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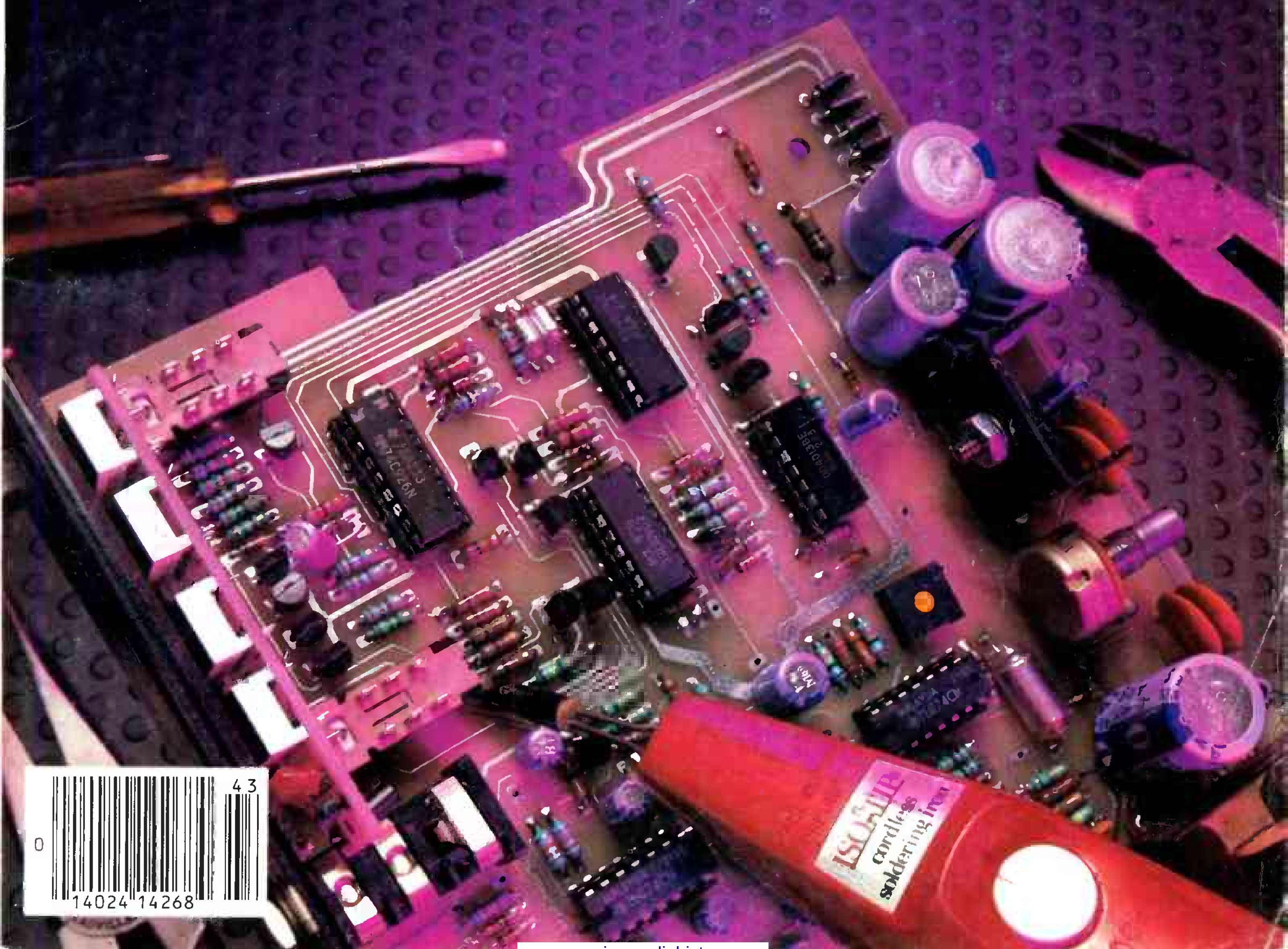

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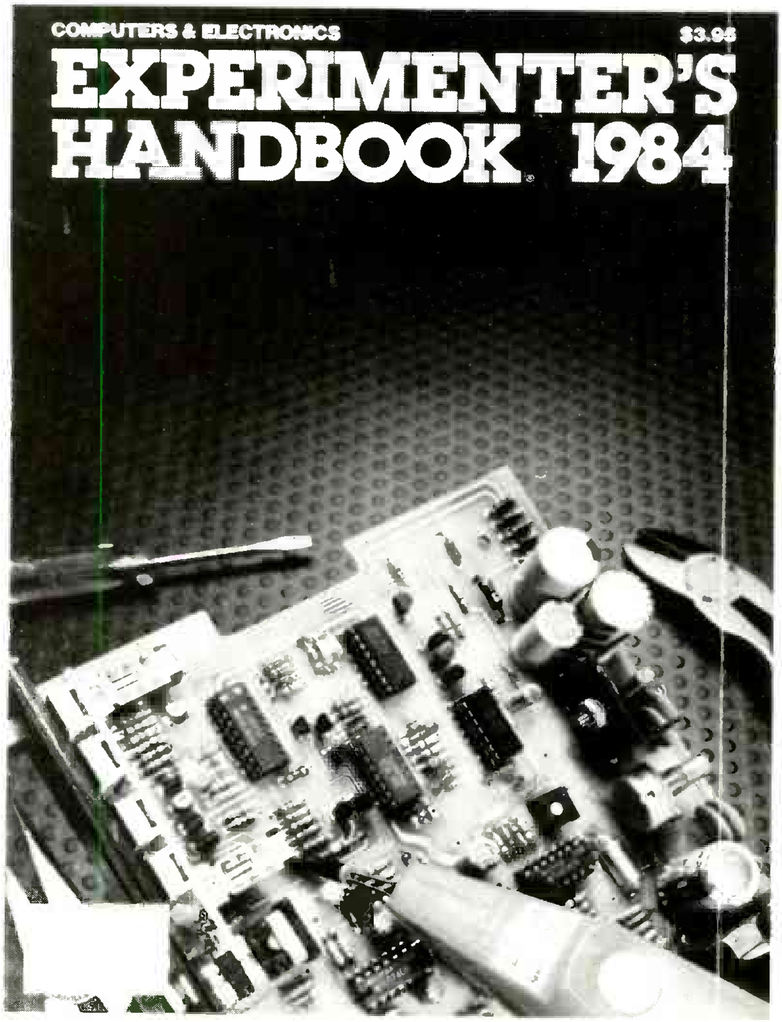

THE COVER

Tools routinely used in the pursuit of the electronics hobby include a variety of screwdrivers, longnose pliers, diagonal wire cutters, and a soldering tool (a Wahl "Iso-Tip" cordless soldering iron is shown). This minimal lineup will suffice for kit and simple project building but is usually supplemented by special-purpose tools for building complex projects from scratch.

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SUCCESSFUL SOLDERING

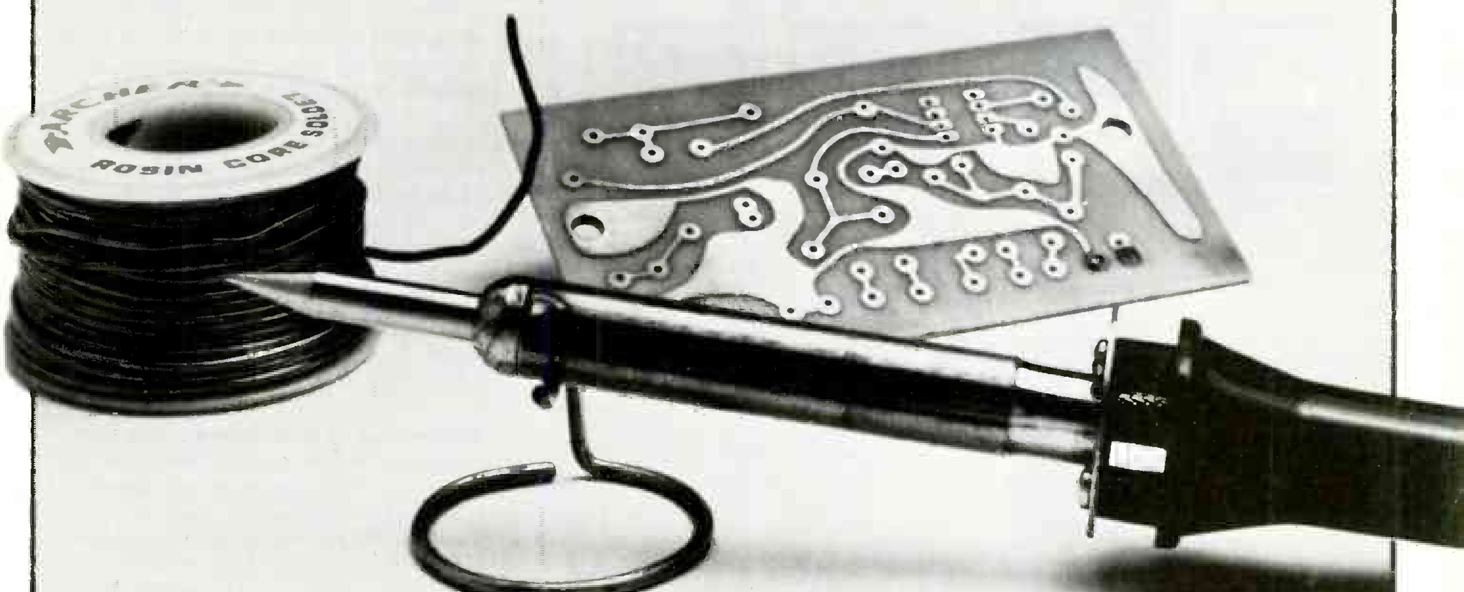
Helpful tips on materials, tools, and techniques

EY JOHN D. BORNEMAN

IN ELECTRONICS, the basic goal of soldering is to electrically and mechanically join two circuit components. For this connection to be reliable, the solder must adhere to or "wet" the mating surfaces of the components being joined. The wetting of solder to a base metal is similar to the action of water spilled on a smooth surface: if the surface is clean and free of dirt, wax and oils, the water will wet and spread evenly over it; if the surface is waxed, the water balls up.

Most manufacturers of electronic components do a good job of making their products of easily solderable material or providing a clean solderable coating. Copper, copper-clad steel, or nickel-steel are some of the common base metals used in the leads of resistors, capacitors, integrated circuits, etc., and they may be coated with silver, tin, tin-lead, or gold to improve solderability. Greases, oils, dirt, and oxides are the principal sources of contamination that prevent good solder wetting despite the original surface. Also, aging deteriorates the surface and inhibits solder wetting by the formation of oxide films.

Solder Alloys and Fluxes. Technically, soldering is the joining of two parts with a metal alloy having a melting point below 800°F. Various solder alloys include combinations of tin, lead, antimony, silver, indium, and bismuth; however, the most common combination is tin and lead. Tin-lead solders range from pure tin to pure lead and include all proportions in between. For plumbing, alloys of 10% tin and 90% lead (10/



90 solder) are commonly used. In electrical soldering, the alloy mix is usually 60% tin and 40% lead (60/40).

Characteristics of alloys of tin and lead are plotted against temperature in Fig.1. This graph, referred to as a phase diagram, allows one to see that only a 63/37 alloy has a eutectic point—that is, a single melting point. All other alloys start melting at one temperature, move through a "pasty" or semisolid stage, and then become liquid at a higher temperature. Any physical movement of the components being soldered while the solder is in the "pasty" range will result in a "cold" joint. Such a joint appears grainy and dull, and is mechanically weaker, thus less reliable. Therefore, 63/37 or 60/40 solder is commonly used in electronics since they do not remain long in a "pasty" phase. However, a 50/50 alloy can be used if proper care is taken.

An often-ignored aspect of soldering is the *flux*. The word flux comes from the Latin root "fluere" meaning "to flow." Soldering flux, which is usually included in the solder as a central core, or separately in liquid or paste form, helps the solder alloy flow around the connection. Flux also cleans the component leads of oxides and films, and allows the solder to wet their surfaces.

Chemically, flux is either acid or rosin based. Always use rosin flux in electronic soldering since the acid may cause corrosion. "Activated" rosin or "RA" flux produces better cleaning and

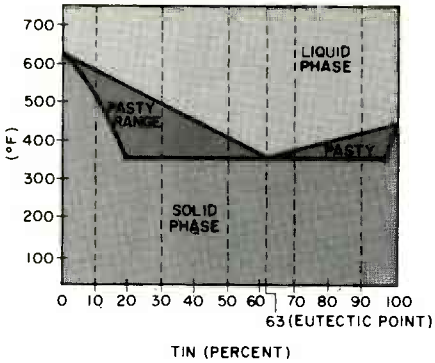


Fig. 1. Melting point, including pasty phase, of alloys of tin and copper.

flowing properties than the popular mildly activated fluxes (RMA), and they are noncorrosive.

Equipment. The tools required to solder electrical connections are: a good soldering iron and a supply of replaceable tips, long-nose pliers for holding parts or bending leads (or as a heat sink for temperature-sensitive components), and desoldering braid (or a suction desoldering tool).

There are basically two types of soldering instruments—the "gun" and the "iron," although most people use these descriptions interchangeably. In essence, a soldering "gun" is a pistol-shaped device consisting of a transformer forming the bulk of the "gun," with the secondary winding extending out to form the replaceable tip. Usually, soldering guns come with high wattages, in most cases too high for use with pc foil patterns. Such guns also generate a high magnetic field around the tip that can de-gauss any magnetically sensitive devices close to it. Using a gun may produce too high a heat on the foil pattern so that the cement that secures the copper foil pattern to the substrate is weakened and the foil separates from the printed circuit board.

The "iron" is often called a "pencil iron" because it resembles a thick pencil that is held in the fingers. These tools feature interchangeable (usually screw-on) tips having various shapes—each for its own purpose. Their wattages are usually low enough to be safely used on pc boards. The latest version of the pencil iron is the low-wattage self-contained rechargeable type that can be used remote from the ac line.

Soldering irons are specified primarily by wattage as shown in the table. Wattage represents the amount of heat capacity available at the iron tip. Irons of all wattages usually run at about the same tip temperature, but a lower-wattage iron will cool faster during soldering. The recommended wattages given in the table are to be used as general guidelines only. Slight variations may give perfectly good performance, depending on the particular soldering situation. A higher-wattage iron is more likely to damage heat-sensitive components. If static-sensitive components are to be soldered, i.e. many MOS devices, be sure the iron has a grounded plug. Soldering irons can produce static voltage spikes that will destroy many integrated circuit components, so a grounded tip is a wise safety measure.

Tips are usually selected by preference. Each type and shape has its place and purpose, but the commonly used pointed, conical type is the most versatile and convenient.

Desoldering equipment is always useful even for experienced solderers. Both braid and suction devices are effective and, again, operator preference is the best guide. If you elect to use a suction desoldering tool, pay close attention to the distance and velocity that the "piston" requires. It is very easy to get a black eye, or have glasses damaged, when using those devices.

Soldering Techniques. The best technique can be outlined simply. First, make sure that the tip of the iron is at operating temperature, and is clean. Then touch the heated tip to the connection, preferrably on the part having the larger mass (Fig. 2). The solder should not be brought to the joint until the

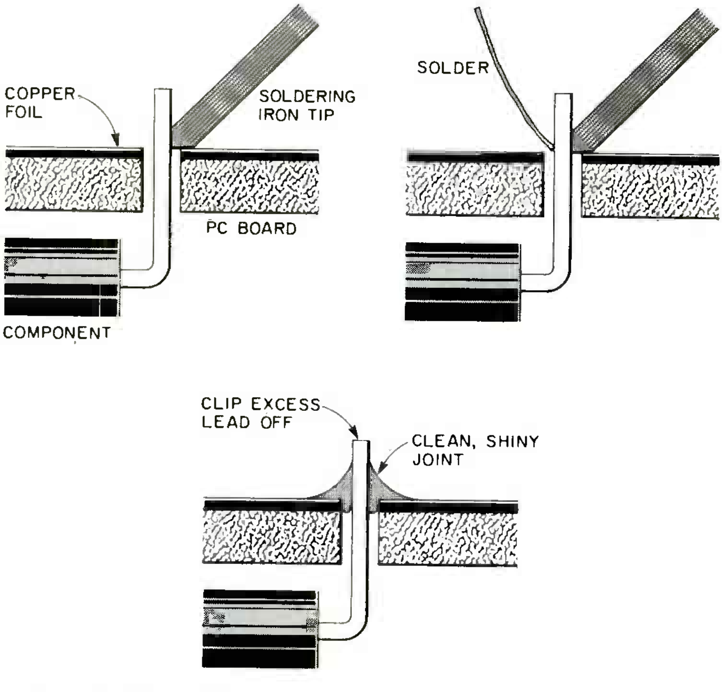


Fig 2. Steps in soldering. Place heated iron to junction of parts to be soldered (top left). Bring flux-cored solder to the joint after it is hot enough to melt solder (top right). When a smooth-contoured fillet has formed, remove the solder and allow to cool without moving.

IRON WATTAGES FOR DIFFERENT SOLDERING TASKS

Type of Soldering	Recommended Iron Wattage
Light duty: single joints, repair, touch-up, delicate parts such as ICs or fine wires. Mass of parts in connection is small.	25 to 30
Medium duty: multiple joints; many in succession. Mass of parts is intermediate (for example, 1/4-watt resistors or conventional disc capacitors).	60 to 100
Heavy duty: Mass is large, as in wires soldered to steel case or wires to screw heads for ground points.	over 100

metals being joined have become hot enough to melt it. How long this takes is quickly learned after a few trials. The flux-cored solder is then brought to the joint and placed at the junction of the two parts. When the solder has melted and flowed into a smooth-contoured fillet, remove the solder. Keep the tip on the joint for a few seconds, then remove it. Do not disturb the newly made connection until it has had time to solidify. A good solder joint will be shiny (Fig. 3). Disturbing the joint before it has solidified may produce a "cold" joint.

Problem Solving.

To Avoid Cold Joints. Even when you know that the parts should not be moved while the solder joint is cooling, it is sometimes difficult to find enough hands to hold a soldering iron, solder, circuit board, and the part being attached. In this case, a small vise or a surgeon's hemostat may be used to hold the board and parts. If you are using rosin flux in liquid or paste form, another method is possible. Using long-nose pliers, hold the part to the circuit board. Apply flux to the pieces being soldered and take up the soldering iron. Touch the iron to a length of solder, creating a ball on the tip. Touch the tip to the connection and hold it there until the fillet is formed. This will create a good joint and free your hands to hold the parts.

To Get Good Solder Wetting. Clean the parts well with isopropyl alcohol to remove greases and oils, and use a 10% solution of hydrochloric acid (HCl) to remove the oxides. Fine steel wool may be used on foil patterns to remove oxide films. These chemicals should be available from any drugstore, but remember to ask about any handling precautions before using them. Note that extra liquid flux can also help in soldering contaminated parts.

To Make Solder Flow. Be sure the soldering iron is providing enough heat, with the iron tip on tight and the proper wattage being used. Also be sure enough flux has reached the component leads and that it is not necessary to add extra liquid or past flux. Do not keep the iron on the joint or continue adding solder if a connection is not made after two trials. This will only damage the components or the circuit board.

To Solder ICs and Other Small Components. Use only a low-wattage iron and sharp tip to avoid excess heat. Also, use 0.031-inch diameter solder to help control the amount of solder deposited. Provide a heat sink by using long-nose pliers to grasp the lead between the component package and the portion to be soldered.

After completely soldering a pc board, an inspection of the soldered joints is suggested. A toenail clipper can be used to trim any lead ends so they don't protrude too far from the solder. To help in the inspection, a bright spotlight and low-power lens can be used to examine each joint. A sharp tool can clear away dross, solder bridges, or anything that looks suspicious between solder pads, and a toothbrush can be used to clean the solder joint. To make sure that all joints are checked, a drop of red nail polish can be placed on each after inspection. A minute spent checking a board can save an hour of troubleshooting later on.

Another problem can arise when a plastic capacitor appears to be "soldered" in place, but is not making an electrical connection. This often happens when a small "sleeve" of nonconducting plastic extends from the capacitor body slightly down each lead. The solder will hold the plastic to the pad, but an electrical connection may not result. Use long-nose pliers to break away the unwanted plastic.

Since your fingers may be dirty or oily, handle parts and circuit boards as little as possible. If there is any question of oily spots on a part, clean it using isopropyl alcohol or fine steel wool. If you use steel wool, use lint-free cloth to remove all vestiges of the wool from the parts or board.

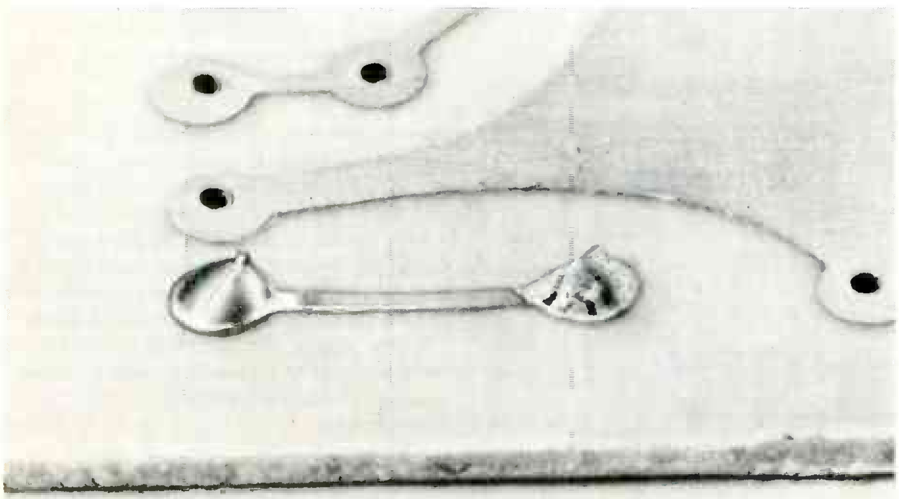


Fig. 3. Photo of two soldered joints. The one at left is shiny indicating a good joint. At right, is a "cold" solder joint.

To Summarize:

(1) Use clean new parts and circuit boards.

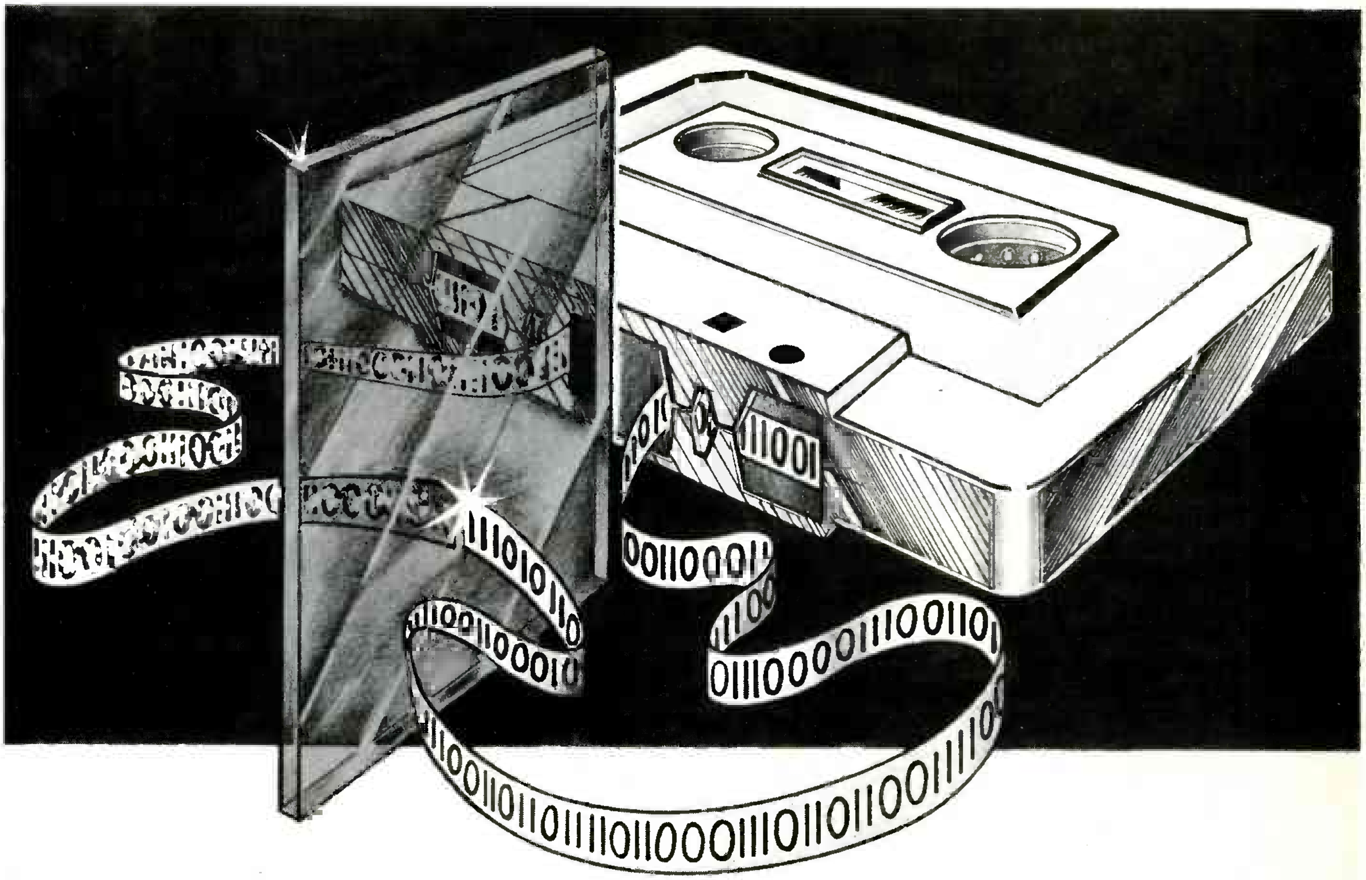
(2) Use 60/40 or 50/50 tin-lead alloy solder with an activated rosin core. Liquid or paste rosin flux may be used to improve wetting when necessary.

(3) Use the proper wattage soldering iron based on the amount of soldering to be done and the type of components being soldered.

(4) Use the proper soldering sequence—tip to parts, solder to parts—solder away from parts—tip away from parts.

(5) Use patience.

(6) Practice. ◇



HARDWARE-SOFTWARE TAPE CONDITIONER FOR TRS-80 COMPUTERS

BY CASS R. LEWART

Reshaping and retiming data pulses ends cassette-tape loading problems for BASIC and SYSTEM data

When difficulties occur in loading data from a cassette tape into a microcomputer, it is usually because the commercial tapes being used are poorly duplicated. This is further compounded by the quality of the tape itself and even the inadequacies of home tape machines. In the case of the popular Radio Shack TRS-80, a narrow tape level setting range and fussy timing requirements exacerbate the problem. Though some peak-reading meters enable one to set the proper level quickly, they do not generally correct for poorly shaped pulses or timing jitter, both of which are major obstacles to successful loads. The Tape Regenerator project described here has been designed to obviate this problem. The Regenerator is an advanced breed of tape-conditioning device. It is for use with TRS-80 Level II BASIC and machine-language (SYSTEM) programs. Unlike other commercially available conditioners, it uses both hardware *and* software. As a result, the computer itself is used for curing timing problems. This permits poorly timed backup copies to be made on a second recorder which, without internal retiming, would produce backup copies that retain or worsen timing jitter.

