numbers 2N6530-2N6533 and 2N6534-2N6537, these new units offer a choice of V_{CBO} ratings of 80, 100, or 120 volts and h_{FE} of 500 or 1000 min. at 3 or 5 amperes. Types 2N6530-2N6533 have device dissipation ratings of 65 watts and are supplied in the TO-220AB straight-lead version of the Versawatt package, while types 2N6534-2N6537 have dissipation ratings of 36 watts and are supplied in TO-66 hermetic packages.

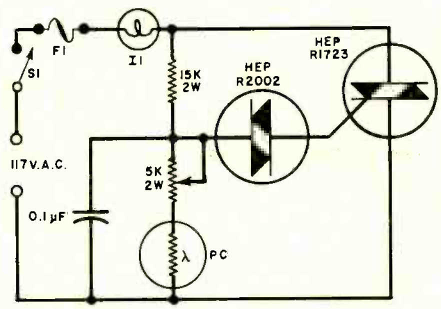
The Fairchild Camera & Instrument Corporation (Integrated Circuits Group, 464 Ellis St., Mountain View, CA 94042) has added a new 7-segment LED decoder/driver to its 9300 TTL family. A BCD-to-7-segment decoder with constant-current sink outputs, the 9374 has low-power latched inputs which can be driven easily from all TTL as well as most MOS and CMOS devices. The unit's 15-mA constant-current outputs can drive virtually all common-anode (MAN-1 type) LED displays directly without the need for external resistors. The device's input latch and low input load currents permit simplified multiplexed display systems, while its constant-current output allows the LED anode supply volt age to be varied between 2.5 and 10 volts without affecting display brightness.

A new series of infrared LED's suitable for use in control systems, intrusion alarms, automatic door openers, interrupted beam counters, and similar projects has been announced by GE's Semiconductor Products Department (Electronics Park, Bldg. No. 7, Mail Drop 49, Syracuse, NY 13201). Identified as the LED55 and LED56 series, the new devices are gallium-arsenide diodes which emit noncoherent infrared energy with a peak wavelength of 940 nanometers and are ideally suited for use with silicon detectors. Packaged in hermetically sealed cases with either flat or lens cap configurations, the units may be used as replacements for the earlier SSL55 and SSL56 devices. ◈

Hobby Scene

DARK-ON LIGHT

Q. ***I would like to have incandescent lights around my home which will turn on at dusk and off at dawn. Can you provide me with a circuit?***
—E. Cassidy, Los Angeles, Calif.



A. The circuit shown will handle up to 1000 W of power. The selection of photocell *PC* is not critical, and any of the experimenter-type CdS cells should work. The light level at which the circuit changes states can be selected by varying the potentiometer. (Its value is not critical, and will depend on the photocell used. Check your junk box.) If more than one bulb *(I1)* will be used, wire them in parallel. Choose the rating of the fuse to agree with the total load requirement. Be sure to adequately heat-sink the triac.

OUTDOOR ANTENNA COUPLING

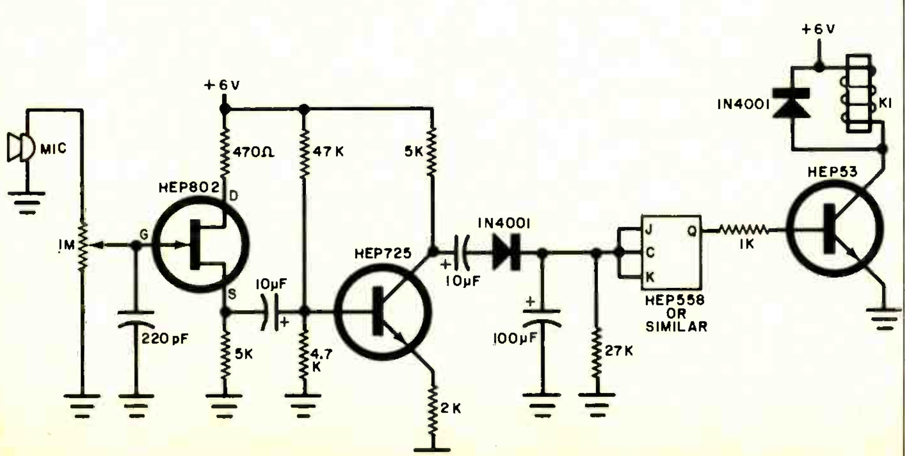
Q. ***How can I couple an outdoor antenna to a table-model transistor AM radio to increase its receiving range?*** —*George Kalenchuk, Saskatchewan, Canada*

A. The easiest way is by inductive means. At the receiver end of the lead-in, wind a husky coil of wire (ferrite forms can be used) and position it close to the ferrite bar or air-core antenna on the back (or inside) of the set. If a directional external antenna is being used, make sure that the built-in antenna is facing the same direction, or you'll have to put the two coils inside a small shielded enclosure to avoid pickup from other directions.