How It Works. The ideal signal waveform and typical "good" and "poor" waveforms found on commercial copies of Level II programs are shown in Fig. 1. As shown in Fig. 1C, superimposed noise, power-line hum, amplitude distortion, and ringing and displacement of the data pulse relative to the clock pulse (timing jitter) can make it likely that the computer will lose bits. And a single lost bit, of course, makes the entire program useless.

Once a BASIC program has been properly loaded, a back-up copy of it can be made using the CSAVE command. Similarly, a backup copy of a machine language (SYSTEM) program can be

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74LS49	16	.75	74LS163	16	.69	74LS365	16	.49
74LS51	14	.25	74LS164	14	.69	74LS366	16	.49
74LS54	14	.29	74LS165	16	1.19	74LS367	16	.49
74LS55	14	.29	74LS168	16	1.19	74LS368	16	.49
74LS73	14	.39	74LS169	16	1.19	74LS373	20	1.29
74LS74	14	.39	74LS170	16	1.49	74LS374	20	1.29
74LS75	16	.39	74LS173	16	.69	74LS375	16	.69
74LS76	16	.39	74LS174	16	.59	74LS386	14	.45
74LS78	14	.39	74LS175	16	.59	74LS393	14	1.19
74LS83	16	.65	74LS181	24	2.49	74LS399	16	1.49
74LS85	16	.69	74LS190	16	.89	74LS670	16	1.49
74LS86	14	.39	74LS191	16	.89	81LS95	20	1.49
74LS90	14	.55				81LS97	20	1.49

74S/PROMS*

74S00	14	.35	74S124	16	2.95	74S243	14	2.49
74S02	14	.35	74S133	16	.45	74S244	20	2.49
74S03	14	.35	74S134	16	.50	74S251	16	1.19
74S04	14	.45	74S135	16	.69	74S253	16	1.19
74S05	14	.45	74S136	14	1.39	74S257	16	1.19
74S08	14	.39	74S138	16	.89	74S258	16	1.19
74S09	14	.39	74S139	16	.89	74S260	14	.79
74S10	14	.35	74S140	14	.55	74S280	14	1.95
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CD4002	14	.29	CD4042	16	.69	CD4507	14	.39
CD4006	14	.89	CD4043	16	.79	CD4508	24	3.95
CD4007	14	.29	CD4044	16	.79	CD4510	16	.89
CD4009	**16**	**.39**	CD4046	16	.89	CD4511	16	.89
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CD4011	14	.29	CD4048	16	.39	CD4514	24	1.79
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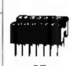

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INTERSIL

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30009 1983 INTERSIL Data Book (1356p.) **$9.95**

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74HC51	14	.75	74HC173	16	1.59	74HC595		3.75
74HC58	14	.75	74HC174	16	1.39	74HC688		3.19
74HC73	14	.75	74HC175	16	1.39	74HC4002	14	.79
74HC74	14	.99	74HC192	16	1.39	74HC4017	16	2.19
74HC75	16	.99	74HC193	16	1.39	74HC4020	16	2.19
74HC76	16	.75	74HC194	16	1.59	74HC4024	14	1.59
74HC85	16	2.19	74HC195	16	1.49	74HC4040	16	2.19
74HC86	14	.99	74HC237	16	2.95	74HC4060	16	2.19
74HC107	14	.75	74HC240	20	2.75	74HC4075	14	.75
74HC109	16	1.39	74HC241	20	3.75	74HC4078	14	.69
74HC112	16	.75	74HC242	14	2.79	74HC4511	16	3.29
74HC113	14	.75	74HC243	14	2.79	74HC4514	24	4.79
74HC132	14	.89	74HC244	20	3.75	74HC4538	16	2.95
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30012 1982 NATIONAL PAL Data Book (176p.) ... **$5.95**

74C—C/MOS

74C00	14	.35	74C95	14	1.39	74C221	16	1.95
74C02	14	.35	74C107	14	.89	74C240	20	1.95
74C04	14	.29	74C151	16	2.49	74C244	20	1.95
74C08	14	.35	74C154	24	3.49	74C373	20	2.49
74C10	14	.35	74C157	16	2.25	74C374	20	2.49
74C14	14	.59	74C160	16	1.19	74C901	14	.59
74C20	14	.35	74C161	16	1.19	74C903	14	.59
74C30	14	.35	74C162	16	1.19	74C906	14	.59
74C32	14	.39	74C163	16	1.19	74C911	28	8.95
74C42	16	1.39	74C164	14	1.49	74C912	28	8.95
74C48	16	1.95	74C173	16	.79	74C915	18	1.19
74C73	14	.79	74C174	16	1.19	74C917	28	8.95
74C74	14	.69	74C175	16	1.19	74C922	18	4.49
74C85	16	1.95	74C192	16	1.49	74C923	20	4.95
74C86	14	.39	74C193	16	1.69	74C925	16	5.95
74C89	16	5.95	74C195	16	1.39	74C926	18	5.95
74C90	14	1.19				80C95	16	.39
74C93	14	1.19				80C97	16	.39

LINEAR

TL071CP	8	.79	LM340T-5		.79	LM709N	14	.49
TL072CP	8	1.39	LM340T-12		.79	LM710N	14	.69
TL074CN	14	1.95	LM340T-15		.79	LM711N	14	.79
TL081CP	8	.59	LM348N	14	.99	LM723N	14	.55
TL082CP	8	1.19	LM350K		4.95	LM733N	14	1.00
TL084CN	14	1.95	LF355N	8	1.10	LM739N	14	1.95
LM301CN	8	.35	LF356N	8	1.10	LM741CN	8	.35
LM302H		1.95	LM370N	14	4.49	LM747N	14	.69
LM304H		1.95	LM373N	14	3.95	LM748N	8	.59
LM305H		.99	LM377N	14	1.95	LM1310N	14	1.49
LM307CN	8	.45	LM380N	14	.89	LM1458CN	8	.59
LM308CN	8	.69	LM381N	14	1.79	LM1488N	14	.69
LM309K		1.25	LM382N	14	1.39	LM1489N	14	.69
LM310CN	8	1.75	LM384N	14	1.79	LM1496N	14	1.95
LM311CN	8	.69	LM386N-3	8	.89	LM1800N	16	1.49
LM312H		2.49	TL494CN	16	2.95	LM1889N	18	1.95
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LM317K		3.95	NE510A	14	4.95	LM2002T		1.49
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LM320T-12		.89	NE555V	8	.35	LM3916N	18	3.49
LM320T-15		.89	LM556N	14	.69	**RC4136N**	**14**	**1.25**
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LM324N	14	.59	LM566CN	8	1.49	NE5532	8	2.49
LM337T		1.95	LM567V	8	.89	NE5534	8	1.69
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LM339N	14	.69	LM703CN	8	1.19	LM13080N	8	1.19
LM340K-5		1.35				LM13600N	16	1.19
LM340K-12		1.35						
LM340K-15		1.35						

MORE AVAILABLE

30003 1982 Nat. Linear Data Book (1952 pgs.) . **$11.95**

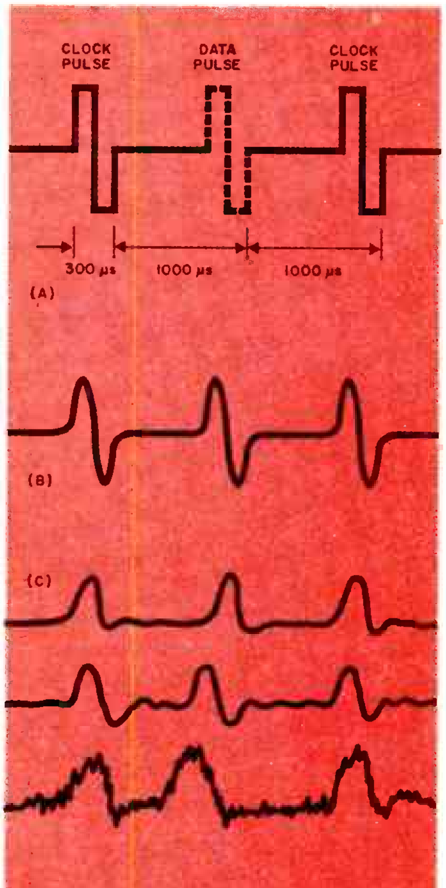


Fig. 1. Waveform (A) is "ideal." That at (B) is a good recording, while those in (C) show various distortions that can occur.

made with a monitor program, e.g. Radio Shack T-BUG. However, the original program must be readable and short enough to fit into memory without overwriting a monitor program.

The Tape Regenerator and associated program, DUB3 (see Table), overcome these limitations by reshaping and retiming the pulses to produce new tape that the TRS-80 can easily read.

Multiple-segment programs (some programs feature a separate loader) or several programs on a single tape pose no problems for the Regenerator, either. Operating on one pair of clock/data pulses at a time without storing the whole program in RAM as monitor programs do, the Regenerator allows even a TRS-80 computer with only 4K of RAM to back-up copies of arbitrarily large programs and handle tapes containing multiple programs in a single cassette pass.

To test the soundness of the Tape Regenerator design, the author created five generations of the same program and found that the fifth-generation tape would load as easily as the original.

Circuit Description. The circuit shown in Fig. 2 reshapes the clock and data pulses received from the tape recorder and feeds them to the computer. Audio transformer *T1* provides dc isolation between the tape recorder and the Regenerator circuit. Switch *S1* and diodes *D1* and *D2* allow selection of the "better" half of the pulse (see Control Adjustments later on), while zener diode *D3* and transistor *Q1* further shape the incoming signal. One OR gate in *IC1* decodes the IN command from the computer (via the *P1* connector) indicating that the computer is ready to accept data. When this command occurs, *IC1* (pin 8) activates *IC2* (via pin 15) to allow the amplified tape recorder signals to pass via the connector *P1* expansion port to the computer data bus. Indicator *LED2* and optional meter *M1* indicate that the tape recorder is sending data at the proper level, and *LED3* glows when regenerating program DUB3 is up and running. If no back-up copies are required, *J2* provides a "quick-and-dirty" direct output to the TRS-80 via the tape recorder plug. The signal at this point is not retimed and is only partially reshaped. This limited processing may make a tape readable.

Power for the circuit (Fig. 3) is provided by transformer *T2*, in conjunction with voltage regulator *IC3*, bridge circuit *RECT1*, and capacitors *C1* and *C2*. Power-on is indicated by *LED1*.

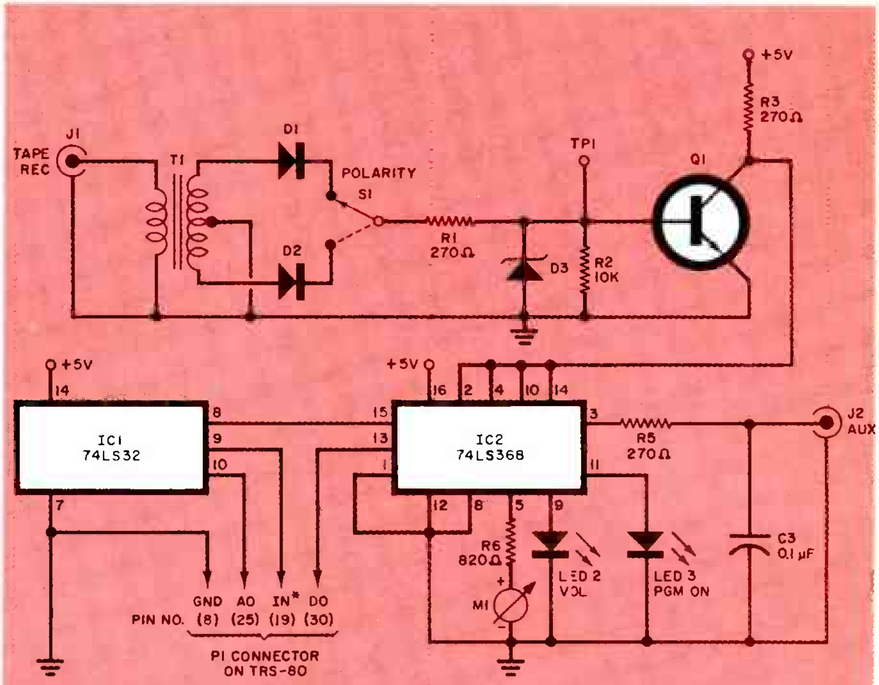


Fig. 2. The Tape Regenerator is controlled by signals from the TRS-80 that are determined by the DUB3 program. A second recorder is connected to the auxiliary output at jack J2.

PARTS LIST

C1—200-µF electrolytic
C2,C3—0.1-µFdisc capacitor
D1,D2—1N914 silicon diode
IC1—74LS32 quad OR gate
IC2—74LS368 hex tri-state buffer
IC3—7805 +5-volt regulator
LED1,LED2,LED3—Red light-emitting diode
M1—1-mA meter (Radio Shack No. 270-1752 or similar)
P1—2 × 20 edge connector on 0.1" centers to fit expansion port on TRS-80 keyboard or expansion interface
Q1—Npn transistor (Radio Shack No. 276-2014 or similar)
R1,R3,R5—270-ohm, ½-W resistor
R2—10,000-ohm, ½-W resistor
R4,R6—820-ohm, ½-W resistor (optional)
RECT1—50-V, 1-A bridge rectifier
S1,S2—Spdt switch
T1—Audio transformer (Radio Shack No. 273-1380 or similar)
T2—12-V transformer (Radio Shack No. 273-1385 or similar)
Misc.—Suitable enclosure; 14- and 16-pin DIP IC sockets; line cord; solder; etc.

Note: An etched, drilled, and silk-screened printed-circuit board listing of DUB3 program in BASIC to allow POKEing into memory are available for $11.95 (plus 6% sales tax for New Jersey residents) from C&R Electronics, P.O. Box 217, Holmdel, NJ 07733.

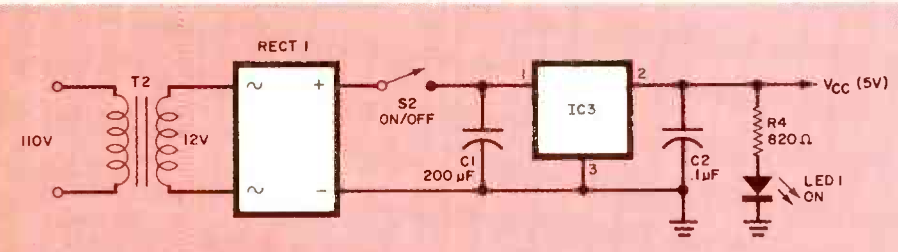


Fig. 3. The power supply is a simple rectified regulator circuit as shown here.

time interval to a second pulse is checked to make sure that the first was not a spurious transient. When the clock pulse is confirmed, it is output after a 200-μs delay using subroutine OUTPUT. This subroutine produces a clean signal lasting 300 μs, as shown in Fig. 1A. A search for the data pulse now begins. The delay of 500 μs excludes any residual ringing from the preceding clock pulse. If no data pulse is found during the following 700-μs window, a search for the next clock pulse begins. If a data pulse is detected in the win-

Construction. The circuit can be assembled on a small pc board, or Wire Wrap techniques can be used. Keep all leads as short as possible. As only four contacts are used on the 40-pin TRS-80 connector, the remaining pins can be expanded with a screwdriver to make plug insertion easier. Before turning on the power, recheck all wiring, especially the leads to the computer expansion port.

Control Adjustments. To properly read a poorly recorded tape, polarity switch *S1* on the Tape Regenerator and the volume control of the tape recorder must be set. These settings will vary from tape to tape. However, back-up tapes made by the Tape Regenerator or CSAVE command should all work with the same settings.

To determine the proper settings for an unknown tape, observe *LED2* and millimeter *M1*, or connect a scope to *TP1*. Play the tape at medium setting of the tape recorder volume control. Flip polarity switch *S1* and leave it in the position corresponding to a stronger signal, as evidenced by a brighter LED, higher reading on the meter, or a cleaner pulse display on the scope. Optimum setting of the recorder playback level is found by advancing the volume control until *LED2* glows brightly, then backing off slightly. If optional meter *M1* is included in the circuit (see Fig. 2), adjust the volume control for a reading between 0.5 and 0.6 mA. As a final alternative, connect an oscilloscope to *TP1* and adjust the control for the cleanest, widest pulses you can.

Regenerator Program DUB3. The reshaping and retiming of Level II clock and data pulses as received via the *P1* connector is performed by the DUB3 program.

After clearing the screen and displaying a message, the DUB3 program searches for a clock pulse. When one is found, the

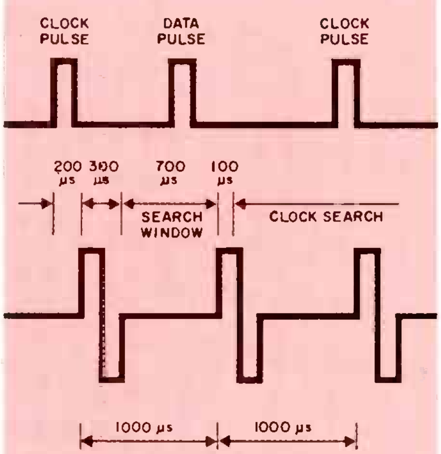


Fig. 4. Timing diagram of DUB3 program. Input at TP1 is at top. Below is output from computer.

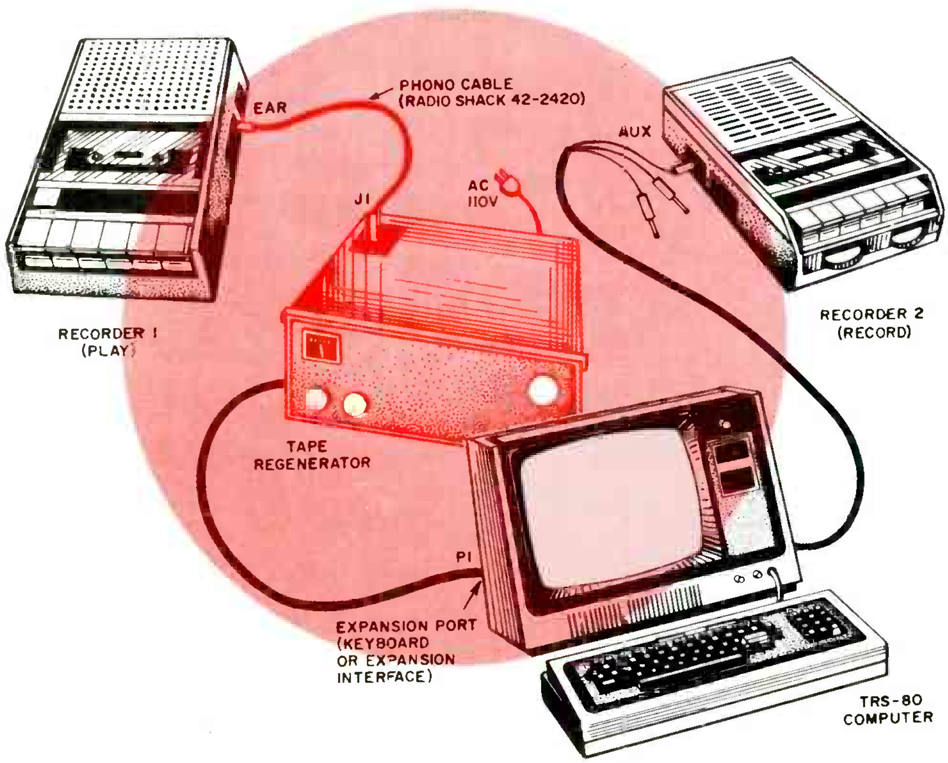


Fig. 5. Electrical interconnection of the Tape Regenerator to the TRS-80 computer and two tape recorders.

TABLE—LISTING OF DUB3 PROGRAM

```
00100  PORT    EQU   00H
00110  CENTER  EQU   04H
00120  HIGH    EQU   05H
00130  LOW     EQU   06H
00140  DL100   EQU   0CH
00150  DL150   EQU   12H
00160  LEN1    EQU   14H
00170  DL200   EQU   1AH
00180  DL700   EQU   22H
00190  LEN2    EQU   22H
00200  CASS    EQU   0FFH
00210  CLS     EQU   01C9H
00220  LINE1   EQU   3DD6H
00230  LINE2   EQU   3E0FH
00240          ORG   4A00H
00250  DUB3    CALL  CLS        ;CLEAR SCREEN
00260          LD    HL,TAB1    ;DISPLAY LINE1
00270          LD    DE,LINE1
00280          LD    BC,LEN1
00290          LDIR
00300          LD    HL,TAB2    ;DISPLAY LINE2
00310          LD    DE,LINE2
00320          LD    BC,LEN2
00330          LDIR
00340  START   LD    B,DL100    ;100 MICS DELAY
00350  DEL0    DJNZ  DEL0
00360  SRCHC   IN    A,(PORT)   ;START CLOCK PULSE SEARCH
00370          RRA
00380          JR    NC,SRCHC   ;CLOCK PULSE FOUND?
00390          IN    A,(PORT)   ;YES, TRANSIENT ONLY?
00400          RRA
00410          JR    NC,SRCHC   ;YES, KEEP SEARCHING
00420          LD    B,DL200    ;NO, SET 200 MICS DELAY
00430  DEL1    DJNZ  DEL1
00440          CALL  OUTPUT     ;PUT OUT CLOCK PULSE
00450          LD    B,DL700    ;START 700 MICS READ WINDOW
00460  SRCHD   IN    A,(PORT)   ;SEARCH FOR DATA PULSE
00470          RRA
00480          JR    C,FOUND1   ;FOUND?
00490          DJNZ  SRCHD      ;NO, WINDOW TIMED OUT?
00500          JR    START      ;YES, SEARCH FOR CLOCK PULSE
00510  FOUND1  IN    A,(PORT)   ;TRANSIENT ONLY?
00520          RRA
00530          JR    C,FOUND2   ;NO
00540          DJNZ  SRCHD      ;YES, WINDOW TIMED OUT?
00550          JR    START      ;YES, SEARCH FOR CLOCK PULSE
00560                           ;DATA PULSE FOUND
00570  FOUND2  INC   IX         ;WASTE 10 CYCLES
00580          BIT   3,(HL)     ;WASTE 12 CYCLES
00590          DJNZ  FOUND2     ;WINDOW TIMED OUT?
00600          CALL  OUTPUT     ;YES, PUT DATA OUTPUT PULSE
00610          JR    START      ;SEARCH FOR CLOCK PULSE
00620  OUTPUT  LD    A,HIGH     ;PUSE OUTPUT
00630          OUT   (CASS),A   ;PULSE HIGH
00640          LD    B,DL150    ;150MIXS DELAY
00650  DEL2    DJNZ  DEL2
00660          LD    A,LOW
00670          OUT   (CASS),A   ;PULSE LOW
00680          LD    B,DL150    ;150 MICS DELAY
00690  DEL3    DJNZ  DEL3
00700          LD    A,CENTER
00710          OUT   (CASS),A   ;RESTORE TO CENTER
00720          RET
00730  TAB1    DEFM  'TAPE BACK-UP PROGRAM'
00740  TAB2    DEFM  'COPYRIGHT (C) 1980 CASS R. LEWART'
00750          END   DUB3
```

dow, it is checked again to exclude a transient and, if confirmed, is output at the end of the 1-ms interval that started at the beginning of the preceding clock pulse (Fig. 4).

A data pulse appearing at any time between 500 μs and 1.2 ms after a clock pulse is correctly retimed to occur exactly 1 ms after the clock pulse. After a 100-μs delay, the program continues with the search for the next clock pulse. The DUB3 program can be loaded using the Radio Shack Editor/Assembler or by keying in the Z80 instructions. For a BASIC version of the DUB3 program that will POKE the instructions into memory, see the Parts List.

Operating Instructions. Electrical interconnection between the Tape Regenerator, both tape recorders, and the computer is shown in Fig. 5. Always turn off power to the computer and Regenerator when plugging or unplugging the 40-pin connector at the rear of the TRS-80 keyboard.

If you have the Expansion Interface connected to your computer, use the expansion port on the left side of the Expansion Interface instead of the expansion port at the rear of the keyboard. When power is applied to the computer and Tape Regenerator, *LED1* should glow and the MEMORY SIZE? prompt should appear on the video monitor. If the prompt does not appear, check connections, particularly the 40-pin connector, between the Tape Regenerator and the TRS-80. Load and run the DUB3 program. Indicator *LED3* (PGM ON) should glow as long as DUB3 is running. The program is in an infinite loop and will run until you press the RESET button on the rear of the TRS-80 or turn off power to the computer.

For initial adjustment, start reading tape from tape recorder 1 and set polarity switch *S1* and the tape recorder volume control as explained under Control Adjustments.

Rewind tape recorder 1 and start it in the play mode while starting tape recorder 2 in the record mode with a clean tape. When the program on tape recorder 1 is finished, *LED2* (VOL) will extinguish and meter *M1* will indicate close to zero. This is the signal for you to turn off both tape recorders. You can continue with as many tapes as desired. When finished, open *S2* to turn off power to the Tape Regenerator, press the RESET button to return the TRS-80 to BASIC, or turn off the computer. The 40-pin connector (*P1*) can be left permanently plugged into the expansion port, as it does not interfere with normal computer operation. If the pulse amplitude on the original tape is very unsteady or the pulses are imbedded in noise, regenerating the tape may not be possible.

Two Projects for Outdoor Use

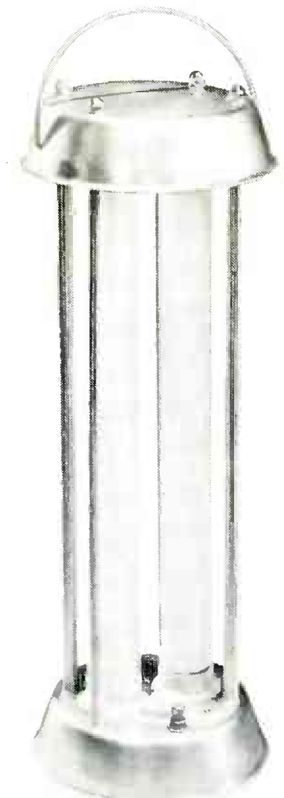
A BATTERY-OPERATED FLUORESCENT LAMP

Portable, high-efficiency light source draws current from a vehicle's 12-volt storage battery, but leaves plenty of charge for engine starting.

BY LAWRENCE M. WALDEN

THE recreational vehicle is becoming more and more popular with campers who want a "home away from home." In such cases, the vehicle's 12-volt battery supply provides a convenient source of power for lighting around the camp. This is very handy, of course; but, for the amount of light they deliver, 12-volt incandescent lamps waste a lot of valuable battery power. Fluorescent lamps, on the other hand, produce good lighting at high efficiency. Unfortunately, they require a dc-to-ac converter.

The low-cost circuit described here not only performs the dc-to-ac conversion, it also provides automatic shutdown when the battery reaches some predetermined voltage level, thus preventing a complete discharge. A LED indicator glows when the turnoff point is reached. Once turned off, the system draws only a few milliamperes.



Circuit Operation. When the 12-volt supply (Fig. 1) is applied to the circuit through fuse *F1*, switch *S1*, and the protective diode, *D1*, multivibrator *IC1* starts to oscillate at a frequency determined by the setting of *R2*. This is approximately 10 kHz. At this time, *Q1* is cut off to allow *IC1* to oscillate.

As the +12 volts are applied to the *R18*/zener diode *D2* network, 7.6 volts are applied to the emitters of *Q3* and *Q4*. At this time, the base of *Q4* is at zero voltage, thus turning this transistor fully on and developing approximately 7 volts across its collector resistor (*R12*). This voltage, applied via *R13* to the base of series-pass transistor *Q5*, turns the transistor on and allows the output of *IC1* to pass through *R7* to driver transistor *Q6*. The latter, in turn, drives power transistor *Q7* to its maximum output.

The collector load of *Q7* is formed by the 6.3-volt winding of transformer *T1*. Thus, as *IC1* oscillates, a high alternating voltage is developed across the 120-volt winding of *T1* and applied to the two series-connected fluorescent lamps (*L1* and *L2*), and across current-sensing resistor *R17*.

At lamp turnon, the voltage developed across *R17* is rectified and filtered by *D3* and *C5* and applied across lamp-current-adjust potentiometer *R16*. A preselected portion of this voltage is applied to the *R15*/*C4* network and to the base of *Q4*. When this voltage approximates the 7.6-volt emitter reference, *Q4* starts to reduce its conductance, thus lowering the voltage developed across collector resistor *R12*. This action lowers the bias on series-pass transistor *Q5*, reducing the drive to *Q6*/*Q7* to lower the lamp drive and reduce the voltage across *R17*. The circuit stabilizes lamp current preset by *R16*.

At initial lamp turnon, approximately 1.3 amperes will flow through *Q7* until the fluorescent lamps fire. This ensures lamp start even in cold weather. Once the lamps strike, the current will range from about 0.9 ampere at 13.2 volts to about 1.1 amperes when the battery voltage drops to near 10.6 volts.

Low battery protection is provided by potentiometer *R6*. The selected voltage is applied via *R8* to the base of *Q3*. In normal operation, *Q3* is cut off since its base voltage is higher than the 7.6 volts applied to its emitter. If the battery voltage drops so that the base of *Q3* goes below the emitter voltage, *Q3* starts to conduct and its collector current flows through *R10* to the base of *Q2*. When *Q2* starts to conduct, the base drive of *Q3* is further reduced until both *Q2* and *Q3* are latched fully on. Once latched on, the collector of *Q3* will be approximately 6 volts, which are applied through *R11*, causing *LED1*—the low-voltage indicator—to glow. This voltage is also applied via *R5* to the base of *Q1* to bias this transistor fully on. When this occurs, pins 2 and 3 of *IC1* become fully positive, thus disabling the multivibrator. At this point, battery consumption drops to about 50 mA, since *Q1*, *Q2*, and *Q3* are the only active elements. Operating power should now be removed via *S1*.

Capacitor *C4* at the base of *Q4* is a high value to prevent oscillation, while *C3* at the base of *Q2* allows the circuit to stabilize before low voltage levels can be detected. Once the circuit is working, it responds very rapidly to voltage drops.

Construction. Since there is nothing critical about the circuit, it can be constructed on a small piece of perf board using point-to-point wiring and sockets for *IC1* and the seven transistors. Transistor *Q7*, transformer *T1*, power on/off switch *S1*, fuse *F1*, and the two fluorescent lamp sockets are mounted on the enclosure.

Select an enclosure that can support the circuit board, the transformer, a heat sink for power transistor *Q7*, and the sockets for the two fluorescent lamps. The two lamps can be mounted vertically on top of the enclosure, and provided with some form of transparent weather protection such as a plastic sleeve. If a metal enclosure is used, it can serve as the *Q7* heat sink when a suitable insulator is used. Connection to the +12 volts can be made with a length of conventional two-conductor lamp cord having a cigarette lighter plug at one end. The author used 33 feet of lamp cord.

Since the secondary of transformer *T1* can develop as much as 1500 volts peak-to-peak across the output, and as much as 225 volts when the lamps are lit, suitable insulation must be used at these points. Also, keep these voltages in mind when performing the adjustments on the circuit.

Adjustments. Before applying power, remove the connection between low-voltage-adjust potentiometer *R6* rotor to the +12-volt end. Then set lamp-current-adjust potentiometer *R16* so that the rotor is at the ground end. Frequency-adjust potentiometer *R2* should be set to the *R1* side (highest resistance).

To make a complete test, use an adjustable power supply between 10 and 14 volts, with a capacity of at least 2 amperes. Connect an ammeter (about 2 amperes) in series with the positive battery connection, and a voltmeter (20-volt range) from the cathode side of *D1* to ground. Connect the power source.

When *S1* is turned on, the lamps may not fire due to the low frequency of the multivibrator, and about 0.3 to 0.4 ampere will be drawn. Transformer *T1* may also make sounds due to lamination movement, which indicates an operating circuit.

Slowly rotate frequency-adjust potentiometer *R2* and note that the ammeter current increases and the lamps start to glow. Continue to increase the frequency very slowly until the lamps come to full brightness at a current of about 0.6 ampere. At this point, the supply current will suddenly jump to about 1.2 to 1.3 amperes. Advance the frequency for an additional 0.2 ampere, but not higher, as both output voltage and efficiency will drop.

If desired, the multivibrator can be "fine tuned" using an oscilloscope. To do this, turn the power off, set the controls as described above, remove the lamps and replace them with four 100-kΩ, ½-W resistors connected in series. Connect the scope leads across *R17*, and set the scope vertical to 5 volts/division. Turn the power on and

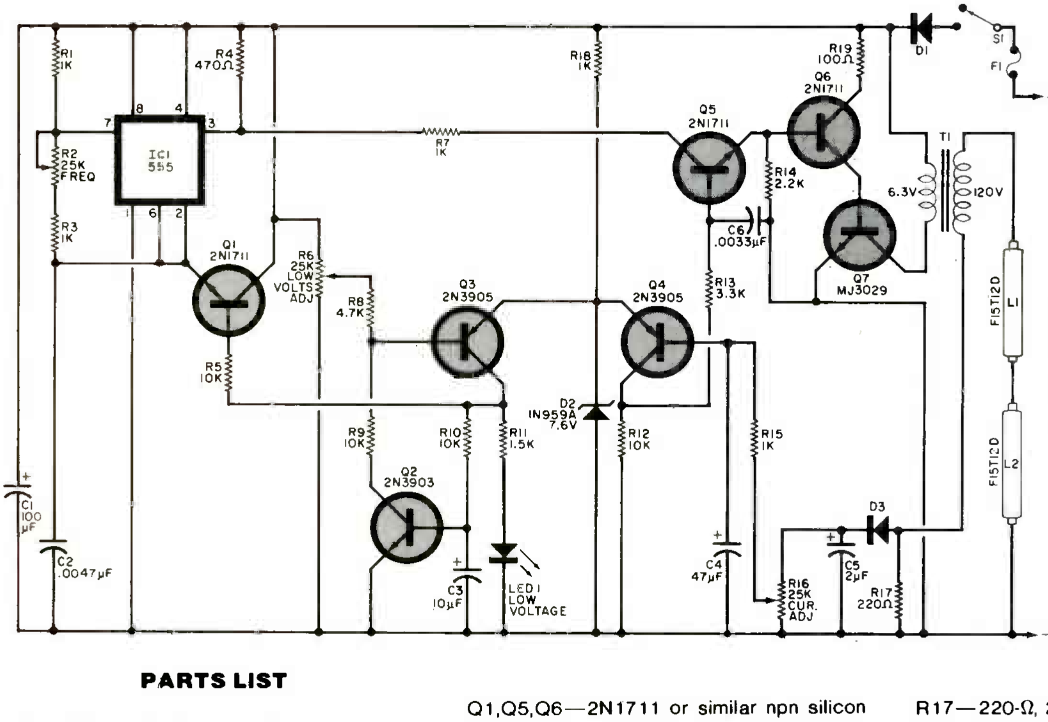
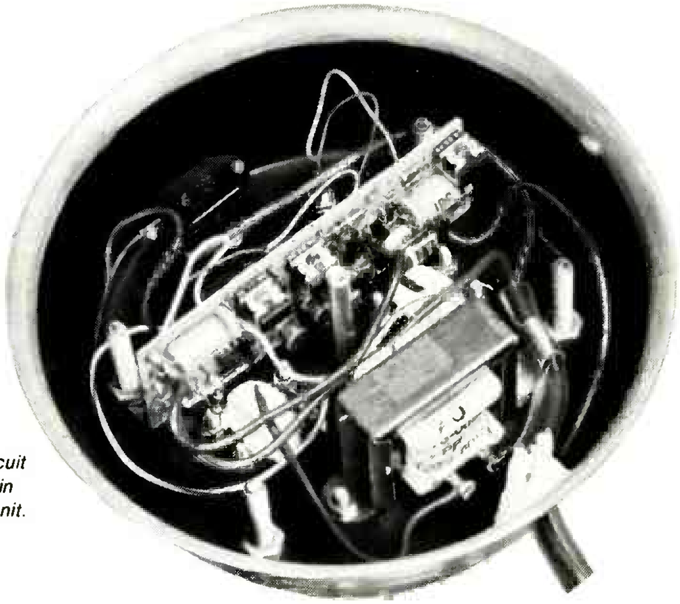


Fig. 1. Schematic diagram of the Battery-Operated Fluorescent Lamp. The low-voltage cutoff point is determined by the setting of potentionmeter R6.

PARTS LIST

C1—100-µF, 25-V electrolytic
C2—0.0047-µF, film capacitor
C3—10-µF, 60-V electrolytic
C4—47-µF, 50-V electrolytic
C5—2-µF, 50-V electrolytic
C6—0.0033-µF, 100-V film capacitor
D1,D3—2-ampere rectifier diode
D2—1N959A, 7.6-V zener diode
F1—4-A fuse and holder
IC1—555 timer
L1,L2—15-watt daylight fluorescent lamps (F15T12D or similar)
LED1—Red LED
Q1,Q5,Q6—2N1711 or similar npn silicon transistor
Q2—2N3903 or similar npn silicon transistor
Q3,Q4—2N3905 pnp or similar transistor
Q7—MJ3029 npn power transistor
R1,R3,R7,R15—1-kΩ, ¼-W resistor
R2,R6,R16—25-kΩ, pc potentiometer
R4—470-Ω, ½-W resistor
R5,R9,R10,R12—10-kΩ, ¼-resistor
R8—4.7-kΩ, ¼-W resistor
R11—1.5-kΩ, ½-W resistor
R13—3.3-kΩ, ¼-W resistor
R14—2.2-kΩ, ¼-W resistor
R17—220-Ω, 2-W resistor
R18—1-kΩ, ½-W resistor
R19—100-Ω, 1-W resistor
S1—Spst switch
T1—6.3-V, 1.2-A transformer
Misc.—Perf board, sockets for *IC1* and transistors, heat sink and thermal insulator for *Q7*, sockets (4) for fluorescent lamps, suitable enclosure, length of conventional lamp cord, automotive cigarette plug, transparent weather shield for lamps, adhesives, mounting hardware, etc.



Lamp circuit mounted in base of unit.

note that about 0.5 ampere flows and a 3-to-4-volt waveform appears on the scope. Slowly increase the frequency (via *R2*) until the scope trace peaks at about 15 volts peak-to-peak. The supply current should reach about 1 ampere at this point. Do not adjust the frequency higher than this, or the efficiency will be reduced. Turn the power off, remove the resistors, and replace the lamps.

To adjust the lamp current regulator with the lamps glowing, slowly rotate current-adjust potentiometer *R16* until the current approaches 0.8 ampere and there is a decrease in light output. Then slowly adjust *R16* until the current reaches 1 ampere. Lower the power supply to 10.6 volts, then re-adjust *R16* for 1.1 amperes current flow. This becomes the maximum current drain at the lowest operating voltage.

Increase the supply voltage from 10.6 to 13.2 volts and note that the light output remains constant as the current decreases. With 12 volts applied, about 1 ampere will flow, and with a 13.2-volt supply, the current drops to about 0.9 ampere.

To adjust the low-voltage cutoff, reconnect *R6* to the +12-volt line. and with the voltmeter still in the circuit, allow a 5-minute lamp warm-up. Reduce the power supply to 10.6 volts (or other desired low-voltage point) and slowly rotate *R6* until the lamps go off and *LED1* glows. Recheck this point several times. If, during operation, the lamps go out, the presence of glowing *LED1* indicates that the low battery voltage has been reached, and the circuit has not been accidentally removed from the power source. ◇

"COINSHOOTER" METAL DETECTOR

Advanced circuit reacts to coins and other precious metal objects while ignoring chunks of iron and steel

BY WILLIAM LAHR

SEARCHING FOR coins and other lost articles along beaches and in parks can be both profitable and fun. The Coinshooter, a novel and inexpensive electronic metal detector, can make such outings more productive. Employing a sophisticated, vlf induction-balance detection system that responds only to the proximity of nonferrous metallic objects, it ignores items containing iron. Moreover, the project can be adjusted to compensate for the soil's mineral content, thus minimizing false indications.

The Coinshooter can detect a dime at an air gap of four inches or a half-dollar at nine inches. It cannot detect coins buried deep in the ground, but will yield excellent results if the coins are at depths of from 1 to 3 inches. Unlike detectors that employ conventional beat-frequency oscillator circuits, the Coinshooter does not require the user to monitor the pitch of a continuous tone. Rather, it alerts the user to the proximity of nonferrous metal by generating one or more beeps. Also, it is lightweight (about 2 lb) and well balanced. Total construction cost is approximately $35, and less if salvaged parts are used.

About the Circuit. The Coinshooter appears schematically in Figure 1. Coplanar search coils are formed by placing a receiving coil (*L3*) over a folded-loop transmitting coil (*L1* and *L2*) so that there is little if any coupling between them unless there is metal present in the search field. A Colpitts oscillator comprising *Q1* and its associated passive components generates a 6.2-kHz signal that drives the transmitting coil. Transistors *Q2* and *Q3* amplify the low-level signal induced across receiving coil *L3* when no metal objects are present in the search field so that a 1-volt p-p signal appears at the collector of *Q3*.

Capacitor *C7* couples this signal to the noninverting input of voltage comparator *IC1A*. The input circuit of the comparator rectifies the ac signal, resulting in the generation of a slightly

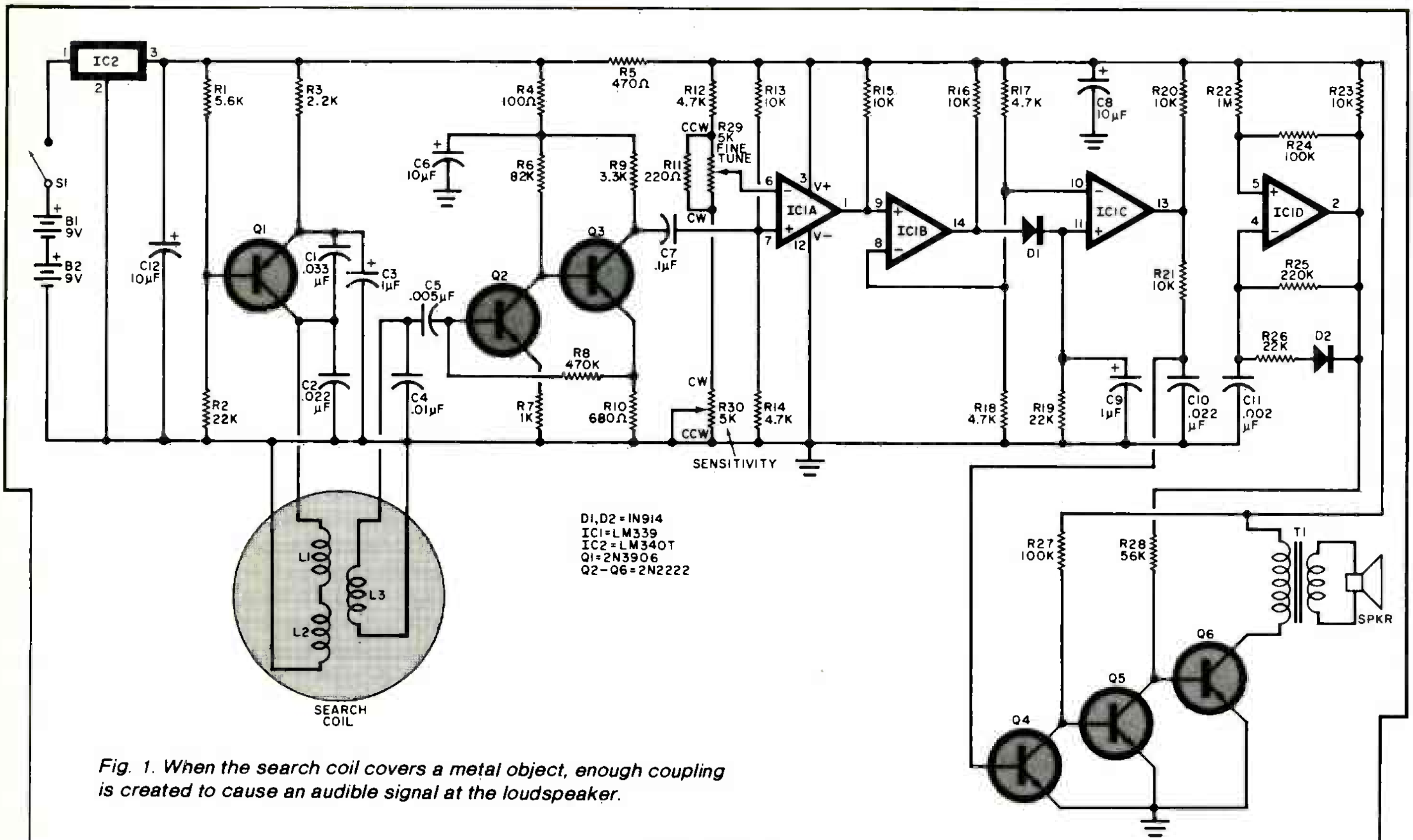


Fig. 1. When the search coil covers a metal object, enough coupling is created to cause an audible signal at the loudspeaker.

PARTS LIST

B1,B2—9-V alkaline battery
C1—0.033-µF, 50-V Mylar capacitor
C2, C10—0.022-µF, 50-V Mylar capacitor
C3, C9—1-µF, 16-V tantalum capacitor
C4—0.01-µF, 50-V disc ceramic capacitor
C5—0.005-µF, 50-V disc ceramic capacitor
C6, C8, C12—10-µF, 16-V aluminum electrolytic capacitor
C7—0.1-µF, 50-V Mylar capacitor
C11—0.002-µF, 50-V disc ceramic capacitor
D1, D2—1N914 silicon switching diode
IC1—LM339 quad voltage comparator
IC2—LM340T-8 +8-V regulator
L1, L2—Air-core inductor: 175 turns of No. 30 wire wound 9½ inches in diameter (see text)
L3—Air-core inductor: 550 turns of No. 38 enamelled wire on 3½" diam.
Q1—2N3906 or similar pnp silicon switching transistor
Q2 through Q6—2N2222 or similar npn silicon switching transistor

The following, unless otherwise specified, are ¼-watt, 5%-tolerance, carbon-composition fixed resistors.
R1—5.6 kΩ
R2, R19, R26—22 kΩ
R3—2.2 kΩ
R4—100 Ω
R5—470 Ω
R6—82 kΩ
R7—1 kΩ
R8—470 kΩ
R9—3.3 kΩ
R10—680 Ω
R11—220 Ω
R12, R14, R17, R18—4.7 kΩ
R13, R15, R16, R20, R21, R23—10 kΩ
R22—1 MΩ
R24, R27—100 kΩ
R25—220 kΩ
R28—56 kΩ
R29—5-kΩ, linear-taper potentiometer
R30—5-kΩ, linear-taper potentiometer with shaft-actuated spst switch

S1—Spst switch (part of R30)
SPKR—2¼-inch, 8-Ω dynamic speaker
T1—1kΩ:8Ω miniature audio output transformer
Misc.—Suitable enclosure, perforated or printed-circuit board, single-conductor shielded cable, hookup wire, No. 30 and No. 38 enamelled copper (magnet) wire, battery clips, battery holders, circuit-board standoffs, grommets or other suitable strain reliefs for shielded cable, PVC electrical tape or silicone cement or other suitable insulating material, 12-inch-by-12-inch sheet of ¼-inch plywood, monofilament fishing line, ¾-inch masking tape, epoxy, hot-melt, and PVC glues, 4 feet of ½-inch O.D., schedule 125 PVC pipe, 2 feet of ½-inch, schedule 40 PVC pipe, 90° elbow PVC pipe joint, 135° elbow PVC pipe joint, tee PVC pipe joint, PVC pipe cap, bicycle steering-bar handgrip, lead buckshot, resin sealant, white paint, solder, hardware, aluminum foil etc.

negative voltage that subtracts from the positive bias voltage supplied by divider *R13R14*. Potentiometers *R29* and *R30* determine the magnitude of the reference voltage applied to the inverting input of *IC1A* and hence the detector circuit's sensitivity. They are adjusted so that the voltages at the two inputs are practically equal.

When the voltage at the noninverting input of the comparator becomes more positive than that at the inverting input, the output terminal (pin 1) switches to the positive supply voltage. This positive pulse toggles comparators *IC1B* and *IC1C*, which are connected in cascade and whose inverting inputs are biased to one-half the positive supply voltage. The charging of *C9* via *D1* and the discharging of *C9* through *R19* stretches the pulse. Transistor *Q4* is triggered into conduction by the elongated pulse that appears at the output of *IC1C*, cutting off *Q5*.

When *Q5* is cut off, *Q6* amplifies the tone produced by the audio oscillator comprising *IC1D* and its associated passive components. The current flowing through the primary of audio-output transformer *T1* and transistor *Q6* increases the voltage drop across *R5*, and this upsets the bias applied to the inverting input of *IC1A*. As a result, the outputs of *IC1A*, *IC1B*, and *IC1C* go low, transistor *Q4* cuts off, and transistor *Q5* saturates, shunting the base drive of *Q6* to ground and cutting that transistor off. This silences the loudspeaker and allows *C8* to charge again to the full positive supply voltage. The higher voltage across the capacitor allows *IC1A* to change state again if the nonferrous metal object is still within the search field.

Iron objects or mineralized ground within the search field will produce an increase in the amplitude of the signal at the collector of *Q3* and thus a less positive bias at the noninverting input of *IC1A*. In contrast, the presence of coins or other nonferrous metal objects within the search field will cause a smaller signal to appear at the collector of *Q3* and a more positive bias at the noninverting input of the first voltage comparator. This allows the Coinshooter to locate coins and other items of interest while ignoring nails, bottle caps, and other junk pieces of iron and steel.

When a small nonferrous item quickly enters and exits the search field, the loudspeaker will generate a single beep. If the object enters and remains in the search field, a series of beeps will be produced. Its rate of repetition will vary with the settings of potentiometers *R29* and *R30*, the size of the object, and the distance between the object and the search coil. The pitch of the beep is determined by the values of *C11* and the resistances in the feedback loop, as well as by the supply voltage. Its frequency is nominally 1.3 kHz.

Power for the Coinshooter circuit is supplied by two series-connected nine-volt batteries. An IC voltage regulator provides a constant supply potential to the rest of the circuit until the batteries are nearly exhausted. Quiescent current demand is approximately 10 mA, so battery replacement should be infrequent if alkaline cells are used. If desired, the Coinshooter can be powered by a single nine-volt battery and the regulator IC omitted. However, the circuit is sensitive to changes in supply voltage, and this alternative is not recommended. But, if this approach is taken, an alkaline battery must be used.

Construction. Procure a circular form 9½" in diameter on which you can wind the transmitting coil. In assembling the prototype, a hamper lid was used, but a mixing bowl or cardboard cylinder would be suitable.

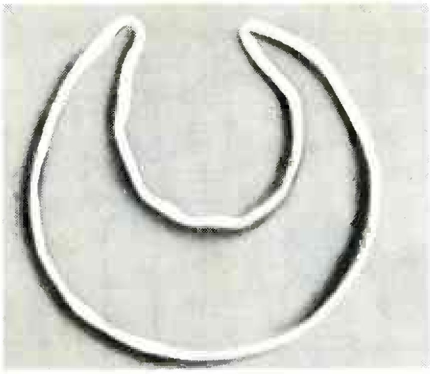


Fig. 2. Transmitting coil has been shaped to form L1 and L2.

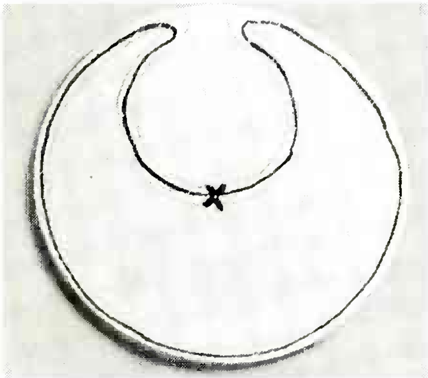


Fig. 3. Positions of L1 and L2 are marked on a plywood disc.

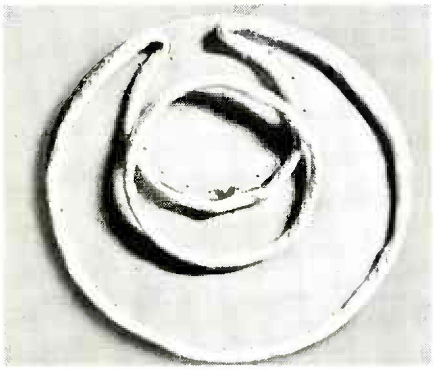


Fig. 4. The disc is shown with L1 and L2 tied in place and L3 on top.

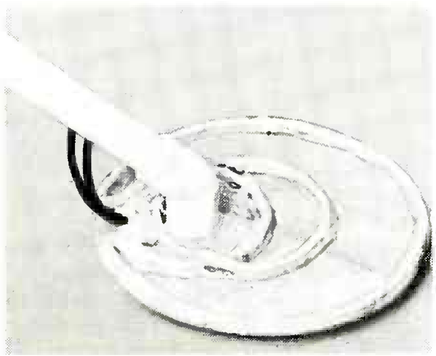


Fig. 5. The search-coil assembly with handle in place.

Wind a layer of masking tape ¾-inch wide around the form so that the adhesive side is exposed. The tape will hold the wire and make winding the coil much easier. Wind a total of 175 turns of No. 30 enamelled copper wire around the form, keeping the wire as close to the center of the tape as possible. The last turn should exit the coil at a point on the circumference 10 inches before the starting point is reached. Fold the tape around the coil and remove it from the form. Spiral-wrap the coil tightly with masking tape. Then shape the coil assembly as shown in Fig. 2 to form the transmitting coil. (*L1* is the large-diameter portion and *L2* is the small-diameter section.) The coils must be shielded so spiral wrap them (starting with *L1* opposite the lead wires) with 1" wide strips of aluminum foil. Cover the coils completely except for a ¼" gap between start and finish of the foil layer. Strip a 6" piece of hookup wire and lay it on the foil so that 2" exits next to one of the lead wires. Then spiral wrap the coils tightly with masking tape, covering the foil completely.