AUDIO-OPERATED RELAY

Q. ***Do you have a circuit for a simple voice- or sound-controlled relay?***—*J. Lengenfelder, Trenton, N.J.*

A. The circuit shown here will perform this function. The Radio Shack 275-004 relay is used. Its contacts can handle 1 ampere at 125 V ac. The diode across the coil protects the transistor from inductive surges. An SCR or triac can be used instead of the relay and the switching transistor if solid-state switching is more desirable. Also, an active filter (bandpass) could be inserted at the FET output if you want to activate the circuit with only one specific tone.



Electronics Library

A FLICK OF THE SWITCH 1930-1950

by Morgan E. McMahon

A words-and-picture tour of the "Golden Era of Radio." Aimed at both nostalgia fans and collectors, the book contains information on broadcasting fare, old radio receivers, early television sets, shipboard radios, and ham stations. Principal manufacturers are listed alphabetically, and products that show promise of becoming collector items are illustrated, described by year, price, number of tubes, type of circuitry, and many by the number of units made. Separate chapters are also devoted to WW2 military equipment, the radioman, collecting, and how it works. The text is well illustrated, and includes old advertisements.

Published by Vintage Radio, Box 2045, Palos Verdes Peninsula, CA 90274. 312 pages. $9.95 hard cover, $6.95 soft cover.

INSTALLING TV & FM ANTENNAS

by Leo Sands

Here's a reference work for those who wish to learn not only how to fasten an antenna so it will stay upright, but also how to make the most of available signals. Basic propagation characteristics are discussed, as well as representative antenna configurations. Transmission lines, lightning protection, and types of hardware available are also treated. Installation procedures for maritime and mobile TV antennas are outlined, and urban and suburban installations are described.

Published by Tab Books, Blue Ridge Summit, Pa. 17214. 168 pages. $7.95 hardcover, $3.95 paperback.

SOLID STATE COMPONENTS

by Rufus Turner

Solid-state devices have virtually taken over many functions previously performed by vacuum tubes. For those who want to know what these devices are, how they work, and what they can do, this book will be of interest. It covers not only semiconductor devices (transistors, diodes, and IC's) but also devices in which the significant action takes place in other solid materials, such as memorycores and piezoelectric crystals. Cross-references to related terms are included. Illustrations include pictorials of devices, circuit diagrams, and characteristic curves.

Published by Howard W. Sams & Co., 4300 W. 62nd Street, Indianapolis, Ind. 46206. 96 pages. $3.95 softbound.

SERVICING ZENITH FOR 1974/1975
SERVICING RCA FOR 1975

by Stan Prentiss

These first volumes of a new series contain full servicing information on each company's entire line of consumer electronics products for the appropriate years. Based on manufacturer's information, these Audel manuals cover color and monochrome television receivers, stereo equipment, tape recorders, and small radios. Each includes fold-out schematics, parts lists, scope waveforms, troubleshooting guides, adjustment and alignment prodcedures, and chassis layouts. In the Zenith manual, operating theory of the FC45 color TV line is discussed, and a wide-ranging solid-state servicing section is partly based on Zenith's 20-week training course available to all technicians. Also, an entire chapter is devoted to the functional aspects of the oscilloscope, while much of another chapter covers new stereo circuitry (including FM) and four-channel decoding systems. The RCA manual follows the same format, and covers some of its 1974 line. Test instruments such as DMM's, function generators, and color-bar generators, are described in one chapter. Another chapter examines IC's (including complete circuit descriptions), modules and motherboards.

Published by Theodore Audel & Co., Div. of Howard W. Sams & Co., 4300 W. 62nd St., Indianapolis, IN 46206. 527 pages (Zenith, not counting foldouts), 384 pages (RCA, not counting foldouts). $12.95 each, soft cover.

DIGITAL DESIGN WITH STANDARD MSI AND LSI

by Thomas Blakeslee

This book gives a thorough design approach to today's MSI and LSI circuits. It shows how to use standardized bargain components to handle many system requirements and how these building blocks can be traded off with other mechanical and electrical components for optimum results. Programmed logic and programming techniques are provided, with description of hardware and software for the Intel and National Semiconductor microprocessors.

Published by John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10016. 357 pages. $19.95 hard cover.

SYLVANIA ECG SEMICONDUCTOR GUIDE

GTE Sylvania's ECG™ line of replacement semiconductors is presented in this catalog and cross-reference. The book provides replacement considerations, specifications, biasing, and outline drawings of the ECG products as well as a replacement directory which cross-references almost 106,000 JEDEC types and manufacturers' part numbers to the replacement devices.

Published by GTE Sylvania Inc., Electronic Components Group, 100 First Ave., Waltham, MA 02154. 214 pages. $2.95 soft cover.

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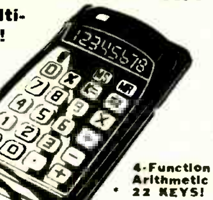

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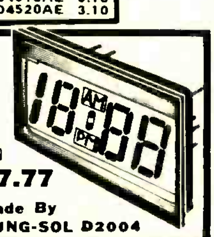

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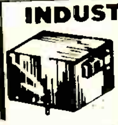

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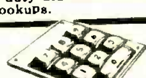

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2.2ufd/50v	8c	10/64c	1c/$ 5.41	22ufd/16v	12c	10/98c	1C/$ 8.31
3.3ufd/50v	8c	10/64c	1C/$ 5.41	22ufd/25v	13c	10/$1.03	1C/$ 8.74
4.7ufd/25v	8c	10/64c	1C/$ 5.41	33ufd/16v	12c	10/$1.00	1C/$ 8.48
10ufd/25v	8c	10/67c	1C/$ 5.66	33ufd/25v	14c	10/$1.13	1C/$ 9.56
10ufd/50v	10c	10/77c	1C/$ 6.58	47ufd/16v	14c	10/$1.13	1C/$ 9.56
22ufd/25v	9c	10/72c	1C/$ 6.09	47ufd/25v	17c	10/$1.32	1C/$11.22
22ufd/50v	12c	10/$1.00	1C/$ 8.48	100ufd/16v	17c	10/$1.32	1C/$11.22
100ufd/6.3v	9c	10/74c	1C/$ 6.32	100ufd/25v	20c	10/$1.57	1C/$13.30
100ufd/16v	11c	10/86c	1C/$ 7.28	100ufd/50v	29c	10/$2.32	1C/$19.70
100ufd/25v	13c	10/$1.08	1C/$ 9.15	220ufd/16v	20c	10/$1.57	1C/$13.30
— Axial Lead —				220ufd/25v	29c	10/$2.35	1C/$19.96
1ufd/50v	11c	10/90c	1C/$ 7.65	330ufd/16v	29c	10/$2.35	1C/$19.96
2.2ufd/50v	12c	10/92c	1C/$ 7.82	330ufd/25v	32c	10/$2.54	1C/$21.62
3.3ufd/35v	12c	10/93c	1C/$ 7.91	470ufd/16v	32c	10/$2.54	1C/$21.62
3.3ufd/50v	12c	10/98c	1C/$ 8.31	470ufd/25v	37c	10/$2.98	1C/$25.36
4.7ufd/35v	12c	10/93c	1C/$ 7.91	1000ufd/16v	39c	10/$3.13	1C/$26.61
10ufd/16v	11c	10/90c	1C/$ 7.65	1000ufd/25v	56c	10/$4.50	1C/$38.23
10ufd/25v	12c	10/98c	1C/$ 8.31	2200ufd/16v	62c	10/$4.94	1C/$41.98

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220pf/500v	4c	10/36c	2C/$ 6.09
470pf/500v	4c	10/36c	2C/$ 6.09
1000pf/500v	4c	10/37c	2C/$ 6.22
2200pf/500v	4c	10/37c	2C/$ 6.22
4700pf/500v	4c	10/32c	2C/$ 5.41
.01ufd/500v	6c	10/50c	2C/$ 8.55
.01ufd/50v	3c	10/24c	2C/$ 4.05
.022ufd/25v	3c	10/28c	2C/$ 4.73
.047ufd/25v	5c	10/42c	2C/$ 7.17
.1ufd/25v	8c	10/62c	2C/$10.57