Next, cut a disc seven inches in diameter from a sheet of ¼-inch plywood. Lay the shaped coil assembly on the disc and trace pencil lines around the inside of *L1* and both sides of *L2* (see Fig. 3). Remove the coil assembly and drill a series of 1/16-inch holes spaced ½ inch apart along the pencil lines. Then place the shaped coil assembly back on the disc and tie it down with monofilament fishing line, looping the line through the series of holes.

Obtain a circular form 3½ inches in diameter on which you can wind the receiving coil. In assembling the prototype, a glass ashtray was used, but a cardboard cylinder would also be acceptable. The form should have a slight taper to facilitate removal of the coil after it has been wound. Apply masking tape to the form as was done in winding the transmitting coil, and wind 550 turns of No. 38 enamelled copper wire, keeping the windings as close to the center of the tape as possible. When the coil has been wound, fold the tape around the windings and remove the coil from the form. Spiral-wrap the coil tightly with masking tape. Wrap the coil with foil and another layer of tape as on *L1* and *L2* being sure to cover the foil completely. If the two foil shields are allowed to touch when the coils are positioned, the detector will not function.

Now assemble the circuit of the Coinshooter. In the construction of the prototype, a small (5 inches by 1-

¾ inches) perforated board and point-to-point wiring were used. Printed-circuit assembly techniques are also acceptable. Because the circuit operates at very low frequencies, parts layout is not especially critical. Use an IC socket or Molex Soldercons for *IC1* rather than soldering the chip's pins directly to the circuit board.

Potentiometers *R29* and *R30* and the loudspeaker are not mounted on the board. Rather, they should be affixed to the enclosure housing the circuit board. Resistor *R11* can be soldered directly across the outer lugs of potentiometer *R29*. A total of four holes (two ⅜ inch in diameter spaced 2 inches apart, and two ⅛ inch in diameter spaced ½ inch above and below the larger holes) should be drilled in the bottom of the project enclosure so that two shielded cables can exit the enclosure and self-tapping screws can provide mechanical support. Additional holes might have to be drilled for circuit-board standoffs.

Prepare the inner conductor and shield at one end of each of two 48-inch lengths of single-conductor shielded cable. Color-code both ends of one of the cables with a dab of enamel paint or nail polish. Connect the shields of the prepared ends of both cables to circuit ground. The inner conductor of the color-coded cable should be connected to the node *C1, C2*, and collector of *Q1;* the inner conductor of the other cable should be connected to the node *C4, C5*. These cables should exit the enclosure housing the circuit board through the two ⅜-inch holes previously drilled through its bottom. Be sure to outfit these holes with grommets or similar bushings that prevent chafing of their outer plastic jackets and that provide strain relief.

When the circuit board has been assembled and mounted in the enclosure along with the other components, place the transmitting-coil assembly and the receiving coil on a desk or on the floor away from any metal. Prepare the free ends of the two shielded cables and tin their inner conductors and shields. Using clip leads, connect the color-coded cable's conductors to the transmitting coil, and the other cable's conductors to the receiving coil. Connect the coil shields to the outer cable conductors. Apply power to the circuit and connect an oscilloscope probe between *Q3*'s collector and circuit ground.

Referring to Fig. 4, position the receiving coil near the center of the plywood disc on which the transmitting coil has been mounted. Adjust the position of the receiving coil for the minimum signal level at the collector of *Q3* as indicated by the scope beam's vertical deflection. Trace a pencil line on each side of the receiving coil after the null position has been determined, and then remove the receiving coil from the disc. Drill a series of 1/16-inch holes, spaced ½ inch apart, along the pencil lines. Reposition the receiving coil on the disc and tie it down with monofilament fishing line, looping the line through the small holes.

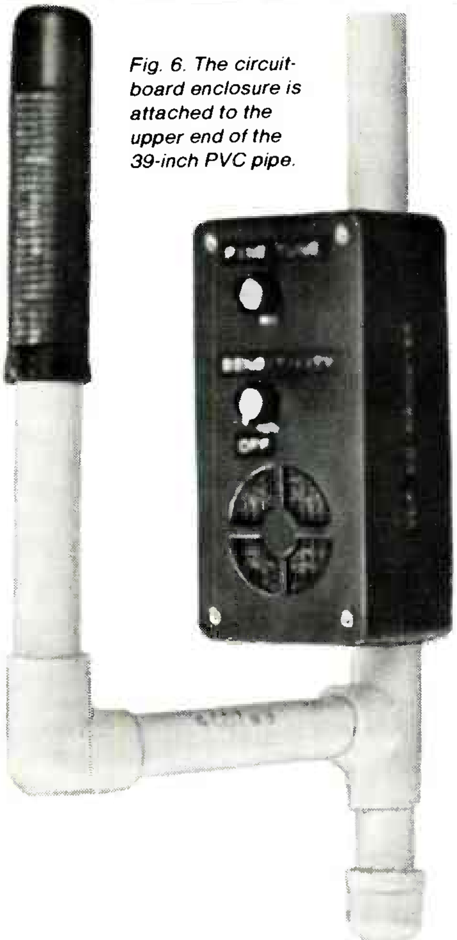


Fig. 6. The circuit-board enclosure is attached to the upper end of the 39-inch PVC pipe.

Using hot-melt or epoxy glue, cement a 135° elbow PVC pipe joint in the area between *L2* and *L3* so that its open end points toward the gap in *L1*. (See Fig. 5.) Cut a 39-inch length of ½-inch O.D., schedule 125 PVC pipe, and drill four ¼-inch holes in it, one above the other, approximately 2 inches in from each end. The two holes at one end of the pipe section should be 2 inches apart from each other, but the holes at the other end can be closer. Also drill two ⅛-inch holes spaced ½ inch above and below the two holes spaced 2 inches apart.

Slip the free ends of the shielded cables exiting the circuit-board enclosure through the ¼-inch holes that are bracketed by the smaller holes and pass the cables through the pipe until they protrude from the far end. Run a bead of hot-melt or epoxy glue on the pipe and attach the bottom of the project enclosure to the pipe. Added mechanical support can be introduced by driving self-tapping screws through the two small holes in the bottom of the enclosure and into the matching holes that were drilled into the pipe section.

Feed the free ends of the shielded cables through the two holes at the other end of the pipe. Insert that end of the pipe into the elbow joint attached to the plywood disc so that the circuit enclosure faces away from the coil assembly. Then glue the pipe to the elbow joint using PVC cement, maintaining the orientation of the enclosure with respect to the coil assembly. (Note that PVC cement sets quickly.) Solder the conductors of the color-coded cable to the transmitting coil and the conductors of the other cable to the receiving coil. The polarities of these connections are unimportant. Connect the coil shield leads to the outer cable conductors. Insulate the solder joints using PVC electrical tape, silicone cement, or some other suitable material. Then cement the cables to the plywood disc in the area between *L3* and the gap in *L1* using hot-melt or epoxy glue.

Cut 6- and 9-inch lengths of ½-inch O.D., schedule 40 PVC pipe. Referring to Fig. 6, assemble a handle using the lengths of pipe, a 90° elbow PVC pipe joint, a tee PVC pipe joint, a bicycle steering-bar handgrip and PVC cement. The handgrip is glued to the 9-inch section of pipe, and one of the two collinear openings of the tee should be glued to the 39-inch pipe section to which the circuit-board enclosure and the search coil assembly are attached. PVC cement is fast-setting, so work quickly and orient the handle with respect to the circuit-board enclosure as it is in Fig. 6. The remaining end of the tee will be left open until the detector is balanced.

Apply power to the circuit and reconnect the oscilloscope probe between the collector of *Q3* and circuit ground. Suspend the search coil in the air away from any metal and rotate the shaft of *R29* to its minimum-sensitivity setting. Monitor the scope trace and, if necessary, slightly adjust the position of *L3* so that a 1-volt p-p signal appears at the collector of *Q3*. Pass a pair of pliers approximately three inches under the search-coil assembly while monitoring the scope trace. If the signal level decreases, shift *L3* through the null point and repeat the test. The signal must increase in amplitude when the pliers are brought near the search-coil assembly, or the detector will ignore coins and respond to the proximity of ferrous objects. Receiving coil *L3* should be positioned as close to the null point as possible yet still provide an increase in signal amplitude when iron or steel is brought near the search-coil assembly.

Next, pass a dime about three inches under the search coil and note the slight increase in signal level as displayed on the oscilloscope. Carefully fix the positions of the coils by bonding them to the plywood disc with quick-setting epoxy cement. When the epoxy has cured, remove the scope probe and button up the circuit-board enclosure. Advance the setting of the SENSITIVITY control until the speaker begins to beep. Then adjust the FINE TUNE control to silence the speaker. Pass a pair of pliers three inches below the search coil and note that the speaker remains silent. Then pass a dime three inches under the coil and note that the speaker starts to beep. The most sensitive area of the search coil is near its center.

The search-coil assembly can be coated with two thin applications of resin to seal it, and then it can be painted white so that it matches the PVC pipe. The coils must be bonded securely to the disc before the application of sealant and paint. To minimize the possibility of displacing the coils, use spray-on resin and paint.

If the coils have shifted position before the resin has cured, a compensating piece of iron or steel can be added to the search-coil assembly. Determine whether this has in fact happened by removing the top of the circuit-board enclosure and reconnecting the oscilloscope probe between the collector of *Q3* and circuit ground. Pass a ferrous object three inches below the search coil and monitor the scope trace. If the proximity of iron or steel causes a decrease in signal level, position a small steel washer on or near receiving coil *L3* to correct for the misalignment. Locate the required position by repeating the test for iron sensitivity and shifting the location of the washer until the correct response is obtained. Then fix the washer in place with epoxy cement.

Final Assembly and Use. Grasp the Coinshooter by its handgrip and check it for proper balance. The search-coil assembly should be parallel with and approximately 2 inches above the floor. Cut a 3-inch piece of ½-inch O.D., schedule 125 PVC pipe, and glue one end of it to a PVC pipe cap. Fill the pipe section with lead buckshot and tape its open end closed with PVC electrical tape. Then tape the shot-laden pipe section to the open end of the tee PVC pipe joint and recheck the balance of the project.

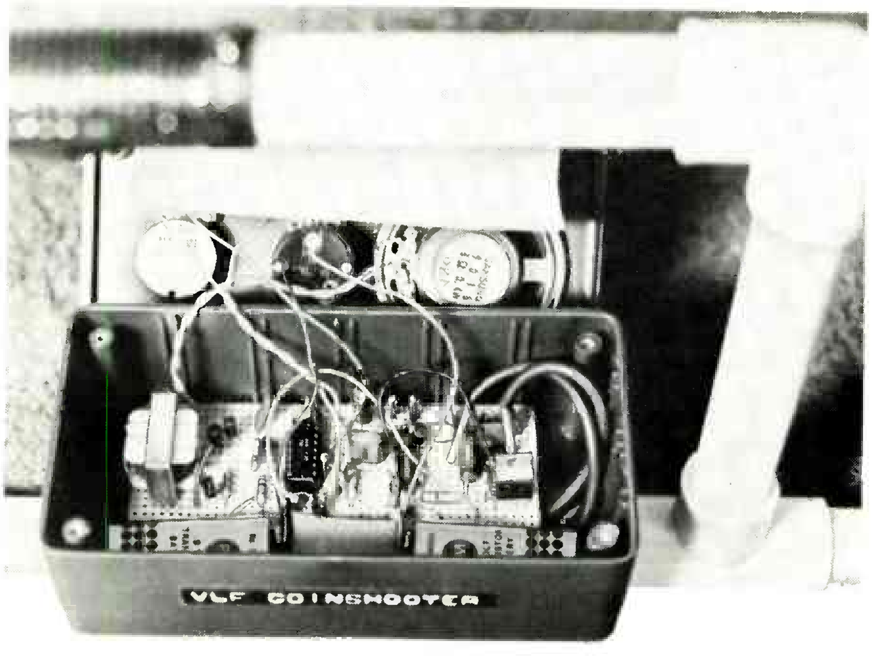
If it is unbalanced, untape the shot-laden pipe section, remove a little shot, tape the section closed again and reattach it to the tee PVC pipe joint. Recheck the balance of the Coinshooter. If necessary, repeat this procedure until the Coinshooter is properly balanced and feels comfortable to the hand. When the correct amount of shot has been determined, remove the pipe section from the tee PVC pipe joint, seal the shot in the pipe section with epoxy, and cement the section to the tee after the epoxy has cured. This completes assembly.

Take the finished project outdoors and hold the search coil 4 to 6 inches above the ground. Apply power to the project and adjust its controls so that the speaker emits a slow series of beeps. Lower the search coil until it is approximately 2 inches above the ground. The beeping should stop. This occurs because most soil is mineralized and affects the Coinshooter much like ferrous objects do.

The detector is now at maximum sensitivity and will detect coins at depths of from 1 to 3 inches, depending on their sizes and positions. Ferrous objects will not trigger the circuit unless they are very large or very close to the search coil or both. The Coinshooter will detect aluminum cans, caps and pull tabs, but it responds best to coins. Raise the search coil from time to time to check for the slow beeps that indicate maximum detector sensitivity. Although the circuit is very stable, the FINE TUNE control might have to be adjusted occasionally to compensate for changes in ground mineralization, temperature, and, if an unregulated power supply is used, battery voltage.

Always hold the Coinshooter so that the search-coil assembly is 1 to 2 inches above and parallel to the ground. Try to keep the search coil at a constant height above the ground. Swing the loop back and forth in front of you, making overlapping arcs. It is best to search slowly, but a coin will usually be detected even if the search coil passes over it quickly. For best results, operate the circuit as close to its switching threshold as possible.

When an object has been detected, move the search-coil assembly over it from front to back and from side to side to pinpoint its location. Keep in mind that the center of the search-coil assembly is its most sensitive point. Probe for the object with a small screwdriver or similar digging tool. If you search for coins in parks and woodlands, do so without disturbing the landscape. Always fill any holes that you make with your digging tool and place any turf that has been disturbed back in its original position. ◇



Photograph shows the circuit-board enclosure mounted on the PVC pipe. The top has been unfastened and laid aside.

The Optimized GRAPHIC EQUALIZER

Part-1—New design approach provides sharper frequency control in the all-important audio midband

By Joe Gorin

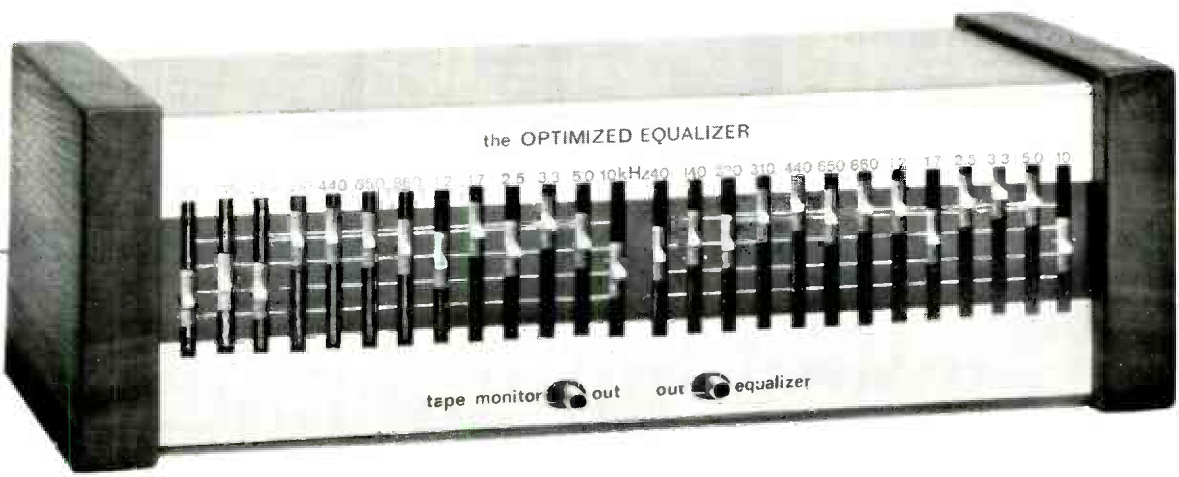
GRAPHIC equalizers are popular audio accessories nowadays. They enable hi-fi buffs to adjust the frequency response of a stereo system to compensate for loudspeaker errors, room acoustic problems, and unsuitably balanced recordings and broadcasts. In essence, they are super tone controls that allow one to change small portions of the audio spectrum.

The 10-band graphic equalizer is the most popular type for home use. But a new design gives improved performance at low cost. It's called the Optimized Graphic Equalizer. Now, instead of equalizing one-octave bands, half-octave control is available for the ten important midrange bands. Although bass and treble suffer somewhat (there are just three controls for these), the overall design allows for better control of frequency response. Additionally, an optional real-time analyzer can be incorporated into the circuit for equalization setup.

Design of the Equalizer. Human hearing is relatively insensitive to frequency response errors of less than ⅓ of an octave (called the "critical bandwidth"). This is why professional equalizers have 24 to 31 bands at approximately ⅓-octave spacings. But the critical bandwidth is actually narrower in the midrange than in the bass or high treble. Also, because the vast amount of musical information occurs in the midrange, this is the most important area for high-resolution (close band spacing) equalization. Normally, equalizers designed for home use have 1-octave spacings. In order to create an economical, but very effective equalizer, the Optimized Equalizer uses ½-octave spacing of bands in the midrange (for five octaves), a relatively wide band in the treble range, and two in the bass.

The most important function of an equalizer is the taming of two kinds of resonances—those with gain and those with loss. But a giant "hole" in the frequency response of a system (for example, a −20-dB "suckout" in a typical second-order speaker crossover) is practically inaudible. This is because the information in a narrow notch is small and masked by nearby signals. Furthermore, it isn't feasible to equalize a narrow notch. Practically speaking, you can't set the frequency and bandwidth close enough, and the phase relationships of the notch are so poorly controlled that, even if the frequency response were right, the actual signal waveforms wouldn't sound right.

On the other hand, resonances that boost the frequency response are painfully obvious to the listener. A +3-dB resonance adds more signal to a system than a −20-dB notch removes, and since it is an error of commission rather than omission, it "pops out" at you. Also, the sound from such a reso-



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2.5 Mhz

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Z80A-PIO	4.95
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6860	9.95
6862	11.95
6875	6.95
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6883	22.95
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6800 = 1MHZ

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68B00 = 2 MHZ

6500

1 MHZ

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6504	6.95
6505	8.95
6507	9.95
6520	4.35
6522	7.95
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6551	11.85

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74LS00	.24	74LS173	.69
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74LS02	.25	74LS175	.55
74LS03	.25	74LS181	2.15
74LS04	.24	74LS189	8.95
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74LS08	.28	74LS191	.89
74LS09	.29	74LS192	.79
74LS10	.25	74LS193	.79
74LS11	.35	74LS194	.69
74LS12	.35	74LS195	.69
74LS13	.45	74LS196	.79
74LS14	.59	74LS197	.79
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74LS28	.35	74LS245	1.49
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74LS33	.55	74LS249	.99
74LS37	.35	74LS251	.59
74LS38	.35	74LS253	.59
74LS40	.25	74LS257	.59
74LS42	.49	74LS258	.59
74LS47	.75	74LS259	2.75
74LS48	.75	74LS260	.59
74LS49	.75	74LS266	.55
74LS51	.25	74LS273	1.49
74LS54	.29	74LS275	3.35
74LS55	.29	74LS279	.49
74LS63	1.25	74LS280	1.98
74LS73	.39	74LS283	.69
74LS74	.35	74LS290	.89
74LS75	.39	74LS293	.89
74LS76	.39	74LS295	.99
74LS78	.49	74LS298	.89
74LS83	.60	74LS299	1.75
74LS85	.69	74LS323	3.50
74LS86	.39	74LS324	1.75
74LS90	.55	74LS352	1.29
74LS91	.89	74LS353	1.29
74LS92	.55	74LS363	1.35
74LS93	.55	74LS364	1.95
74LS95	.75	74LS365	.49
74LS96	.89	74LS366	.49
74LS107	.39	74LS367	.45
74LS109	.39	74LS368	.45
74LS112	.39	74LS373	1.39
74LS113	.39	74LS374	1.39
74LS114	.39	74LS377	1.39
74LS122	.45	74LS378	1.18
74LS123	.79	74LS379	1.35
74LS124	2.90	74LS385	1.90
74LS125	.49	74LS386	.45
74LS126	.49	74LS390	1.19
74LS132	.59	74LS393	1.19
74LS133	.59	74LS395	1.19
74LS136	.39	74LS399	1.49
74LS137	.99	74LS424	2.95
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74LS145	1.20	74LS624	3.99
74LS147	2.49	74LS640	2.20
74LS148	1.35	74LS645	2.20
74LS151	.55	74LS668	1.69
74LS153	.55	74LS669	1.89
74LS154	1.90	74LS670	1.49
74LS155	.69	74LS674	9.65
74LS156	.69	74LS682	3.20
74LS157	.65	74LS683	3.20
74LS158	.59	74LS684	3.20
74LS160	.69	74LS685	3.20
74LS161	.65	74LS688	2.40
74LS162	.69	74LS689	3.20
74LS163	.65	74LS783	24.95
74LS164	.69	81LS95	1.49
74LS165	.95	81LS96	1.49
74LS166	1.95	81LS97	1.49
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7404	.19	74143	2.95
7405	.25	74145	.60
7406	.29	74147	1.75
7407	.29	74148	1.20
7408	.24	74150	1.35
7409	.19	74151	.55
7410	.19	74152	.65
7411	.25	74153	.55
7412	.30	74154	1.25
7413	.35	74155	.75
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7421	.35	74161	.69
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7430	.19	74170	1.65
7432	.29	74172	5.95
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7442	.49	74177	.75
7443	.65	74178	1.15
7444	.69	74179	1.75
7445	.69	74180	.75
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7447	.69	74182	.75
7448	.69	74184	2.00
7450	.19	74185	2.00
7451	.23	74190	1.15
7453	.23	74191	1.15
7454	.23	74192	.79
7460	.23	74193	.79
7470	.35	74194	.85
7472	.29	74195	.85
7473	.34	74196	.79
7474	.33	74197	.75
7475	.45	74198	1.35
7476	.35	74199	1.35
7480	.59	74221	1.35
7481	1.10	74246	1.35
7482	.95	74247	1.25
7483	.50	74248	1.85
7485	.59	74249	1.95
7486	.35	74251	.75
7489	2.15	74259	2.25
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7491	.40	74273	1.95
7492	.50	74276	1.25
7493	.35	74279	.75
7494	.65	74283	2.00
7495	.55	74284	3.75
7496	.70	74285	3.75
7497	2.75	74290	.95
74100	1.75	74293	.75
74107	.30	74298	.85
74109	.45	74351	2.25
74110	.45	74365	.65
74111	.55	74366	.65
74116	1.55	74367	.65
74120	1.20	74368	.65
74121	.29	74376	2.20
74122	.45	74390	1.75
74123	.49	74393	1.35
74125	.45	74425	3.15
74126	.45	74426	.85
74128	.55	74490	2.55

LINEAR

LM301	.34	LM340 (see 7800)		LM566	1.49	LM1800	2.37
LM301H	.79	LM348	.99	LM567	.89	LM1812	8.25
LM307	.45	LM350K	4.95	NE570	3.95	LM1830	3.50
LM308	.69	LM350T	4.60	NE571	2.95	LM1871	5.49
LM308H	1.15	LM358	.69	NE592	2.75	LM1872	5.49
LM309H	1.95	LM359	1.79	LM709	.59	LM1877	3.25
LM309K	1.25	LM376	3.75	LM710	.75	LM1889	1.95
LM310	1.75	LM377	1.95	LM711	.79	LM1896	1.75
LM311	.64	LM378	2.50	LM723	.49	ULN2003	2.49
LM311H	.89	LM379	4.50	LM723H	.55	LM2877	2.05
LM312H	1.75	LM380	.89	LM733	.98	LM2878	2.25
LM317K	3.95	LM380N-8	1.10	LM741	.35	LM2900	.85
LM317T	1.19	LM381	1.60	LM741N-14	.35	LM2901	1.00
LM318	1.49	LM382	1.60	LM741H	.40	LM3900	.59
LM318H	1.59	LM383	1.95	LM747	.69	LM3905	1.25
LM319H	1.90	LM384	1.95	LM748	.59	LM3909	.98
LM319	1.25	LM386	.89	LM1014	1.19	LM3911	2.25
LM320 (see 7900)		LM387	1.40	LM1303	1.95	LM3914	3.95
LM322	1.65	LM389	1.35	LM1310	1.49	LM3915	3.95
LM323K	4.95	LM390	1.95	MC1330	1.69	LM3916	3.95
LM324	.59	LM392	.69	MC1349	1.89	MC4024	3.95
LM329	.65	LM394H	4.60	MC1350	1.19	MC4044	4.50
LM331	3.95	LM399H	5.00	MC1358	1.69	RC4136	1.25
LM334	1.19	NE531	2.95	MC1372	6.95	RC4151	3.95
LM335	1.40	NE555	.34	LM1414	1.59	LM4250	1.75
LM336	1.75	NE556	.65	LM1458	.59	LM4500	3.25
LM337K	3.95	NE558	1.50	LM1488	.69	RC4558	.69
LM337T	1.95	NE561	24.95	LM1489	.69	LM13080	1.29
LM338K	6.95	NE564	2.95	LM1496	.85	LM13600	1.49
LM339	.99	LM565	.99	LM1558H	3.10	LM13700	1.49

H = TO-5 CAN T = TO-220 K = TO-3

RCA

CA 3023	2.75	CA 3082	1.65
CA 3039	1.29	CA 3083	1.55
CA 3046	1.25	CA 3086	.80
CA 3059	2.90	CA 3089	2.99
CA 3060	2.90	CA 3096	3.49
CA 3065	1.75	CA 3130	1.30
CA 3080	1.10	CA 3140	1.15
CA 3081	1.65	CA 3146	1.85
CA 3160	1.19		

TI

TL494	4.20	75365	1.95
TL496	1.65	75450	.59
TL497	3.25	75451	.39
75107	1.49	75452	.39
75110	1.95	75453	.39
75150	1.95	75454	.39
75154	1.95	75491	.79
75188	1.25	75492	.79
75189	1.25	75493	.89
75494	.89		

BI FET

TL071	.79	TL084	2.19
TL072	1.19	LF347	2.19
TL074	2.19	LF351	.60
TL081	.79	LF353	1.00
TL082	1.19	LF355	1.10
TL083	1.19	LF356	1.10
LF357	1.40		

CMOS

4000	.29	4527	1.95
4001	.25	4528	1.19
4002	.25	4531	.95
4006	.89	4532	1.95
4007	.29	4538	1.95
4008	.95	4539	1.95
4009	.39	4541	2.64
4010	.45	4543	1.19
4011	.25	4553	5.79
4012	.25	4555	.95
4013	.38	4556	.95
4014	.79	4581	1.95
4015	.39	4582	1.95
4016	.39	4584	.75
4017	.69	4585	.75
4018	.79	4702	12.95
4019	.39	74C00	.35
4020	.75	74C02	.35
4021	.79	74C04	.35
4022	.79	74C08	.35
4023	.29	74C10	.35
4024	.65	74C14	.59
4025	.29	74C20	.35
4026	1.65	74C30	.35
4027	.45	74C32	.39
4028	.69	74C42	1.29
4029	.79	74C48	1.99
4030	.39	74C73	.65
4034	1.95	74C74	.65
4035	.85	74C76	.80
4040	.75	74C83	1.95
4041	.75	74C85	1.95
4042	.69	74C86	.39
4043	.85	74C89	4.50
4044	.79	74C90	1.19
4046	.85	74C93	1.75
4047	.95	74C95	.99
4049	.35	74C107	.89
4050	.35	74C150	5.75
4051	.79	74C151	2.25
4053	.79	74C154	3.25
4060	.89	74C157	1.75
4066	.39	74C160	1.19
4068	.39	74C161	1.19
4069	.29	74C162	1.19
4070	.35	74C163	1.19
4071	.29	74C164	1.39
4072	.29	74C165	2.00
4073	.29	74C173	.79
4075	.29	74C174	1.19
4076	.79	74C175	1.19
4078	.29	74C192	1.49
4081	.29	74C193	1.49
4082	.29	74C195	1.39
4085	.95	74C200	5.75
4086	.95	74C221	1.75
4093	.49	74C373	2.45
4098	2.49	74C374	2.45
4099	1.95	74C901	.39
14409	12.95	74C902	.85
14410	12.95	74C903	.85
14411	11.95	74C905	10.95
14412	12.95	74C906	.95
14419	7.95	74C907	1.00
14433	4.18	74C908	2.00
4502	.95	74C909	2.75
4503	.65	74C910	9.95
4508	1.95	74C911	8.95
4510	.85	74C912	8.95
4511	.85	74C914	1.95
4512	.85	74C915	1.19
4514	1.25	74C918	2.75
4515	1.79	74C920	17.95
4516	1.55	74C921	15.95
4518	.89	74C922	4.49
4519	.39	74C923	4.95
4520	.79	74C925	5.95
4522	1.25	74C926	7.95
4526	1.25	74C928	7.95
		74C929	19.95

74S00

74S00	.32	74S163	1.95
74S02	.35	74S168	3.95
74S03	.35	74S169	3.95
74S04	.35	74S174	.95
74S05	.35	74S175	.95
74S08	.35	74S181	3.95
74S09	.40	74S182	2.95
74S10	.35	74S188	1.95
74S11	.35	74S189	6.95
74S15	.35	74S194	1.49
74S20	.35	74S195	1.49
74S22	.35	74S196	1.49
74S30	.35	74S197	1.49
74S32	.40	74S201	6.95
74S37	.88	74S225	7.95
74S38	.85	74S240	2.20
74S40	.35	74S241	2.20
74S51	.35	74S244	2.20
74S64	.40	74S251	.95
74S65	.40	74S253	.95
74S74	.50	74S257	.95
74S85	1.99	74S258	.95
74S86	.50	74S260	.79
74S112	.50	74S274	19.95
74S113	.50	74S275	19.95
74S114	.55	74S280	1.95
74S124	2.75	74S287	1.90
74S132	1.24	74S288	1.90
74S133	.45	74S289	6.89
74S134	.50	74S301	6.95
74S135	.89	74S373	2.45
74S138	.85	74S374	2.45
74S139	.85	74S381	7.95
74S140	.55	74S387	1.95
74S151	.95	74S412	2.98
74S153	.95	74S471	4.95
74S157	.95	74S472	4.95
74S158	.95	74S474	4.95
74S161	1.95	74S482	15.25
74S162	1.95	74S570	2.95
		74S571	2.95

IC SOCKETS

	1-99	100
8 pin ST	.13	.11
14 pin ST	.15	.12
16 pin ST	.17	.13
18 pin ST	.20	.18
20 pin ST	.29	.27
22 pin ST	.30	.27
24 pin ST	.30	.27
28 pin ST	.40	.32
40 pin ST	.49	.39
64 pin ST	4.25	call
ST = SOLDERTAIL		
8 pin WW	.59	.49
14 pin WW	.69	.52
16 pin WW	.69	.58
18 pin WW	.99	.90
20 pin WW	1.09	.98
22 pin WW	1.39	1.28
24 pin WW	1.49	1.35
28 pin WW	1.69	1.49
40 pin WW	1.99	1.80
WW = WIREWRAP		
16 pin ZIF	6.75	call
24 pin ZIF	9.95	call
28 pin ZIF	10.95	call

ZIF = TEXTOOL (Zero Insertion Force)

VOLTAGE REGULATORS

7805T	.75	7905T	.85
78M05C	.35	7908T	.85
7808T	.75	7912T	.85
7812T	.75	7915T	.85
7815T	.75	7924T	.85
7824T	.75		
		7905K	1.49
7805K	1.39	7912K	1.49
7812K	1.39	7915K	1.49
7815K	1.39	7924K	1.49
7824K	1.39		
		79L05	.79
78L05	.69	79L12	.79
78L12	.69	79L15	.79
78L15	.69		
		LM323K	4.95
78H05K	9.95	UA78S40	1.95
78H12K	9.95		

C, T = TO-220 K = TO-3 L = TO-92

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4 POSITION	.85
5 POSITION	.90
6 POSITION	.90
7 POSITION	.95
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8T95	.89
8T96	.89
8T97	.89
8T98	.89
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DP8304	2.29
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DS8836	.99

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MC3480	9.00
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95H90	7.95
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Yellow	.18	.15

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MAN 74	.3"	CC	.99
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FND-500 (503)	.5"	CC	1.49
FND-507 (510)	.5"	CA	1.49

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MM5375	4.95
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ICM7208	15.95

9000

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9401	9.95
9601	.75
9602	1.50
96S02	1.95

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ADC0809	4.49	DAC1022	5.95
ADC0817	9.95	MC1408L6	1.95
DAC0800	4.95	MC1408L8	2.95

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AY3-8910	12.95
AY3-8912	12.95
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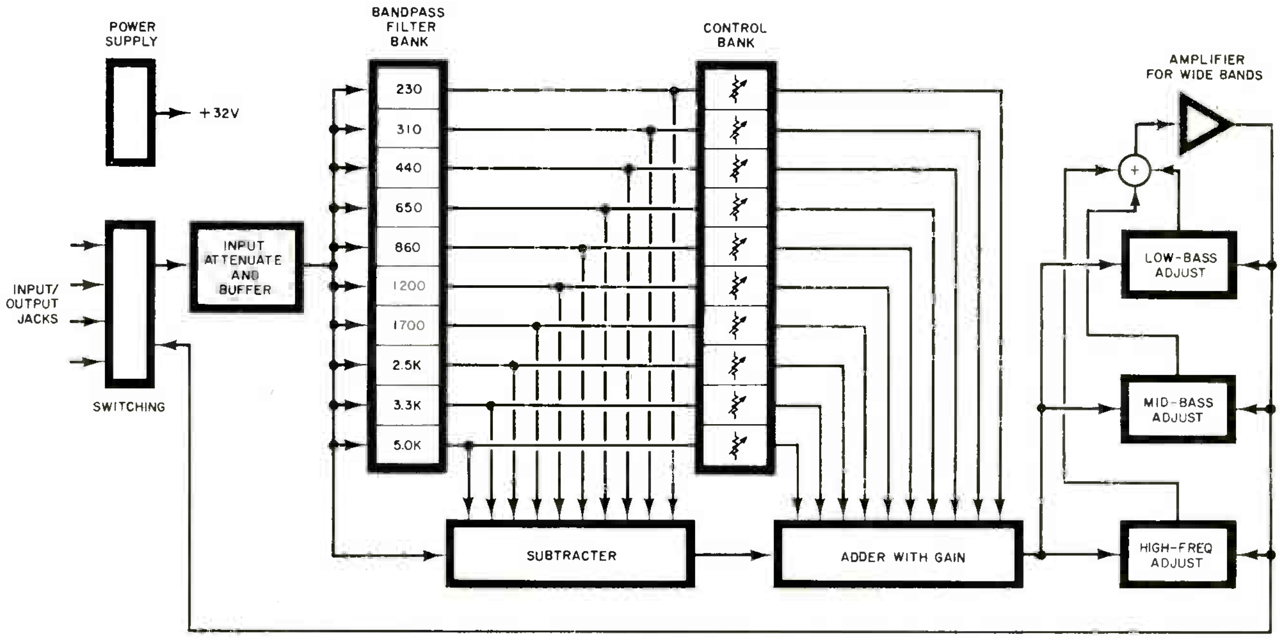


Fig. 1. Block diagram of the Equalizer. Midband frequency selection is made by filter bank.

nance continues in the room long after the signal to the loudspeaker has stopped. An equalizer eliminates this problem, even if it isn't "right on" the frequency of the resonance, by reducing the energy that drives it.

Thus, it's more important for an equalizer to cut signals than to boost them. We chose to allow only +3 dB of boost in the midrange bands, but a full 12 dB of cut. This is enough range to tame the worst resonances.

The bottom bass band of the Optimized Equalizer is just the opposite in range. It goes from −3 dB to +12 dB, with the hinge frequency of the band moving higher with more boost. This band is thus optimized to improve the bottom useful octave of home loudspeaker response, usually stretching it from 45 to 65 Hz downward.

The mid-range band is placed at about 140 Hz in the Optimized Equalizer. This covers the space between the other bands and coincides with the typical midbass hump (the one that helps speakers sell so well in the hi-fi stores). Most persons will need to reduce the gain slightly at this frequency for improved accuracy, but a full ±8 dB is allowed because boosting this band can be fun, even if it is unrealistic.

The treble band covers the range above the last midrange band. Because of the large variations in loudspeakers and recorded material, ±10 dB is allowed on this band.

Circuit Operation. Figure 1 is a block diagram of the Optimized Equalizer. The midband frequency selection is done by the filter bank. Since the filters have gain, the signal is attenuated at the input. This prevents even the largest signals at the tape monitor terminals of your amplifier from causing clipping of the filters. By subtracting three-quarters of the signal using the filter outputs, the result is a gain of −12 dB at the filter center frequency. Next, a variable amount of the filter output is added back to the signal. When the control is set to 0 dB, the added signal cancels the subtracted signal exactly for flat frequency response.

An important point about this block diagram is that the arrangement of the input attenuator and filter bank is exactly that required for a real-time analyzer (which will be discussed next month).

The signal from the adder (which has gain to make up for the input attenuator) goes to a three-band circuit that is similar to those found in preamplifiers. The controls adjust the amount of feedback, and thus gain, in a particular frequency region.

Figure 2 is the complete schematic for the Optimized Equalizer. The power supply is a full-wave bridge rectifier (*D201-D204*) with a wall-plug transformer. The use of a remote transformer obviates the need for coaxial cables (without the penalty of hum pickup). Power to *IC2-IC6* is unregulated because the power-supply noise rejection of these ICs is so good that hum pickup is trivial. However, power to *IC1* and *IC7* is passed through an RC filter to reduce hum by 18 dB because the circuits that use these two ICs are more sensitive to supply noise.

Resistors *R202-R204* and capacitors *C203* and *C204* bias the ICs at 15 V. This double filter reduces the hum from the power supply to about 1 μV. The circuit could not be any quieter even with dual, fully regulated, power supplies (which would be much more expensive than the single supply used here).

Resistors *R1* and *R2* form the input attenuator. Capacitor *C1* reduces the attenuation at high frequencies where the filter bank

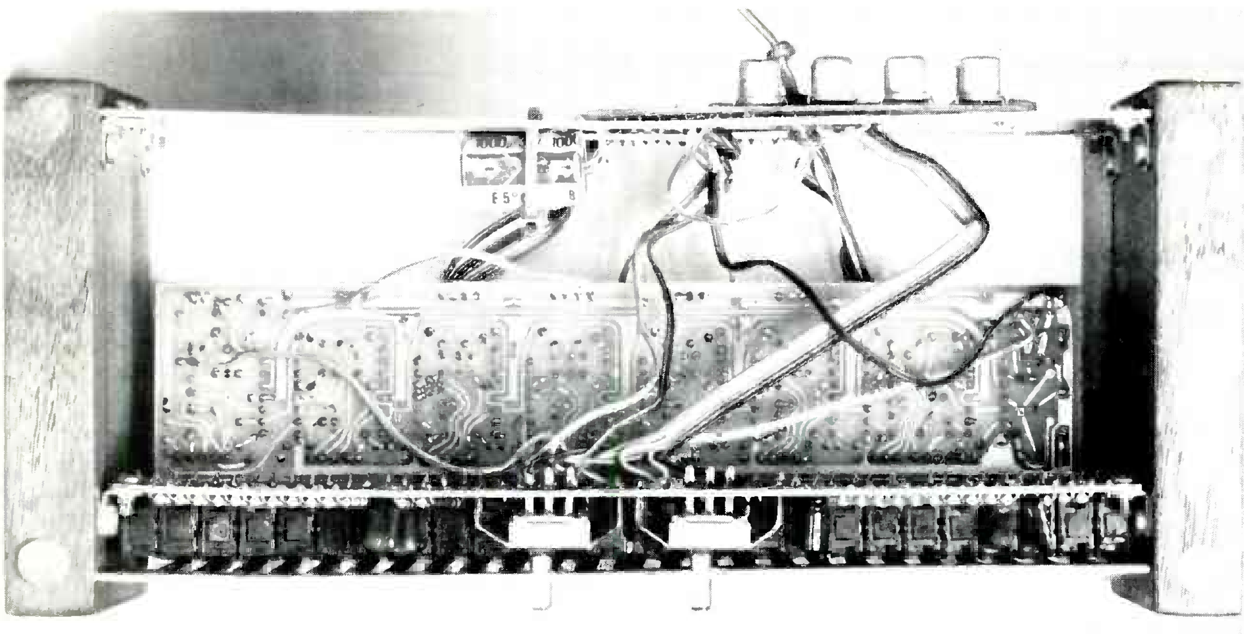


Photo of the author's prototype showing internal arrangement of the boards.

cannot clip because the filters have low gain. Reducing the attenuation here allows the reduction of the gain, and thus noise, later on. Capacitor *C2* couples the attenuated signal to *IC1A*, a gain-of-one stage that presents a high input impedance, but can drive the low impedance of the filter bank.

Op amps *IC2A* through *IC4B* are ten parallel filters. All have a bridged-T configuration. Let's examine *IC2A* as an example. At low frequencies, the input signal from *R22* is blocked from *IC2A* by the high impedance of *C22*. At frequencies much higher than the filter's center frequency, the low impedance of *C21* bypasses the signal from *R22* into the low output impedance of *IC2A*, preventing its amplification. At the center frequency, though, the stage has a high gain. The signal from *R22* is coupled through *C22* to be amplified and inverted by *IC2A*. The output of *IC2A* is coupled back through *C21*. Due to the phase shift of the capacitor circuits and the op amp's inversion, this feedback signal is in phase with the direct signal. Resistor *R23* controls the gain and positive feedback.

The signals from *R55* and the even-numbered resistors, *R34* through *R52*, are added at the input to *IC1D*. The filter outputs are all inverted at their center frequencies, which forms the subtractor in the block diagram. Controls *R24* through *R33* adjust the amount of signal added back in *IC1C*, which implements the adder. The feedback around *IC1C* rolls off the gain at high frequencies to make up for rolling off the attenuation with *C1*. It thus allows better signal-to-noise ratio with flat response.

Op amp *IC1B* adds the last three bands to the equalizer. Consider first the bass band, controlled by *R60*. If it is set to full boost, then at low frequencies the input signal is applied to *IC1B* through relatively low-valued resistor *R59*, for little attenuation. Feedback comes from *R62, R61*, and *R60*; very large values imply little feedback and thus a large gain. If *R60* is set to the other end, there is more attenuation and more feedback, for a net attenuation. At high frequencies, the bass control is bypassed by *C26* and *C27* and the midbass control is coupled in through *C28*. Above the midbass frequencies, *C29* and *C30* bypass the midbass control, and *C31* couples the high-frequency control to *IC1B*.

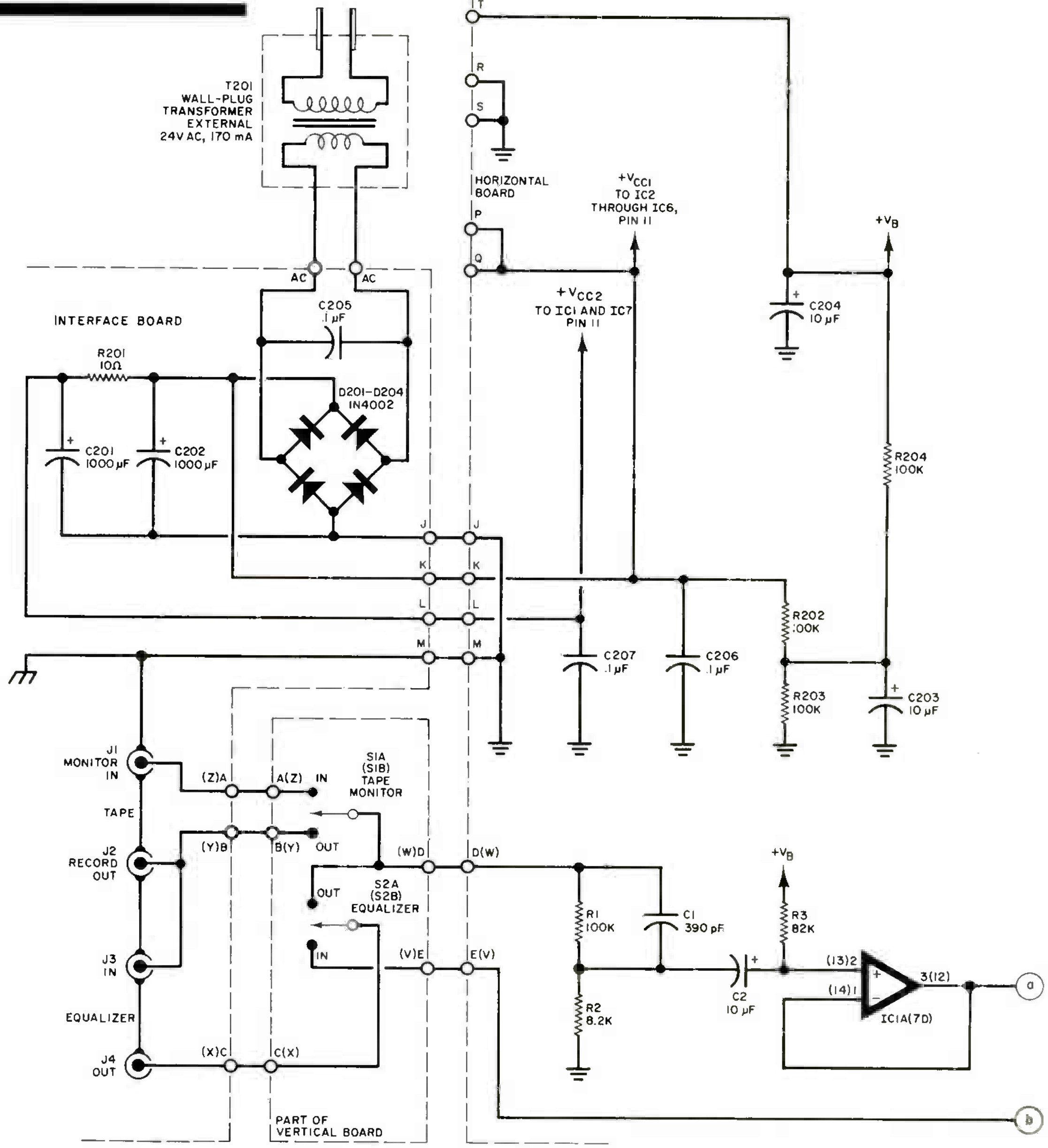
The output of *IC1B* is coupled through *C32* to eliminate the 15-V dc bias from the output. Resistor *R72* increases the output impedance to about 600 ohms and prevents possible oscillation of *IC1B* due to highly capacitive connecting cables.

Construction. The Optimized Equalizer, except for the power supply input connectors and options, is built on two pc boards. The foil patterns for these boards are shown in Fig. 3, and the parts placement diagrams are given in Fig. 4. By placing all the controls on one board (the vertical board) and most of the remainder of the unit on the horizontal board, front panel space requirements are minimized. This makes for an efficient, compact assembly. The boards are connected

TECHNICAL SPECIFICATIONS—OPTIMIZED EQUALIZER

Frequency Response: 10 to 80,000 Hz +1/−3 dB
Gain: 0 dB nominal
Distortion: Less than 0.02%, from 20 to 20,000 Hz at rated output
Rated Output: 0.5 V
S/N per IHF-A202: 82 dBA ref: 0.5 V
Maximum Input/Output: 9 V rms
Input Impedance: Approx. 100 kilohms in parallel with 390 pF
Output Impedance: Less than 600 ohms
Total controls: 13 bands per channel
Range:
Midrange: +3 to −12 dB nominal
Bass: −2 to +10 dB nominal
Midbass: ±8 dB nominal
Treble: ±10 dB nominal

...EQUALIZER



(A)

PARTS LIST

Horizontal Board

C1,C101—390-pF, 5% capacitor
C2,C32,C102,C123,C24,C124,C132, C203, C204,—10-µF, 25-V aluminum electrolytic
C3 through C22,C103 through
C122—0.0022-µF, 5% polyester film capacitor
C25,C125—0.001-µF, 5% polyester film capacitor
C28,C128—0.22-µF, 10% polyester film capacitor
C31,C131—0.01-µF, 10% polyester film capacitor
C206,C207—0.1-µF, +80/−20% ceramic disc capacitor
IC1 through IC7—RC4136 quad op amp
The following are 1/4-W, 5% carbon-film resistors unless otherwise noted:
R1,R101,R202 through R204—100 kilohms
R2,R102—8.2 kilohms
R3,R5,R103,R105—82 kilohms
R4,R104—2.7 kilohms
R6,R106—3.9 kilohms
R7,R107—120 kilohms
R8,R108—5.1 kilohms
R9,R109—160 kilohms
R10,R110—7.5 kilohms
R11,R111—240 kilohms
R12,R112—11 kilohms
R13,R113—330 kilohms
R14,R114—15 kilohms
R15,R115—470 kilohms
R16,R116—20 kilohms
R17,R117—620 kilohms
R18,R118—30 kilohms
R19,R119—910 kilohms
R20,R120—43 kilohms
R21,R121—1.3 megohms
R22,R122—56 kilohms
R23,R123—1.8 megohms
R54,R154—16.2 kilohms, 1% metal film
R55,R155—1.62 kilohms, 1% metal film
R56,R156—24.9 kilohms, 1% metal film
R57,R157—36 kilohms
R58,R158—3 kilohms
R64,R71,R164,R171—5.6 kilohms
R72,R172—560 ohms

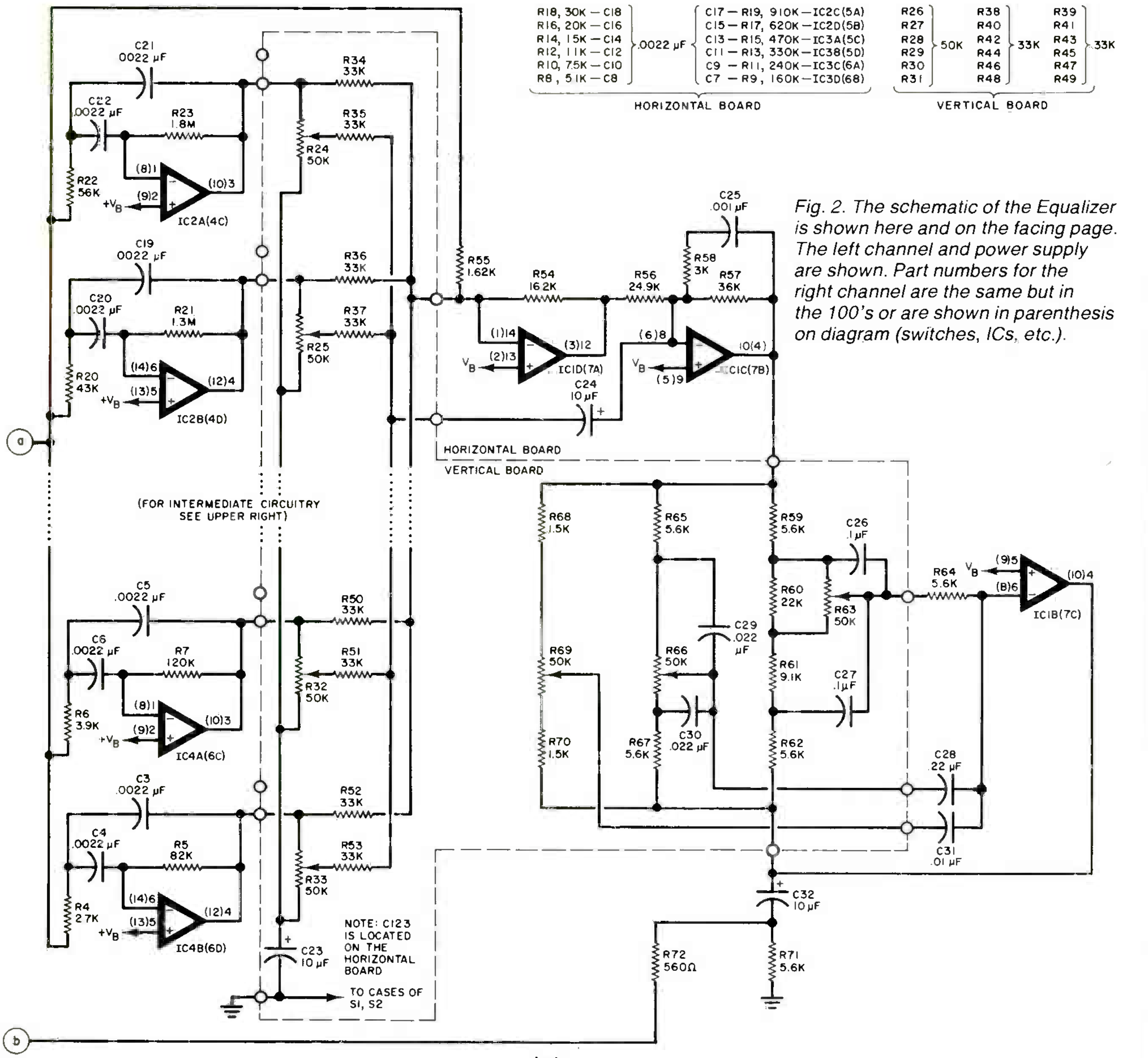


Fig. 2. The schematic of the Equalizer is shown here and on the facing page. The left channel and power supply are shown. Part numbers for the right channel are the same but in the 100's or are shown in parenthesis on diagram (switches, ICs, etc.).