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6-32 1/2 Screw	88c/C	$ 7.00/M
8-32 3/8 Screw	$1.05/C	$ 8.40/M
8-32 5/8 Screw	$1.35/C	$10.80/M
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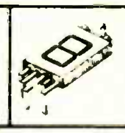

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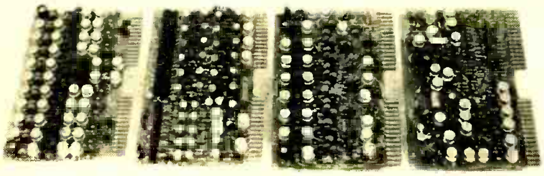

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DIODES

21-10270	1N270 Germanium Switching Diode	.12
42-14001	1N4001, 1Amp, 50PRV, Rec Diode	.07
42-14002	1N4002, 1Amp, 100PRV, Rec Diode	.08
42-14003	1N4003, 1Amp, 200PRV, Rec Diode	.09
42-14004	1N4004, 1Amp, 400PRV, Rec Diode	.10
42-14005	1N4005, 1Amp, 600PRV, Rec Diode	.11
42-14006	1N4006, 1Amp, 800PRV, Rec Diode	.12
42-14007	1N4007, 1Amp, 1000PRV, Rec Diode	.13
42-14148	1N4148 Silicon Switching Diode	.08
73-10746	1N746A, 3.3V, 5%, 400MW, Zener Diode	.15
73-10747	1N747A, 3.6V, 5%, 400MW, Zener Diode	.15
73-10748	1N748A, 3.9V, 5%, 400MW, Zener Diode	.15
73-10749	1N749A, 4.3V, 5%, 400MW, Zener Diode	.15
73-10750	1N750A, 4.7V, 5%, 400MW, Zener Diode	.15
73-10751	1N751A, 5.1V, 5%, 400MW, Zener Diode	.15
73-10752	1N752A, 5.6V, 5%, 400MW, Zener Diode	.15
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73-10754	1N754A, 6.8V, 5%, 400MW, Zener Diode	.15
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73-10757	1N757A, 9.1V, 5%, 400MW, Zener Diode	.15
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TRANSISTORS

54-23860	2N3860 NPN General Purpose Transistor	.21

TRIACS

45-03003	3mA Gate 50V 3 Amp. TRIAC	1.31
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7403	.20	7489	3.50
7404	.21	7490	.68
7405	.21	7491	1.00
7406	.40	7492	.68
7407	.40	7493	.68
7408	.22	7494	.98
7409	.22	7495	.98
7410	.20	7496	.98
7411	.21	74100	1.25
7413	.45	74104	.60
7416	.38	74105	.60
7417	.38	74107	.42
7418	.30	74121	.48
7420	.20	74122	.60
7421	.20	74123	1.00
7423	.40	74141	1.25
7425	.40	74145	1.21
7426	.26	74150	1.42
7430	.20	74151	1.00
7437	.44	74153	1.25
7438	.44	74154	1.95
7440	.20	75155	1.25
7441	1.00	74156	1.25
7442	1.00	74157	1.30
7443	1.00	74158	1.30
7444	1.00	74161	1.50
7445	1.20	74162	1.50
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7447	.90	74164	1.50
7448	1.00	74165	1.50
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7459	.20	74177	1.75
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7483	1.30		

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74S40	.55
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74S51	.50
74S60	.50
74S65	.50
74S74	.99
74S76	.99
74S78	.99
74S107	.99
74S112	.99
74S113	.99
74S114	.99

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4001	Quad 2-Input Positive NOR Gate	.29
4002	Dual 4-Input Positive NOR Gate	.29
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4007	Dual Complimentary Pair Plus Inverter	.29
4008	4-Bit Full Adder W/Parallel Carry Out	1.36
4009	Hex Buffer, Inverting Type	.74
4010	Hex Buffer, Non-Inverting Type	.74
4011	Quad 2-Input Positive NAND Gate	.29
4012	Dual 4-Input Positive NAND Gate	.29
4013	Dual D Type Flip-Flop W/Set-Reset	.67
4014	8-Stage Static Shift Register	1.86
4015	Dual 4 Stage Static Register	1.79
4016	Quad Bilateral Switch	.67
4017	Decade Counter/Divider W/Decoded Outputs	1.69
4018	Presettable Divide-By-"N" Counter	1.86
4019	Quad AND-OR "Select" Gate	.67
4020	14-Stage Ripple-Carry Binary Counter/Divider	1.86
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4024	7-Stage Binary Counter	1.43
4025	Triple 3-Input Positive NOR Gate	.29
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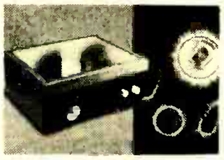