(B)

Vertical Board

C23—10-µF, 25-V aluminum electrolytic
C26,C27,C126,C127—0.1-µF, 5% polyester film capacitor
C29,C30,C129,C130—0.022-µF, 5% polyester film capacitor
The following are ¼-W, 5% carbon-film resistors unless otherwise noted:
R24 through R33,R63,R66,R69,R124 through R133,R163,R166,R169—50-kilohm slide potentiometer
R34 through R53,R134 through R153—33 kilohms
R59,R62,R65,R67,R159,R162,R165,R167—5.6 kilohms
R60,R160—22 kilohms
R61,R161—9.1 kilohms
R68,R70,R168,R170—1.5 kilohms
S1,S2—Dpdt nonshorting switch

Power Supply

C201,C202—1000-µF, 35-V aluminum electrolytic
C205—0.1-µF, +80/−20% ceramic disc capacitor
D201 through D204—IN4002 (or equivalent)
R201—10-ohm, ¼-W, 5% resistor
J1 through J4, J101 through J104—Phono jack
T201—24-V, 170-mA wall-plug transformer (Dormeyer PS14201 or equivalent)

Misc.—No. 20 AWG bus wire (6′), ribbon cable (14 conductor, 7½″), angle bracket (#6-32 threaded, one side, 8), #6 × ⅜″ sheet metal screw (11), #6-32 × ¼″ machine screw (8), chassis, 16-pin DIP socket, 14-pin DIP socket.

Note: The following are available from Symmetric Sound Systems, 856 Lynn Rose Ct., Santa Rosa, CA 95404 (707-546-3895): complete Optimized Equalizer kit (EQ-4) with unfinished walnut end panels at $100; complete Optimized Analyzer kit (AN-1) at $60. Also available separately: horizontal and vertical pc boards for Equalizer (EQ-4PC) at $17.; Analyzer and interconnect pc boards (AN-1PC) at $13.; slide potentiometers #EQ-4SP, $.95 each. Quad op-amp IC #4136, $1.75 each. Set of IC's for the analyzer #AN-1IC, $6.00. Wall plug transformer #EQ-4PT, $7.50. Minimum order $10.00. All prices include shipping on prepaid orders in the U.S. Canadians add $4.00 shipping and handling. California residents add sales tax.

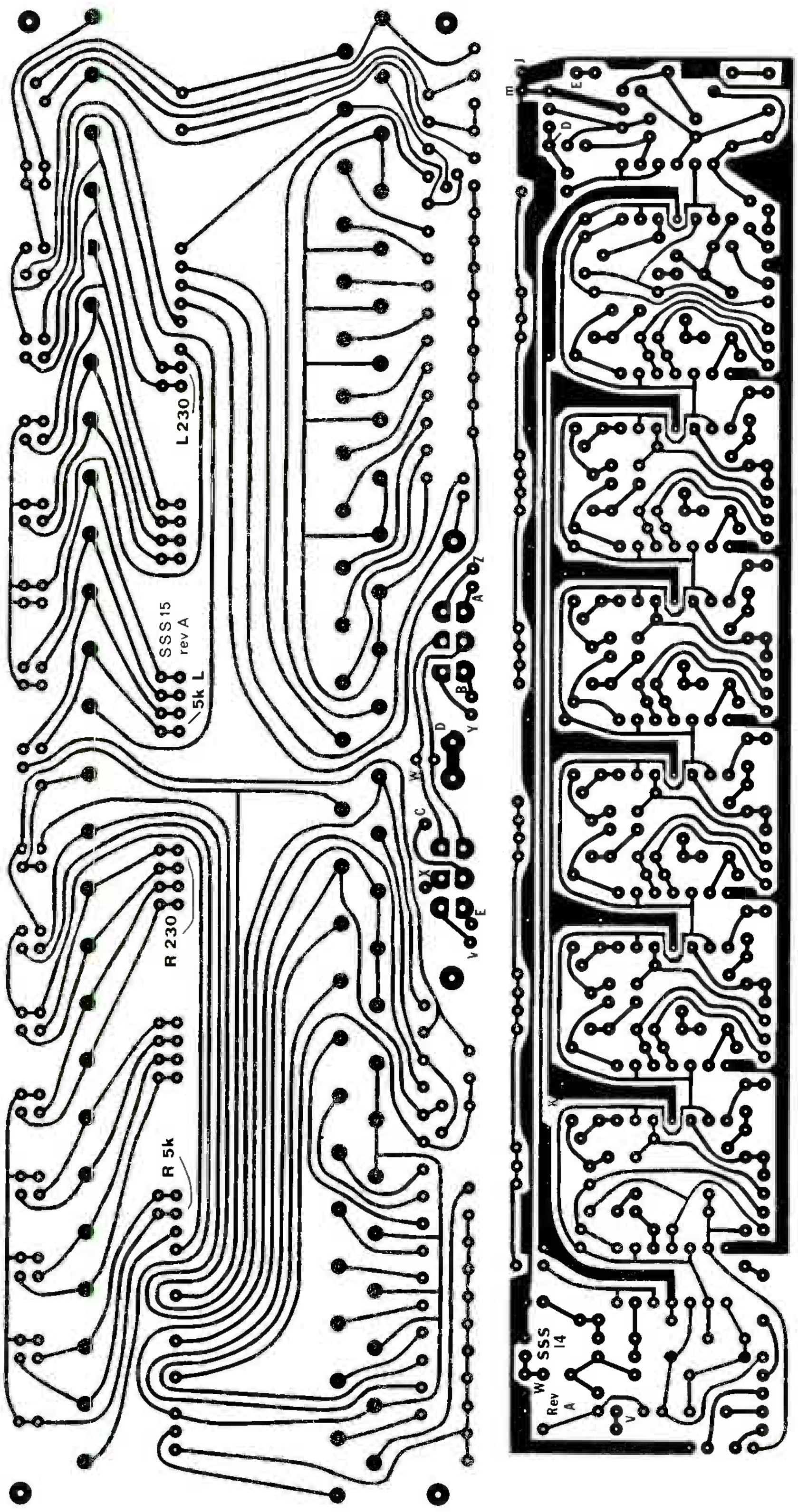


Fig. 3. Foil patterns for the Equalizer pc boards

together with #20-AWG bus wire between adjacent pads. The bus wire is stiff enough to make a rigid assembly of the boards, with easy access to both sides of boards for testing and experimenting.

Components should be soldered to the horizontal board first, in order of resistors, capacitors, jumpers, and ICs. Be careful to observe the index marking on the ICs and the polarity of the electrolytic capacitors. Next solder components to the vertical board—slide potentiometers first, then resistors, capacitors, and switches (observe the polarity on *C123*).

To connect the boards, push #20-AWG bus wire or solid uninsulated wire through the pads in the long line on the vertical board from the back side, and solder to the pads. Taper the length of these pieces of wire from 3/4" on one end to 3" on the other end. Starting on the long end, and with the copper-clad sides of both boards facing each other, push the leads through the matching pads on the horizontal board, working your way to the short end. Bend the horizontal board, and thus all the wires, until it is perpendicular to the vertical board and flush against it. Solder all the wires.

Wire the switches, jacks, and boards together according to the schematic (wires A through E, M, and V through Z). Wire the power supply on a terminal strip, and connect it to the horizontal board (wires J through L). A foil pattern for an interconnect board is given in Fig. 5. One 16- and one 14-pin DIP socket are wired to this board. The sockets are used to connect to the real-time analyzer, which will be covered in Part 2.

Because of the compactness of the pc-board assembly, many mechanical configurations are possible. In the prototype, the vertical pc board was attached to two pieces of walnut. The rear of an inverted "U" chassis was also attached to the walnut. The chassis provides marking for all the controls, switches, and jacks. Grounding the chassis to circuit ground shields the circuit from radio-frequency interference and electrostatic pick-up of 60 Hz and its harmonics.

Installation. Most component high-fidelity systems can accommodate signal processors, such as the Optimized Equalizer, through the tape-monitor loop. Connect the "tape out" or "tape record" output of your amplifier to the equalizer's input. Then connect the equalizer's output to the "tape in," "tape monitor," or "tape play" jacks of your amplifier. Switch the amplifier's tape monitor switch to "on" to enable the equalizer. The tape monitor function is replaced on the equalizer. Connect your tape deck to the equalizer as it had been connected to the amplifier.

Some amplifiers have separate tape source switches to enable you to play one source while recording another. In this case, you will have to use your tape source switch as your selector. Switch the selector switch to tape, so that the signal always passes through the equalizer.

Equalizer Adjustment. There are a number of different techniques available to adjust your equalizer; these vary in convenience, cost, and accuracy. Audiophiles with very good familiarity with live music can adjust the bands by ear to match their idea of the way the music should sound. A different technique is to use a test record, perhaps with the aid of a sound-level meter, to adjust the bands for flat response.

An easy way to adjust an equalizer is with a real-time analyzer. Although this can be a costly audio accessory, it's not in this case. The equalizer was designed to inherently contain much of the circuitry of the analyzer. In Part 2, we will describe the design, construction, and use of the analyzer.

With the high performance and build-it-yourself economies of the Optimized Equalizer/Analyzer, you can anticipate an impressive improvement in the sound of your system.

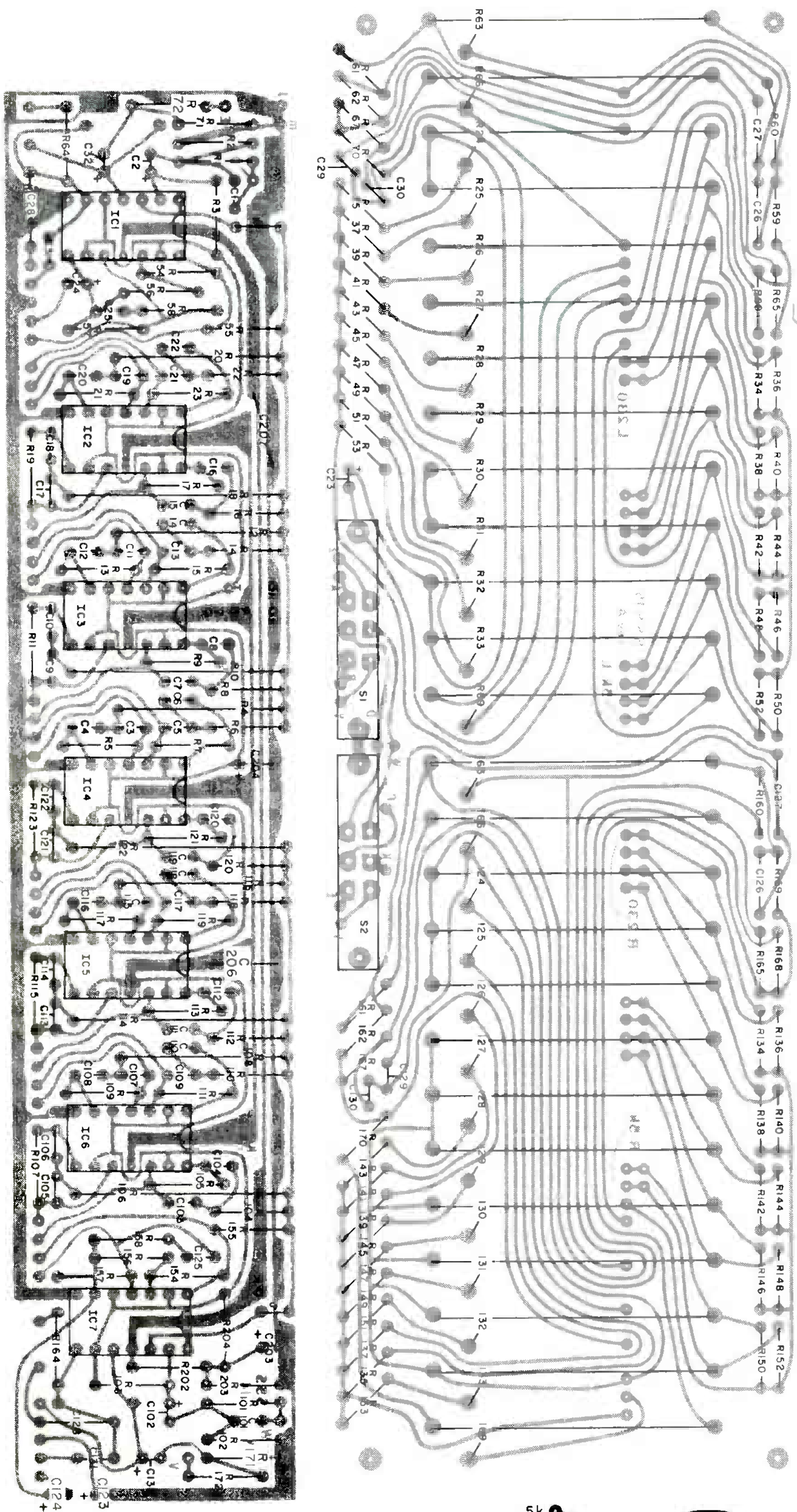


Fig. 4. Component layouts for the pc boards.

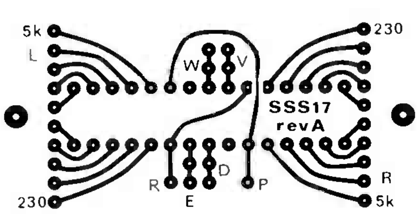
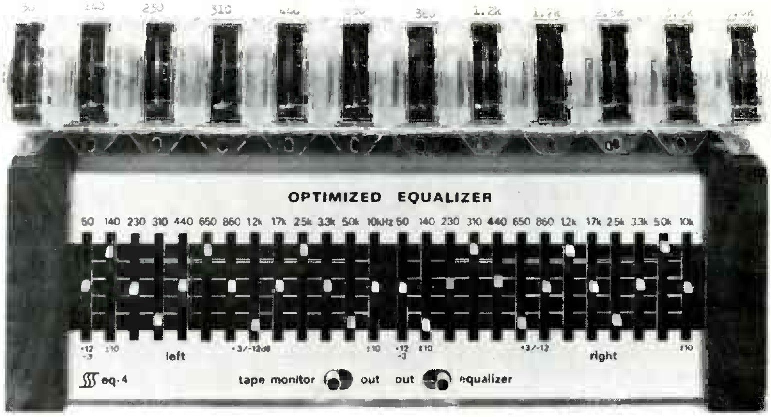


Fig. 5. Foil pattern for the connector board to the analyzer.



Part 2—An integral analyzer for accurately setting up the audio equalizer in Part 1

In the first part of this article, we presented a new kind of equalizer circuit that offers high performance at an economical cost. In this second part, we will describe a Flatness Analyzer, an accessory you use to rapidly and accurately adjust the equalizer. The details follow.

Circuit Operation. Figure 6A is a block diagram of the equalizer/analyzer combination (part of which is identical to Fig. 1). The analyzer plugs directly into the equalizer. Figure 6B is a block diagram of the equalization test procedure.

Here's how the Flatness Analyzer tests one channel (the right) of the Optimized Equalizer. Pink noise is applied to the right-channel input of the equalizer. The equalized output of the right channel is then fed through an amplifier and speakers into the room. From here, the microphone picks it up.

The signal is then amplified by the microphone preamp and applied to the left-channel input of the equalizer, as well as two filters in the analyzer. The outputs of these 12 filters drive simple biased-diode detectors and a bank of 12 meters to show the deviations from flatness. If the system response is flat, all meters will have equal deflections. The output of the left channel is grounded to prevent the amplified microphone signal from passing back out through the left speaker and perturbing the measurements or causing oscillations.

To test the left channel, the interconnecting plug is reversed and offset in its socket, and the above procedure is repeated with left and right channels reversed.

Figure 7 is the schematic of the analyzer. Integrated circuits *IC2* and *IC3* constitute a digital white-noise generator. The circuits in *IC3A* and *IC3B* form a square-wave oscillator with an output frequency of about 100 kHz. This clocks 18-stage shift register *IC2*, which keeps shifting the output of *IC3D*, the exclusive-OR function of the 14th and 17th stages of the shift register. These taps (14 and 17) are chosen so that the register outputs random ones and zeroes; it only repeats after going through all but one of the 2^{17} possible states. This is called a pseudo-random sequence generator (since it repeats, it isn't truly random). Its output spectrum is very white if you pass the digital output through a low-pass filter. Integrated circuit *IC3C* and its associated components ensure that *IC2* cannot get locked up in the all-zeroes state.

Components *R29* through *R32* and *C20* through *C23* are a pinking filter. The gain vs. frequency of this network falls off at 3 dB per octave on the average, about half as fast as a single RC filter. The noise is amplified by *IC4B* and rolled off at high frequencies to compensate for the increased gain of the testing channel at high frequencies (due to the reduction in input attenuation as explained previously).

The output is ac coupled with *C25*, and its level is controlled with *R32*. The level could be controlled with the stereo's master volume control, but having a control on the analyzer is a real convenience. The signal from the level control now passes to the channel under test.

The stereo speakers convert the noise to sound, which comes back for analysis through the microphone, *MIC1*. A small electret is used here, which has typical accuracy of ±1 dB with help from the preamp, *IC1B*. This stage provides a gain of 27, and *C33* and *R44* tame an upper-midrange peak that is common to most inexpensive electret microphones.

The microphone signal is further amplified in *IC1A* and passed through *R48* and *C32* to the testing channel's filters. Resistor *R48* is provided as protection in case the input to the equalizer is not disconnected.

Besides the ten filters in the equalizer, *IC1C* and *IC1D* filter the frequencies around 40 to 100 Hz and 140 Hz to help adjust the bottom bands of the equalizer.

The filtered signals from the equalizer are ac-coupled by *C1* through *C10* (to remove the dc components) and detected by *D3* through *D12*. To minimize the errors due to the *on* voltage of these diodes, a small current is passed through *D15* and buffered by *IC4A* to offset the positive side of the meters by approximately the diode *on* voltage. As a result, the meters respond to the average value of the noise level, which is a much more accurate parameter than the peak response frequently used in such an analyzer.

The outputs of *IC1C* and *IC1D* are passed through RC filters *R18*, *R19*, *R24*, and *R25* and *C12* and

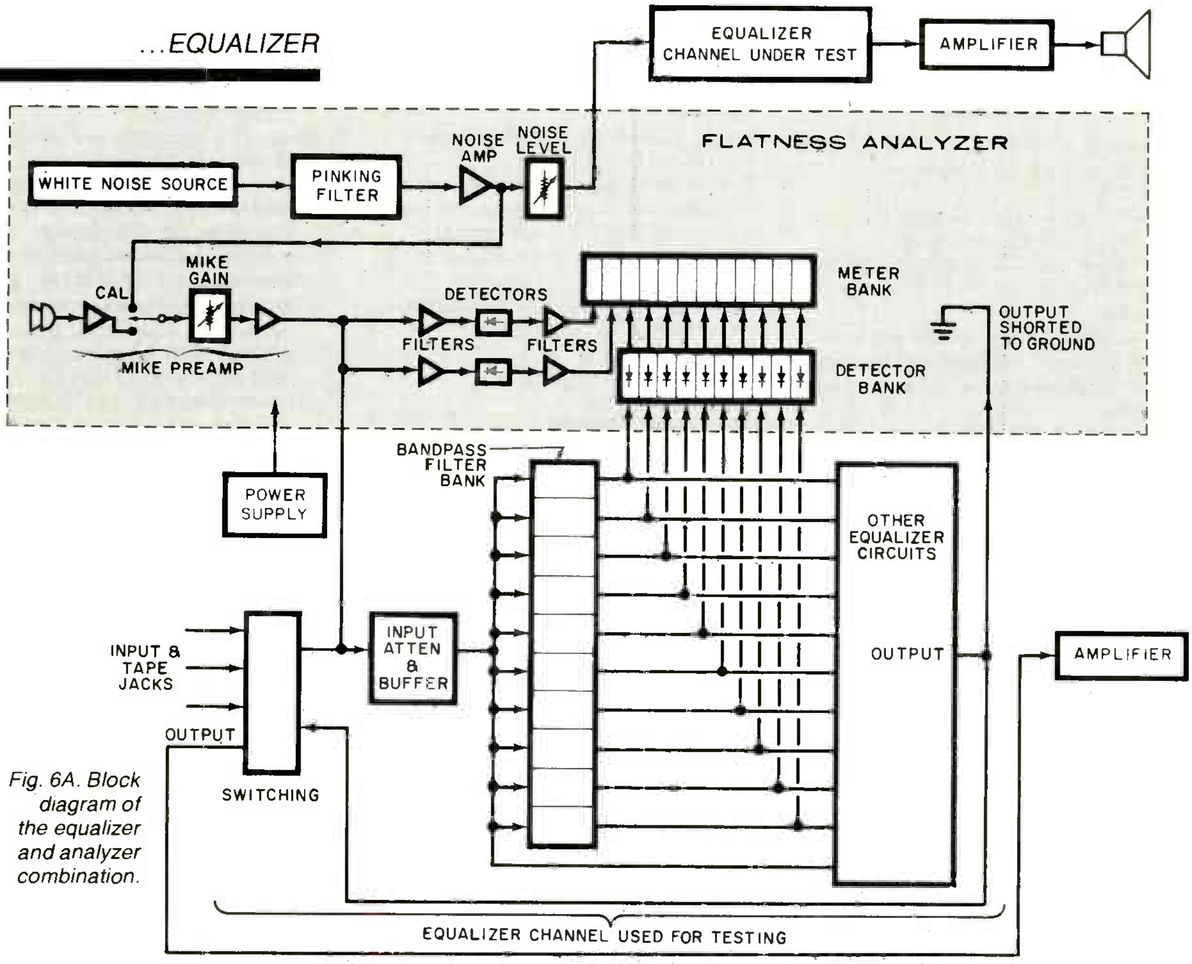


Fig. 6A. Block diagram of the equalizer and analyzer combination.

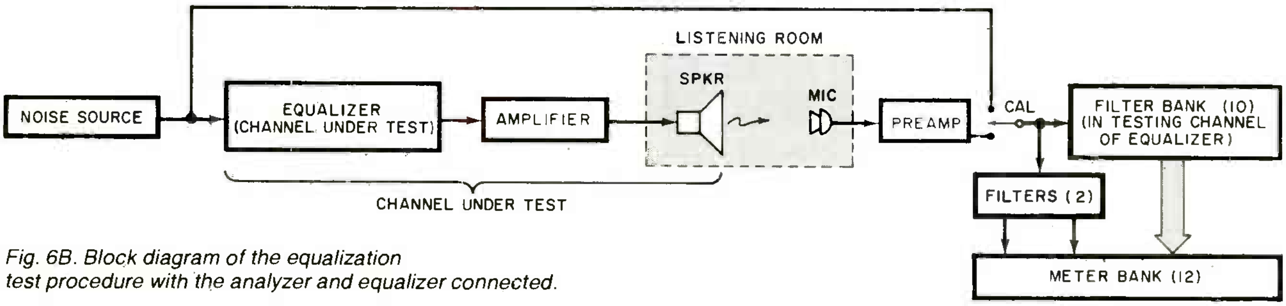


Fig. 6B. Block diagram of the equalization test procedure with the analyzer and equalizer connected.

C16 to reduce the fluctuations of the bottom band meters and to reduce the gain, in order to make up for the effect of the attenuator at the input of the testing channel on the ten other bands.

Resistor *R17* and diode *D16* provide a +9-V supply for the microphone and white-noise generator, and also supply bias for *IC1*.

Switch *S1* allows the response of the analyzer to be observed without the speaker-microphone link, to see how flat it is. This calibration permits adjustments to be made that will provide compensation for component tolerance errors, especially in the meter sensitivities (±1 dB) and pinking-filter components.

Construction. Figure 8 is the foil pattern for the analyzer pc board, and Fig. 9 is the foil pattern for the interconnection pc board. A component-placement diagram for the analyzer is given in Fig. 10.

Solder all components to the board. except the slide potentiometers. Don't forget the two jumpers. Carefully orient the ICs, diodes, and electrolytic capacitors according to pin number or polarity. Integrated circuits *IC2* and *IC3* are CMOS, and thus static-sensitive; so don't remove them from their conductive packaging until you are ready to install them. Then discharge yourself, your soldering iron, and the pc traces to ground.

Connect the microphone element, *MIC1*, to the shielded pair cord and solder the cord to the appropriate pc board holes—red wire for positive, white for signal, and shield for ground. Connect a stiff piece of wire over the shield and solder to the two holes right behind it to act as a strain relief.

The connection to the equalizer is through a DIP plug. Cut a standard DIP-plug to DIP-plug 16-wire cable in half and solder the unterminated wires to the appropriate pads of the DIP pattern on your board (the wires will alternate sides). Or just install a whole DIP-plug right in the pattern. Pass the wires across *R35*'s position, and then mount *R35*

PARTS LIST

C1 through C10,C12,C13,C16,C17,C24, C30, C32—10-μF, 25-V aluminum electrolytic
C11,C28—0.1-μF 50-V ceramic disc
C29—10-μF, 25-volt electrolytic
C14—0.0047-μF, 5% polyester capacitor
C15,C18,C19,C25—0.1-μF, 5% polyester apacitor
C20—0.022-μF, 5% polyester capacitor
C21—0.0068-μF, 5% polyester capacitor
C22,C26,C34—0.0022-μF, 5% polyester apacitor
C23—0.001-μF, 5% polyester capacitor
C27—24-pF, 5% capacitor
C31—not used
C33—39-pF ceramic disc capacitor
D1 through D15—1N4148 diode
D16—9.1-V zener (1N5239 or 1N960)
IC1—RC4136 quad op amp
IC2—CD4006 18-stage shift register
IC3—CD4070 quad ex-OR gate
IC4—LM358 dual op amp
M1-M12—200-μA 1-kilohm edgewise meter
MIC1—Electret microphone element
P1—16-pin DIP plug
The following are ¼-W, 5% carbon-film resistors unless otherwise noted:
R1 through R10,R40—470 ohms
R11,R39,R46,R49—1.5 megohms
R12 through R16—Not used
R17,R20,R26,R28,R48—2.2 kilohms
R18,R19,R50—8.2 kilohms
R21—300 kilohms
R22,R34,R43—3.9 kilohms
R23—39 kilohms
R24,R25—11 kilohms
R27—62 kilohms
R29—270 kilohms
R30,R37,R38—150 kilohms
R31,R41—47 kilohms
R32,R33,R36,R44,R47—15 kilohms
R35,R45—50-kilohm potentiometer
R42—100 kilohms
S1—Spst slide switch
Misc.—Pc board for analyzer, press-on rubber feet (4), 16-wire ribbon cable, jumper wires, etc.

Note: The following are available from Symmetric Sound Systems, 856 Lynn Rose Ct., Santa Rosa, CA 95404 (707-546-3895): complete Optimized Equalizer kit (EQ-4) with unfinished walnut end panels at $100; complete Analyzer kit (AN-1) at $60. Also available separately: horizontal and vertical pc boards for Equalizer (EQ-4PC) at $17; analyzer and interconnect pc boards (AN-1PC) at $13; slide potentiometers (#EQ-4SP) at $.95 each; quad op amp IC #4136 at $1.75 each; set of ICs for analyzer (#AN-1IC) at $6.00. Wall-plug transformer (#EQ-4PT) at $7.50. Minimum order $10.00. All prices include shipping on prepaid orders in the U.S. Canadians add $4.00 shipping and handling. California residents, add sales tax.

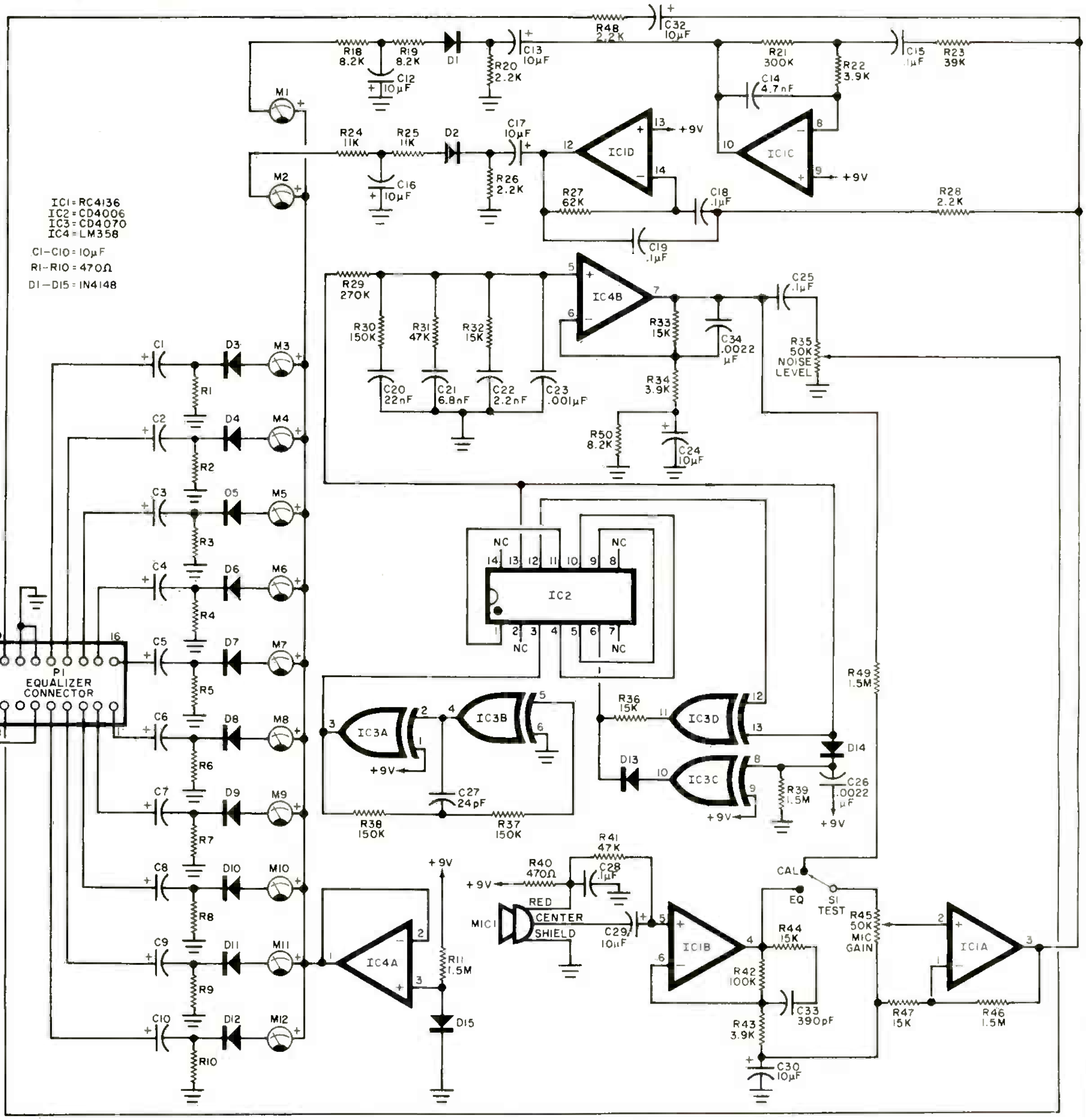


Fig. 7. Schematic of the circuit in the analyzer.

over them as a strain relief. Also mount the other slide potentiometer in its proper location.

In the prototype, the bases of the edgewise meters were glued to the pc board and wired with short jumpers. It is a good idea to use stick-on rubber feet to prevent shorting to the chassis of the equalizer or scratching it during use.

Since the analyzer is a sophisticated accessory and not for display, to save effort and expense, you need not put it in a fancy chassis.

Adjustment and Use. Using the Optimized Equalizer and the Analyzer combination is easy because all the information you need is right in front of you at all times.

With the power off, connect the equalizer outputs to your stereo. Do not connect the equalizer inputs to anything. Connect the analyzer to the equalizer and turn the slide pots to OFF. Set the TEST switch to EQ and the EQUALIZER switch to IN. Set all the equalizer controls to 0 dB. Place the measuring microphone at your favorite listening location. Apply power to the equalizer/analyzer and your stereo.

Adjust the mike gain upwards until there is significant deflection of some of the meters. This point shows how large the room noise is. Back down on the gain until there is no more than 10% deflection on any meter. Now slowly advance your noise-level control and stereo-volume control until you are getting an average of over 70% of full deflection on your meters. Depending on the ambient levels in your room, this is likely to be relatively loud.

Adjust the bands of the channel

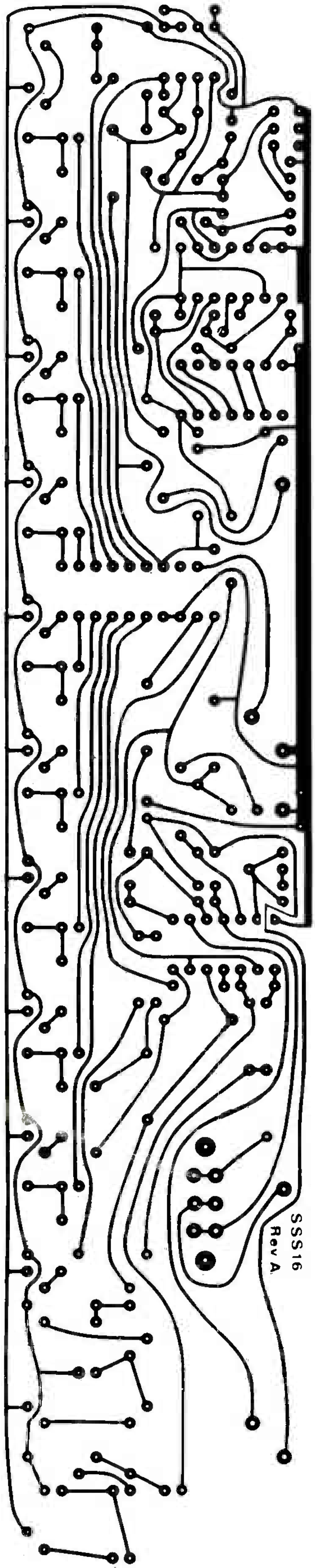
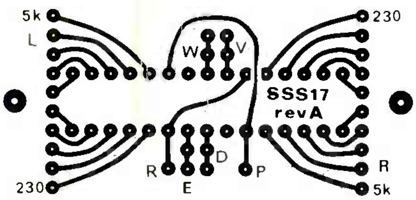


Fig. 8. Foil pattern for the analyzer pc board.

Fig. 9. Foil pattern for connector board to equalizer.



WHAT'S WRONG WITH THE FLATNESS ANALYZER?

According to traditional thinking, there is quite a bit wrong with the analyzer. First, its output devices are meters. Unlike bargraph LEDs, meters cannot be easily read from far away. They are also slow and cannot show the dynamics of music well, due to mechanical inertia. But we are not building a music analyzer; we are building a flatness analyzer. It is designed to be placed next to the equalizer so that the controls can be adjusted while watching the meters. Only the microphone needs to be usable from a distance, and it comes with a long cord.

The slowness of the meters is in fact desirable because it evens out the flucututations in the noise levels. Actually the meters act as filters without extra components to do that filtering (except in the lowest bands, where the fluctuations are slow enough that additional filtering is desirable). However, the most important reason for using meters is that they give better resolution and "feel" for that signal level. Their fluctuations can be averaged visually much faster and more accurately than LEDs, especially in designs with 2.5 dB/step LED resolution.

Next, the Flatness Analyzer will not analyze music. Since the signal levels in the testing channel must be adjusted to drive the meters appropriately, this channel cannot be used to process music. This precludes the fascinating light-shows of some analyzers, but it is necessary for the economy of reusing the equalizer's filters. We're out for performance here, not a show.

Finally, the Flatness Analyzer does not have a top-end meter to help adjust the equalizer's 10-kHz control. One is easily added, but it is not worthwhile for a number of reasons. First, a microphone that has even marginally predictable response in the top octave will cost more than the entire equalizer/analyzer combination; using it would produce the worst kind of diminishing return on your investment. Secondly, recorded music in the top octave is notoriously variable in relative level due to varying microphone techniques and engineer's tastes. Finally, all speakers, microphones, musical instruments and ears are extremely directional at high frequencies. Unlike the situation at lower frequencies where most of the signal you equalize has been reflected from room boundaries; at high frequencies, you would be equalizing the direct signal from the loudspeakers. The desired ratio of this signal level to the reverberantly measured levels at other frequencies is not well controlled.

Thus, no one equalizes for a flat high end. Rather, they try to accomplish some smooth roll-off. The author strongly recommends setting this band by ear and resetting it (and perhaps the top two or three narrow bands slightly) according to the particular piece of music being played. ◇

under test by reducing the level of the band corresponding to the meter with the highest deflection. After you have adjusted a few bands this way, continue by moving the bands either up or down to come as close as possible to uniform deflection of all bands. Adjust the noise level as necessary to keep the average deflection at about 70%.

The noise source, being pseudorandom, audibly repeats every 1.5 seconds, and the meters will show this periodicity. When fine tuning, visually average the motion during this interval. When the result is close to flat, switch the TEST switch to CAL, adjust the MIKE GAIN for 70% average deflection, and observe the errors of the test system. Then switch back to EQ and fine-tune the equalizer to match the CAL response, which will be slightly different than truly flat. Then turn everything off, switch the connection from the analyzer to the equalizer, and repeat for the other channel. Then remove the analyzer and connect the equalizer normally.

Hints on Equalizing. Over the long term, the sound from your system will be exceptionally smooth and accurate. But be wary of short-term reactions. After listening so long to the errors that your system and room make, your mind gets accustomed to these distortions of reality and expects them. Thus, any change toward either more or less realistic sound is initially perceived as unnatural. Also, the equalization technique given will reduce the overall level somewhat. Unless you compensate by increasing the volume control setting, you are likely to initially consider the sound to be poorer when equalized.

But give yourself about 15 minutes with your de-resonated stereo and then switch to unequalized. You will notice a hollow, boxy sound that you missed before because you were so used to it. Now simply switch back to equalized sound and you will find some really fine listening. ◇

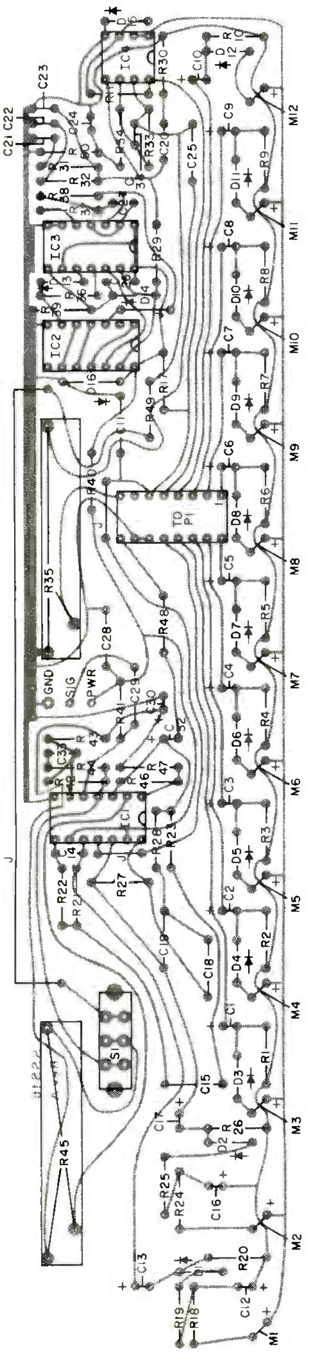
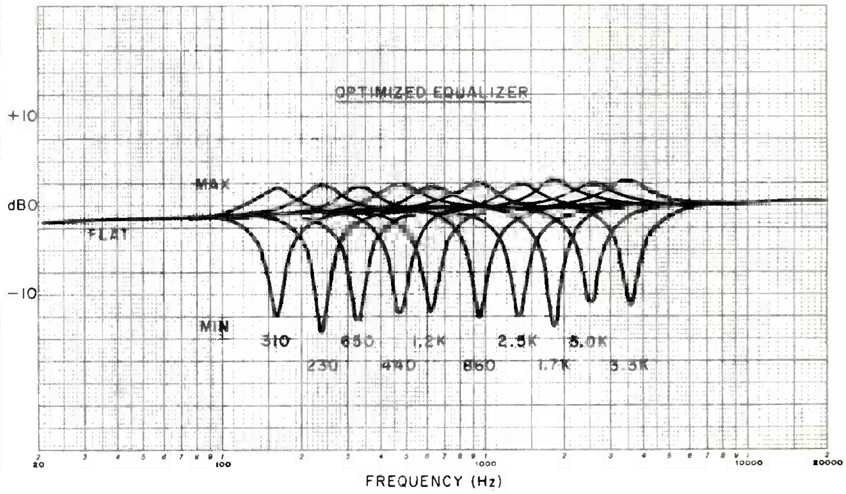


Fig. 10. Component layout on analyzer pc board.

TESTING THE EQUALIZER/ANALYZER



Boost and attenuation effects of the ten filter points.

The concept of having the analyzer use some of the circuits in the equalizer is an interesting one and makes for economy in achieving both analysis and equalization. In addition, the recognition that a limited amount of boost and much more "cut," are required for room/speaker equalization is something we have not seen discussed before. It differs sharply from conventional practice, which provides symmetrical (more or less) boost.

The measured characteristics of the various filters in the analyzer and equalizer confirm the statements made in the article. It is interesting to note that using only the extreme controls (40 Hz and 10 kHz) one can simulate quite well the effect of a conventional tone control system. The distortion of the equalizer was negligible and well within the stated limits. The noise (which was below our measurement limit) appeared to meet the claimed performance comfortably.

Following the instructions, we used the system to equalize a stereo music system. It would be helpful if the meters could be marked to match the corresponding slider controls; we had to use some "cut and try" methods in doing the qualization, but the end result seemed to be reasonable. According to a spectrum analysis of the "pink noise" from the system, it is not quiet pink. However, since one uses the meters to read the noise spectrum as well as the qualized acoustic spectrum, this error is of no importance. —*Julian Hirsch*

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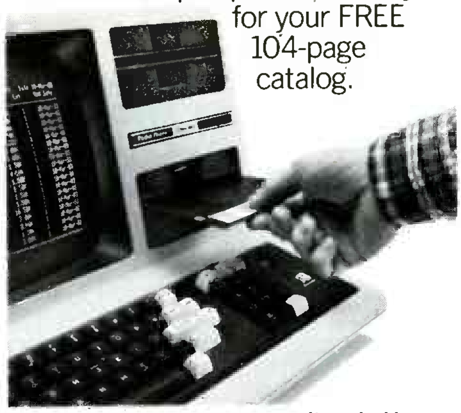

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BY TOM FOX

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Measures from −13° to +185° F with 1° accuracy and 0.1° resolution

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With some simple circuit modifications, Lidith can perform other functions, such as reading the temperature in °C and displaying both indoor and outdoor temperatures.

Circuit Operation. Shown in Fig. 1 is the schematic diagram of Lidith. (See Box for details on sensors.) Resistor *R11* is the series voltage dropper for the 6.8-volt zener diode in the temperature transducer (*IC2*). The *R12/C6* network provides additional stability if the transducer is used as a remote sensor. Resistors *R9* and *R10* form a precision voltage divider to insure that the proper proportion of the transducer's output voltage goes to the digital panel meter (DPM) circuitry.

Several points should be noted about the *IC2* circuit. At room temperature (77°F), the transducer's output from pins 1 and 2 to pin 3 is nominally 2.98 volts and increases by 10 mV for every 1°C or 1.8°F increase in temperature. This potential is measured with respect to +9 volts, not ground. This means that at 77°F, pins 1 and 2 are at −2.98 volts, with respect to +9 volts.

The heart of the DPM is the Intersil ICL7106 single-chip 3½-digit MOS A/D (analog-to-digital) converter that drives the LCD. The 7106 uses dual-slope conversion, in which nonlinearities tend to cancel out. Therefore, the circuit does not require extremely accurate or stable (and expensive) components. Also, as long as it remains unchanged for a single conversion cycle, the clock frequency does not have to be precise or extremely stable. The only real requirement is a stable current reference.

In addition to ease of use and relatively low cost, the 7106 has several other features that make it ideal for use in Lidith. Since the thermometer employs CMOS circuitry, it consumes little current (about 0.8 mA). It has true autozeroing, will directly drive LCD displays, and has a guaranteed ±1-count accuracy over its entire ±2000-count range.

The RC network for the 7106's inter-

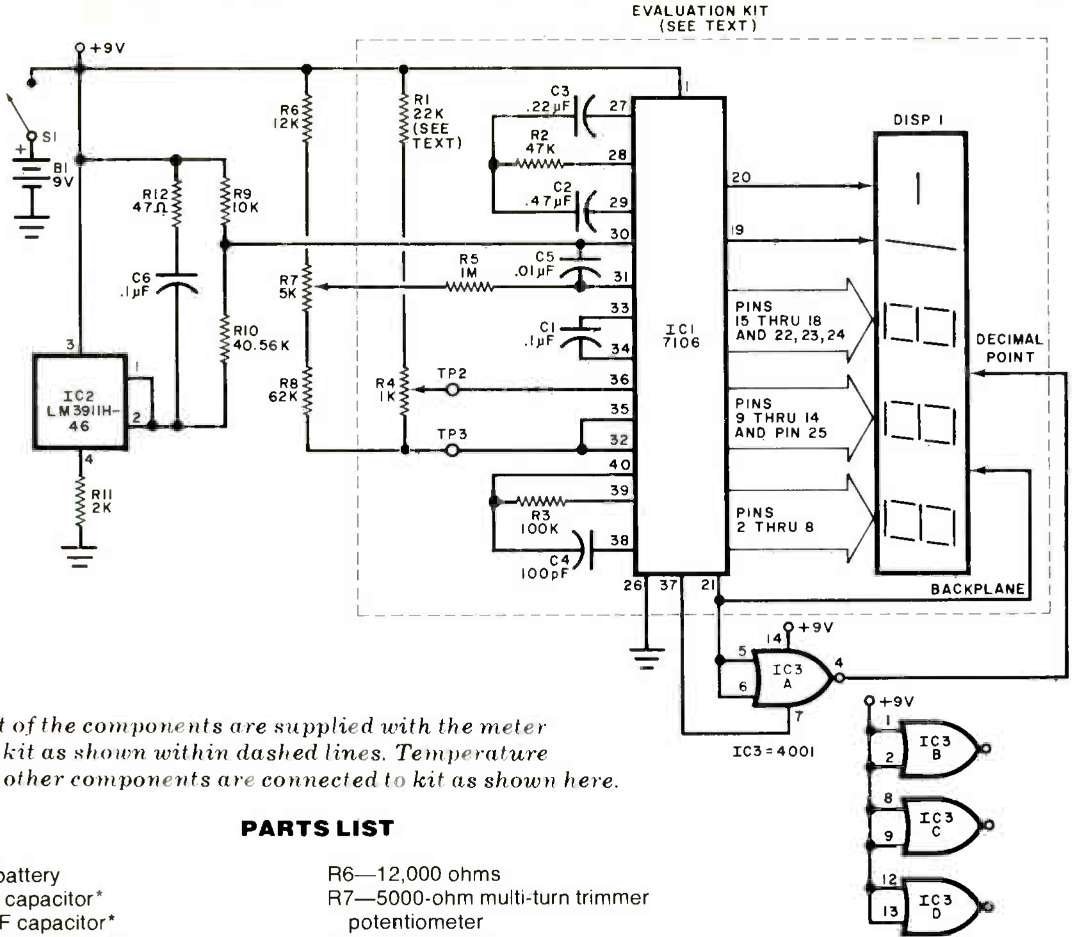


Fig. 1. Most of the components are supplied with the meter evaluation kit as shown within dashed lines. Temperature sensor and other components are connected to kit as shown here.

PARTS LIST

B1—9-volt battery
C1—0.1-µF capacitor*
C2—0.47-µF capacitor*
C3—0.22-µF capacitor*
C4—100-pF capacitor*
C5—0.01-µF capacitor*
C6—0.1-µF capacitor
DISP1—3½-digit LCD display*
IC1—7106 3½-digit A/D converter (Intersil)
IC2—LM3911H-46 temperature sensor (National)
IC3—4001 quad 2-input NOR gate
The following are 5%, ¼-watt resistors unless otherwise specified:
R1—22,000 ohms
R2—47,000 ohms*
R3—100,000 ohms*
R4—1000-ohm trimmer potentiometer*
R5—1 megohm*
R6—12,000 ohms
R7—5000-ohm multi-turn trimmer potentiometer
R8—62,000 ohms
R9—10,000 ohms, 1%
R10—40,560 ohms, 1%
R11—2000 ohms
R12—47 ohms, 10%
Misc.—Battery holder; IC socket; three-conductor flexible cable; 3/16" to ¼" ID thin-wall brass or copper tubing; insulated tubing; E-POX-E ribbon; acrylic spray; plastic case; ⅛"-thick clear plastic sheet; black spray paint; glue; machine hardware; etc.
*These items are supplied in the 7106EV Intersil Single Chip Panel Meter Evaluation Kit available for $34.95 plus 5% shipping & handling from Jameco, 1355 Shoreway Rd., Belmont, CA 94002.

Note: The following are available from Magicland, 4380 S. Gordon, Fremont, MI 49412: Kit containing one LM3911H-46, R9, and R10 for $9.95 postpaid (request #ST2RB for conventional kit, #CT2RB for Celsius version). Also available separately: LM3911H-46 temperature sensor (with data sheet) for $6.50; matched pair of LM3911H-46s (±1° C or better) for $20.00; R9 and R10 for $1.75 each.

nal oscillator is made up of *R3* and *C4*. With the values shown, oscillator frequency is about 48 kHz. Capacitor *C3* and resistor *R2* are the integrating components, while *C1* is the reference capacitor and *C2* is the auto-zero capacitor. Low-pass RC filter *R5/C5* is used for improved noise rejection.

A stable 2.8-volt reference potential between pin 1 (V+) and pin 32 (COMMON) is provided by the 7106. Resistors *R1* and *R4* form an adjustable voltage-divider network that applies a suitable proportion of this reference voltage to pin 36 (REF HI) and pin 35 (REF LO). Adjustment of *R4* is made for a potential of 0.110 volt (110 mV) between REF HI and REF LO. In Lidith, *R4* is basically a scale-adjust trimmer potentiometer.

Another adjustable voltage-divider that uses the 7106's 2.8-volt reference is made up of *R6*, *R7*, and *R8*. Notice that temperature-adjust trimmer *R7*'s wiper is connected through filter resistor *R5* to pin 31 (IN HI) of the 7106.

Once the thermometer is calibrated, with *R7* at a fixed position, IN HI is at a fixed voltage. For the DPM to display 00.0, its IN LO (connected to the transducer's voltage-divider network) must be exactly equal to its IN HI point. Thus, after calibration, the voltage at *R7*'s wiper must be identical to that coming from the transducer's *R9/R10* divider network (and connected to IN LO) when the transducer's temperature is at 0°. We can conclude, then, that *R7* can be viewed as a 0° trimmer pot. However, since 0° F is not easy to achieve, *R7* will actually be set for a display of 32.1 when the transducer is immersed in ice water.

As the transducer's temperature rises, its output at pins 1 and 2 becomes more negative, with respect to +9 volts. This more-negative potential is felt at the 7106's IN LO input. When IN LO becomes more negative, with respect to IN HI (which is set at a constant voltage after calibration), the 7106 senses this as a positive voltage at its input, since IN HI is now more positive, or less negative, than IN LO. Therefore, the DPM displays a positive number.

When the transducer's temperature goes below 0°, IN LO is less negative than IN HI and the DPM indicates a negative temperature.

The 7106 directly powers all segments of the LCD. Pin 21 goes to the display's backplane, while the frontplane segments connect to pins 2 through 25, excluding pin 21, which connects to the decimal point between the units and tenths decades in the display. Between the decimal point and pin 21 is a CMOS inverter that provides the proper ac voltage with an insignificant dc offset. It may seem wasteful to use an entire 4001 for this trivial task when a single MOS transistor would do the same job, but a 4001 is less expensive and more readily available.

Construction. Unless you can obtain a suitable 3½-digit LCD at reasonable cost, we strongly recommend Intersil's ICL7106EV/KIT Single Chip Panel Meter Evaluation Kit. It is available from Jameco (see Parts List) and other Intersil distributors. If you are set on building your thermometer from scratch instead, follow Fig. 1 and the pin configuration guide for the LCD you buy.

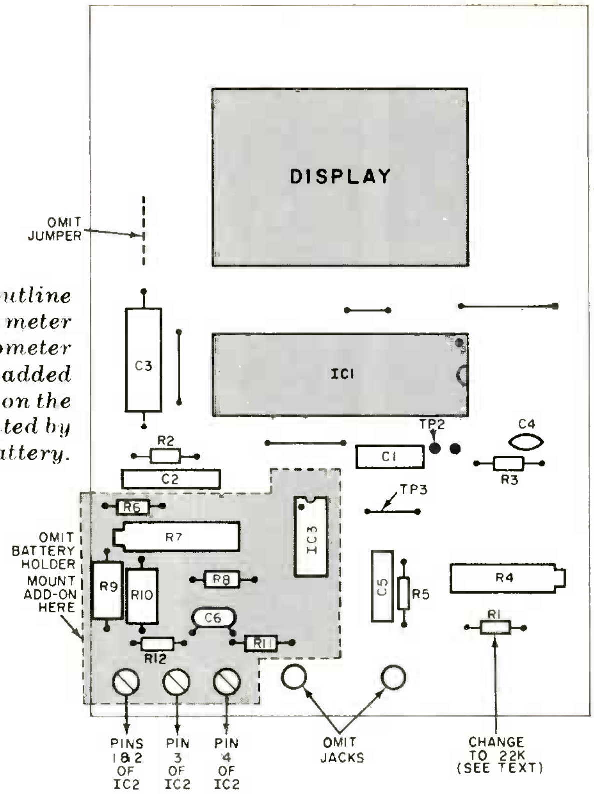


Fig. 2. The main outline here is that of the meter evaluation kit. Thermometer components can be added to the "open" area on the kit board created by taking off the battery.

Except for the remote sensing transducer, all thermometer components mount on the Evaluation Kit's circuit board. Build the Kit following the instructions supplied with it. Then, referring to Fig. 2, replace *R1* supplied with the Kit with a 22,000-ohm 5% (or better) tolerance carbon or metal-film resistor. (If you can adjust *R4* for 0.115 volt or more between *TP2* and *TP3*, *R1* need not be changed.) Eliminate the battery holder, specified jumper, and banana jacks. Drill holes for and mount the extra circuitry as shown. Refer back to Fig. 1 and interconnect all on-board components.