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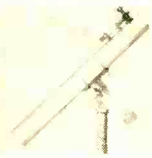

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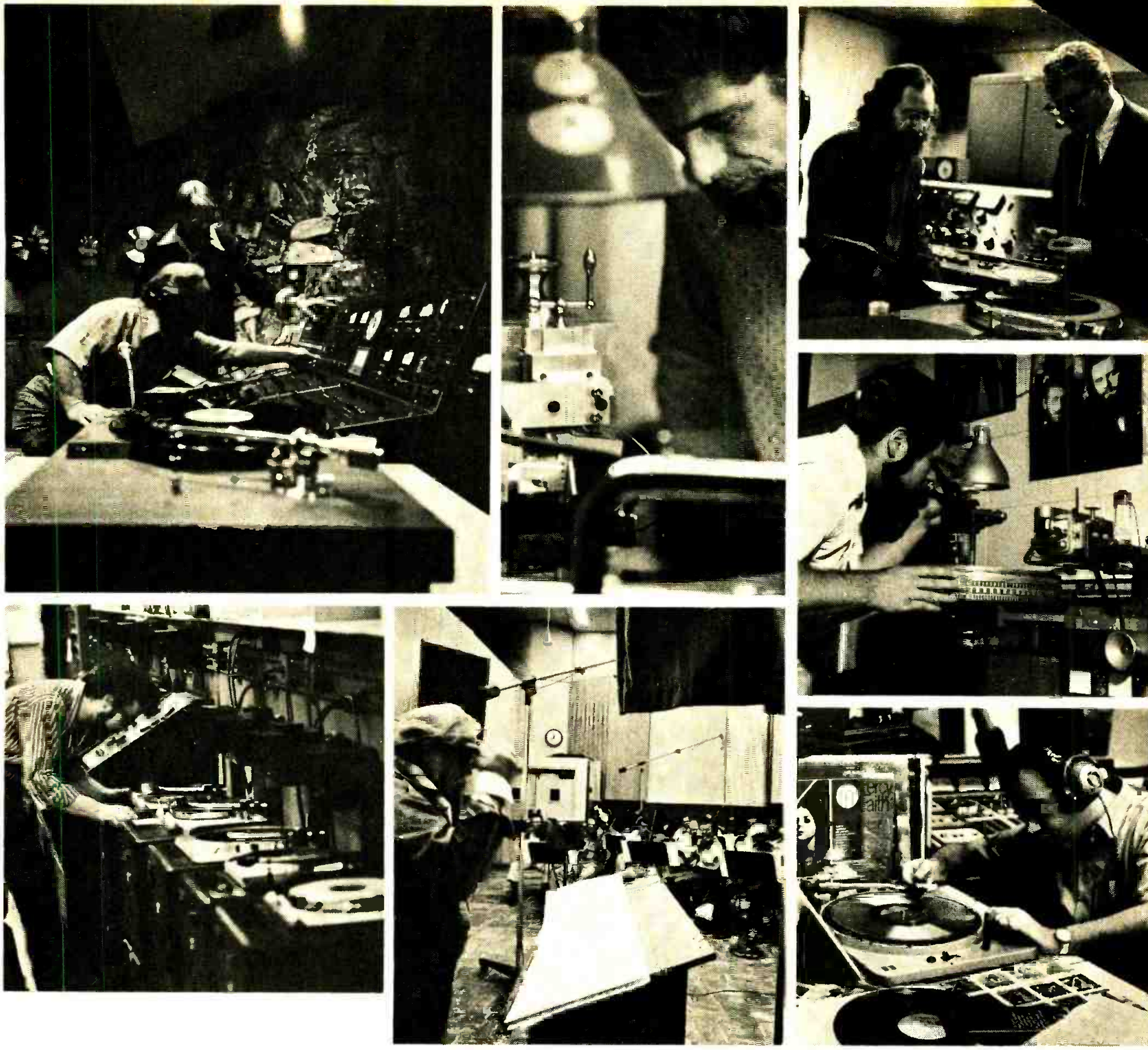

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