A 1" to 2" (25.4- to 50.8-mm) length of 3/16" to ¼" (4.8- to 6.4-mm) inner-diameter thin-walled brass or copper tubing should be used as a heat sink for the transducer if you plan to measure air temperatures. If you plan to use Lidith primarily for taking body and liquid temperatures, you can omit the tubing. Use a length of flexible three-conductor cable to interconnect transducer and circuit assembly. The cable can be up to 50' (15.2 m) long with no problems.

Referring to Fig. 3, slip the metal tubing onto the cable as shown. Then remove about 1" of the cable's outer jacket and prepare the ends of the conductors. Slip a length of plastic tubing over each

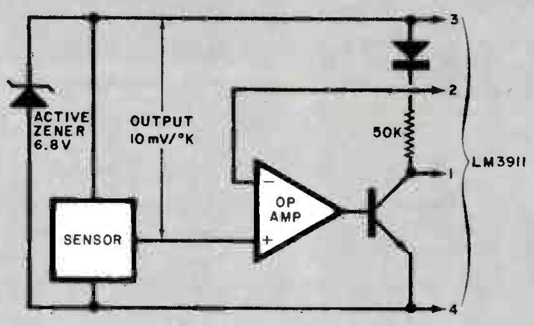
TEMPERATURE SENSOR SUPPLIERS

There are a number of manufacturers who produce temperature sensors suitable for use with Lidith. The following is a list of a few such manufacturers, followed by brief descriptions of the suitable sensors.

Precision Monolithics Inc. (1500 Space Park Dr., Santa Clara, CA 95050) produces Ultra-Matched Monolithic Dual Transistors, Series MAT-01, which, with suitable amplification, can be used in an electronic thermometer. For details, consult the company's application note No. AN-12 titled "Temperature Measurement Method Based on Matched Transistor Pair Requires No Reference."

Analog Devices (Rte. 1, Industrial Park, P.O. Box 280, Norwood, MA 02062) has recently released the AD590 Two-Terminal Temperature Transducer. It produces an output current proportional to the absolute temperature. At room temperature (77° F or 25° C), a 298.2-μA output is available. For every 1° C rise or fall, current increases or decreases by 1 μA. Premium model AD590M has a guaranteed maximum calibration error of ±0.5° C at 25° C. If you prefer to deal with voltages instead of currents, simply add a precision resistor in series with the transducer.

National Semiconductor Corp. (2900 Semiconductor Dr., Santa Clara, CA 95051) produces the LM3911 IC temperature transducer specified in Lidith's Parts List. As shown in the diagram in this box, the transducer includes a built-in operational amplifier, internal zener diode to provide voltage regulation, and output transistor whose collector can be returned to a potential as great as 36 volts.
turned to a potential as high as 36 volts.



There are undoubtedly other semiconductor manufacturers who make sensors and transducers similar to those mentioned above, and this is not intended to be a complete list. ◇

conductor. Using a heat sink between transducer and tie points, solder the conductors of the cable to the leads on the transducer. Then spray several coats of plastic insulation (such as GC's Koloid K-29 or Clear Acrylic Plastic) over the connections and exposed wires. Alternatively, dip the entire transducer assembly in GC Liquid Tape. When the coating dries, push the plastic tubing down until it contacts the transducer's body and covers all bare wires.

Clean the transducer and metal tubing with fine steel wool or sandpaper. Referring to Fig. 4, solder the transducer to the tube, taking care to be sparing with the heat.

Finally, use epoxy putty to make a waterproof probe out of the transducer assembly. Prepare the putty according to directions and then wet your hands and form a rough cylinder around the transducer assembly. Do not be concerned if your work appears messy. Just make sure the transducer and connections are completely sealed. With damp hands, roll the rough cylinder between your hands until it is smooth and nearly perfectly cylindrical and has a blunt cone-shaped tip.

Mount the thermometer circuit inside a housing large enough to accommodate it and its battery.

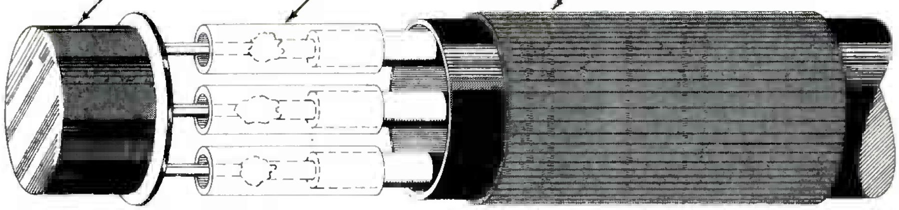


Fig. 3. Temperature probe construction. Make sure all soldered connections are well insulated. Thin metal tubing is optional.

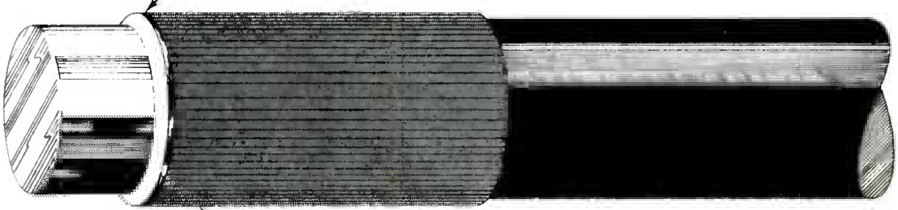


Fig. 4. Solder the optional heat sink to the heat sensor. Then use epoxy putty to form a waterproof probe out of the transducer assembly.

Calibration. If possible, the following reference-voltage adjustment should be performed with the aid of a digital multimeter. However, a good-quality analog voltmeter can be used if its input impedance is 1 megohm or greater. If you have a laboratory thermometer, you can do away with the need for a meter altogether, but calibration will take considerably more time. (More about this later.)

Turn on the power and let the thermometer warm up for at least 2 minutes. Then, with the meter set to its lowest range, connect the negative prod to *TP3* (actually a jumper) and positive prod to *TP2*. Referring to Fig. 2, carefully adjust *R4* for a reading of 0.110 volt.

To calibrate the thermometer, you will need a plastic bucket filled about three-quarters full with compact clean snow, ice chips, or ice cubes. Pour in enough cold water to nearly fill the bucket. Place the transducer probe in the center of the ice/water mixture and wait a few minutes until the LCD stabilizes at some number.

Vigorously stir the ice mixture and adjust *R7* for a display of 32.1. This display figure is more desirable than the usual 32.0 because you will most likely be performing calibration in a warm room where ice in water will be melting. In any event, what you are really measuring is the temperature of the *water*, which will not be exactly 32° F. If Lidith is calibrated exactly as described above, there are only two possible sources of error left—the transducer's slope and linearity errors. Fortunately, the transducer specified is almost perfectly linear. According to the conversion specifications, the linearity of the LM3911 is typically less than ±0.05%. The only possible significant error left, then, is a slight slope error. With a laboratory thermometer and some patience, even this error can be removed.

Photo showing back of meter evaluation kit board after extra holes have been drilled and components for temperature sensor have been added.

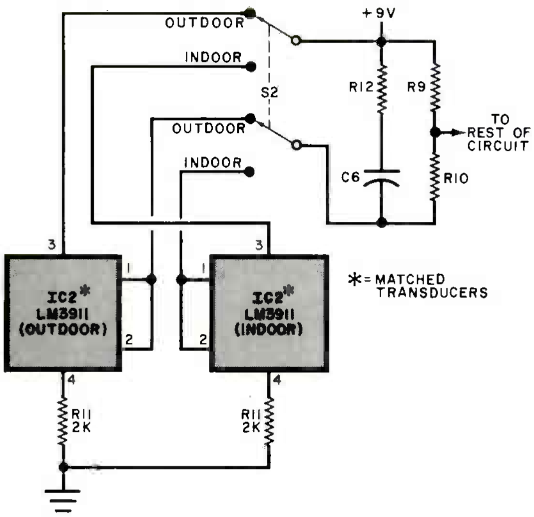


Fig. 5. Diagram shows how to connect two temperature sensors to the basic thermometer. For best results, sensors used should be matched.

To remove the slope error, adjust *R4* and *R7* exactly as described above. (If a DMM is not available, initially set *R4* to its midpoint.) Place the probe and lab thermometer in warm (about 120° F) water and, while stirring the water, adjust *R4* until Lidith's display indicates exactly the same temperature as the lab thermometer. Then place the probe in a bucket of ice/water and adjust *R7*, if necessary, for a reading of 32.1. Return the probe to the warm water and, if necessary, readjust *R4*. Repeat the immersion-and-adjustment procedure until it is no longer necessary to trim the settings of the potentiometers.

Using the Thermometer. In addition to the obvious use of measuring room and ambient temperature, Lidith is ideal for measuring temperatures in pools, for isolating excessively warm electronic components in an operating circuit, as a remote-indicating freezer or refrigerator thermometer, and as a medical thermometer. (If you calibrate accurately for 98.6° F against a good-quality oral mercury thermometer, the accuracy of Lidith can approach ±0.1° F over a 92° to 110° F range.) The Celsius version can also be used by auto hobbyists as a water-temperature monitor.

To accurately measure outside-air temperatures, you need both an accurate thermometer like Lidith and a suitable thermometer shelter. (For details on measuring outside-air temperature, see pages 23 and 25 of *Unique Electronic Weather Projects* published by Howard W. Sams & Co., or refer to some other suitable book on weather instruments.)

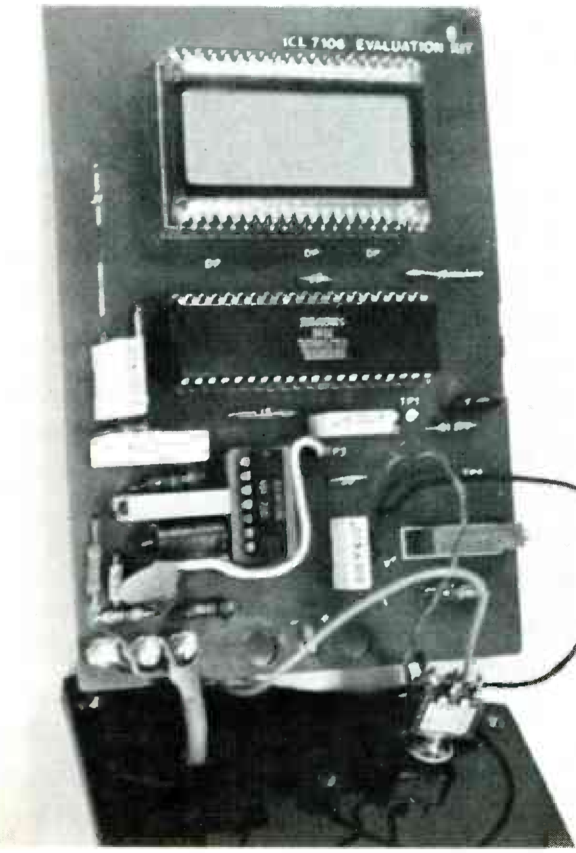
If you turn on Lidith only when you wish to know the temperature and leave the power off at all other times, a standard 9-volt battery should last more than a year. For a continuous display, omit *S1* and use six alkaline D cells in series instead of the 9-volt battery. In continuous use, the D cells should last about a year or more.

The thermometer can be used to measure temperatures in two different locations, such as indoors and outdoors, using the circuit shown in Fig. 5. Bear in mind, however, that if you select two LM3911H-46 transducers at random, one of the temperatures measured will typically be off by 5° to 10° due to the offset error of the devices. However, if you use a pair of custom-matched transducers (see Parts List), your maximum error will be ±2° F.

With a few changes in component values, you can make Lidith measure temperatures in Celsius over a range of from −25° to +85°C.

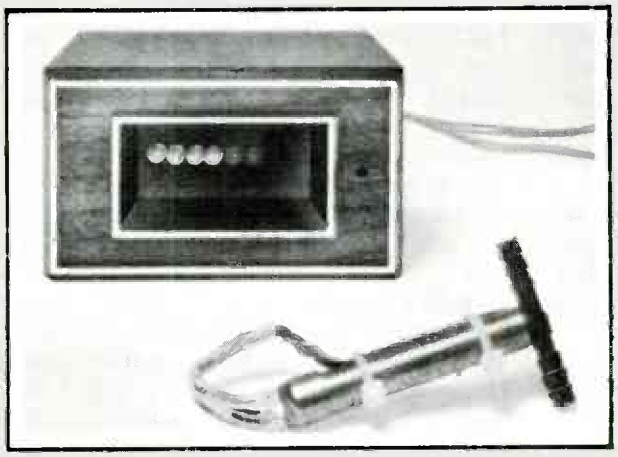
The following changes are required for the Celsius version. First, change *C2* to a 1-μF Mylar capacitor, *R2* to a 220,000-ohm, 5%-tolerance carbon-film resistor, and *R4* and *R7* to 10,000-ohm, 15-turn trimmer potentiometers. Then adjust *R4* so that the potential between *TP2* and *TP3* is 0.500 volt. Also, change *R6* to 20,000 ohms, *R8* to 22,000 ohms, and *R10* to a 10,000-ohm, 1%-tolerance precision resistor. Calibrate by adjusting *R7* for a reading of 00.1 on the LCD when the probe is immersed in an ice/water mixture, as before.

Summing Up. Lidith is a truly state-of-the-art precision digital thermometer. With a few minor changes, it can be "tailored" to your needs. And, in ordinary use, it is highly energy-efficient, thanks to the use of low-power MOS circuitry and liquid-crystal display. ◇



Front view of meter evaluation kit showing components for temperature sensor added in area where battery holder was.

CURB "FUELISHNESS"
with the
Automotive Econometer



Solid-state vacuum gauge monitors gas consumption and driving habits

BY BILL GREEN

POOR DRIVING habits can reduce fuel economy by up to 50% regardless of how well-tuned and maintained the vehicle. In the era of high-cost energy and shortages, you want to get as much as possible from every drop of fuel your car burns. One good way to do this is by using a device such as the Econometer described here. It constantly and accurately monitors the relative fuel consumption of your car so that you can adjust your driving technique accordingly.

The Econometer is an electronic device that keeps tabs on intake-manifold vacuum. It has a display consisting of a row of eight LEDs. At idle, four or five LEDs normally glow. With your vehicle in motion, more or fewer LEDs glow, the maximum number (high vacuum) corresponding to high engine rpm and a small throttle opening and the minimum indicating low rpm and open throttle. High vacuum conditions give maximum fuel economy.

You will not be able to maintain high vacuum under all driving conditions. Naturally, accelerating from a standing start, driving up a steep grade, or hauling a heavy load all take more fuel than cruising on a level surface with a light load. But by observing the Econometer, you will be able to avoid using more throttle than necessary for any conditions, thereby saving fuel.

About the Circuit. The simple circuit of the Econometer is shown schematically in Fig. 1. The vacuum transducer, a proprietary device manufactured by Alpha Electronics, receives power from 5-volt regulator *IC2* through current-limiting resistor *R1*. The output signal from the transducer is developed across *R2*, which is also connected to the stable 5-volt source.

The transducer mounts in the vacuum line from the carburetor. Its electrical output across *R2* varies from 0.3 to 1 volt, depending on instantaneous manifold pressure. This voltage is applied to 10-step analog detector *IC1*.

The new integrated circuit used for *IC1* contains 10 comparators and a reference-voltage network that detects the level of the analog signal at the input. Each comparator drives an open-collector transistor that is capable of sinking 40 mA at 32 volts. Since the comparators are arranged in a "totem pole," as input signal level increases, the LEDs light in succession. Potentiometer *R3* provides a means for setting the operating thresholds.

Construction. Because of the simplicity and noncritical demands of the circuit, any convenient board-type method of assembly—Wire Wrap, point-to-point on perforated board, or printed-circuit board—can be used. An actual-size etching-and-drilling guide for a pc board is shown in Fig. 2.

Mount the LEDs with their tops flush and their bottoms about ¼" (6.2 mm) above the surface of the board, carefully observing polarity during installation. Then install the single jumper and two ICs, again taking care to properly orient them. Use of a socket for *IC1* is optional, but if you do use a socket, try to find a means of securing the IC (a daub of silicone rubber cement will do) so it will not vibrate loose.

Before mounting it in an enclosure, test the circuit board assembly. To do this, temporarily connect a jumper wire between the SNS (sense) point and GND (ground) in the circuit, apply 12 volts dc to the circuit, and check for a 5-volt dc reading between the junction formed by *R1* and *R2* and the ground bus. With *R3* fully clockwise, all LEDs should light; turning the pot fully counterclockwise should extinguish all LEDs. Disconnect the dc power and remove the temporary jumper from the circuit.

Temporarily mount the circuit-board assembly in the enclosure in which it is to be housed. Carefully determine and mark the locations of the display and adjustment slot of *R3* on the enclosure. Remove and temporarily set aside the circuit assembly. Then cut the display-window slot and drill a screwdriver access hole for *R3*. Drill another hole through the side or rear of the enclosure to provide entry for the wires that will interconnect the circuit with its transducer and the vehicle's electrical system. Deburr all holes and glue a red plastic filter over the display window. Line the wire-entry hole with a rubber grommet if you are using a metal enclosure.

Installation. Five well-insulated color-coded wires, preferably 18-gauge stranded, are required to interconnect the Econometer with its transducer and the vehicle's electrical system. Lengths of the wires are determined by the mounting location of the Econometer where it will be easily visible at a glance and the location of the engine's vacuum hose. Starting from where the Econometer will be positioned and leaving several extra inches, route a black-insulated wire to a metal chassis connection or screw that is at chassis ground. Repeat this procedure with a red-insulated wire, this time terminating it at a source of fused +12 volts that is "live" only when the ignition is on. Connect and solder the free ends of the black and red wires to the GND and POS pads, respectively, on the circuit-board assembly. Identify on your schematic diagram the colors used for each function for future reference.

Locate a source of intake-manifold vacuum (usually a rubber hose near or on the carburetor) so that the transducer and its leads will not be near a moving part or engine heat. Using this as your reference point, route three wires with different color insulation (not red or black) back along the chassis, through the firewall, and into the passenger compartment under the dashboard. Continue routing to the Econometer's case location, leaving several inches of slack at both ends of the wires before cutting to final length.

Now, working with only one wire at a time, strip away 1/4" of insulation from the first selected, slip on a 3/4" (19-mm) length of insulated tubing, and solder the wire to the terminal closest to the black dot on the transducer. Solder the other end of this same wire to the SNS pad on the circuit board.

Remove 3/4" of insulation from the second selected wire and connect and solder it to *both* center lugs on the transducer. Solder the other end of this wire to the GND pad on the board. Then, prepare the last wire in the same manner as for the first, including the insulated tubing, and solder it at one end to the remaining lug on the transducer (push the tubing down over both connections) and to the SRCE pad on the circuit board at the other end. Indicate your wire colors on your schematic.

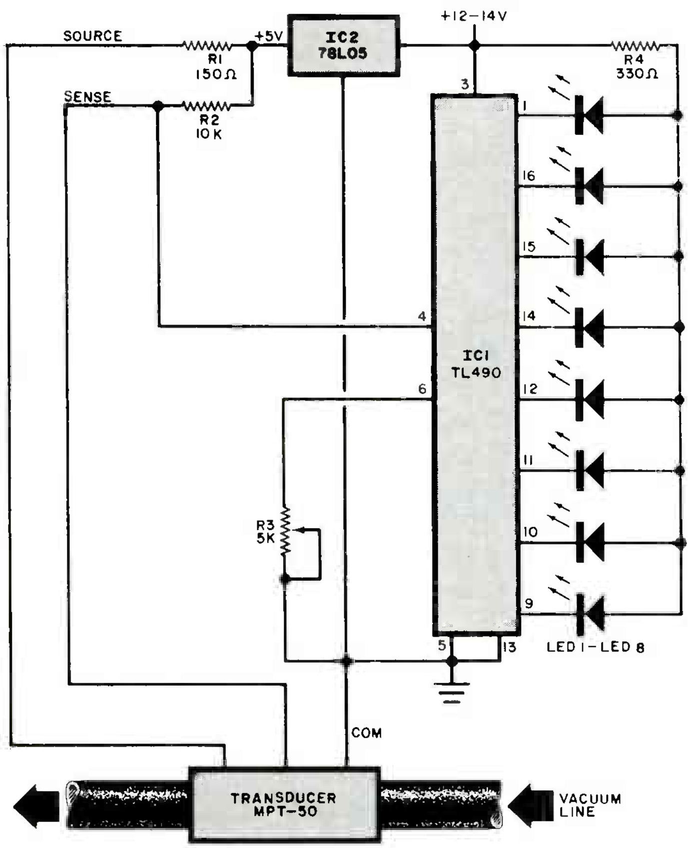


Fig. 1. The transducer converts vacuum level to a dc voltage. This is measured by level detector IC1 and displayed on a series of LEDs. More LEDs glow as the vacuum increases.

PARTS LIST

IC1—TL490 10-step adjustable analog level detector (Texas Instruments)
IC2—78L05 5-volt regulator
LED1 thru LED8—Red light-emitting diode
R1—150-ohm, 1/4-watt resistor
R2—10,000-ohm, 1/4-watt resistor
R3—5000-ohm pc-type potentiometer
R4—330-ohm, 1/4-watt resistor
Transducer—MPT-50 (see Note below)
Misc.—Enclosure; red plastic filter; color-coded stranded insulated wire (see text); insulated tubing; machine hardware; solder; etc.

Note: The following items are available from Alpha Electronics, P.O. Box 1005, Merritt Island, FL 32952 (Tel: 305-453-3534): Complete kit of parts less case and wire, for $28.00 plus $2 in US, $4 in Canada, $8 all other countries for postage and handling. Included in kit, but also available separately: No. PC179 etched and drilled printed-circuit board for $5.50 in U.S. (add $2 for Canada, $4 for all other countries); No. MPT-50 transducer for $20 in US (add $2 for Canada, $4 for all other countries); TL-490 for $4.50 in US (add $2 for Canada, $4 for all other countries). Florida residents, please add 4% sales tax.

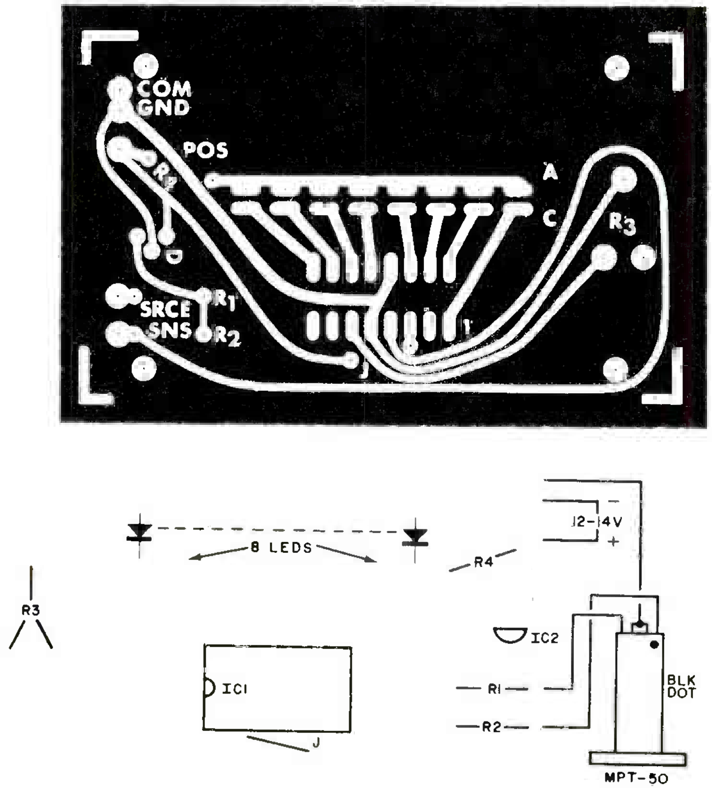


Fig. 2. Same-size etching and drilling guide for pc board is at top. Component placement directly above.

Bend the three-wire cable over the side of the transducer's case, taking care to avoid obstructing the small hole in the case, and secure with a cable tie. Now, cut the vacuum hose and install the transducer in series with the cut ends. (You can install the transducer in either direction.) After installation, make sure the connections to the transducer are airtight.

Position the three-wire cable so that it and the transducer do not contact any moving parts and are away from engine heat. Bundle the cable conductors together with cable ties and secure the assembly to the vehicle's chassis. Then assemble the project's enclosure.

Checkout and Calibration. Start your vehicle's engine and allow it to idle in neutral. Using a small screwdriver, adjust *R3*, through the small hole in the front of the enclosure, until four or five LEDs are on. Still in neutral, slowly press the accelerator and note that the display changes by one LED. Release and then quickly press and release the accelerator. At first, only one LED should be on for a second or so, four or five as the engine returns to idle.

In some vehicles, the vacuum connection is located above the throttle butterfly valves. If this is the case, slightly press the accelerator and adjust *R3* to turn on only three LEDs. Completely releasing the accelerator should cause the display to have only one of the LED indicators lighted.

In Use. A quick glance at the Econometer's display will suffice to keep you informed of your driving efficiency. The idea is to drive so that the maximum number of LEDS is glowing, indicating the highest vacuum and, consequently, the least fuel/burned. As you become familiar with the glowing display and accelerator position during driving, any marked change that persists in the display may indicate a problem in the operation of your engine.

One final note: "right foot awareness" has a great effect on driving efficiency and, thus, fuel economy. Using the Econometer (or any other vacuum-measuring device) reveals how little accelerator pressure is needed to keep a vehicle moving at cruising speed with maximum vacuum. You may be surprised at how far you can back off the gas pedal before your vehicle slows down. So, when you get your vehicle up to the desired speed use a feather touch instead of a lead foot. ◇

POWER SUPPLIES FOR OP AMPS

BY ARTHUR F. BLOCK

For best performance from operational amplifiers, special power-supply needs should be satisfied

OPERATIONAL-amplifier circuits almost always call for power sources that furnish clean, stable dc. Batteries are sources of good dc, but their expense relegates them principally to portable applications where commercial ac power is not readily available. The more economical solution to the problem of powering op amps is to use a *power supply* to convert commercial ac into smooth dc. In this article, we will examine several basic power-supply circuits that are well suited for use with operational amplifiers.

Symmetry is one of the principal characteristics required of most op-amp power supplies. Integrated operational amplifiers usually have two power-supply terminals—V+ and V−. If the voltages applied to these terminals are not symmetrical with respect to the input signal's ground potential (be it earth ground or an "artificial" ground), the output signal will ride on a dc level proportional to the power-supply asymmetry. This is usually undesirable—if a dc voltage is to be amplified, there will be error; if an ac voltage is to be amplified, capacitive coupling might be needed to prevent the upsetting of a subsequent stage's bias levels. Also, the possibility exists that the output signal will be asymmetrically clipped.

There are two basic types of power supplies that can be used with operational amplifiers—*bipolar* and *single-ended*. In a bipolar supply, positive and negative output voltages (usually equal in absolute value) are generated. The required symmetry arises from the fact that both the positive and negative supply rails are removed from ground by equal but opposite voltages. A single-ended supply generates only one voltage referenced to ground—either positive or negative. The ground of the power supply functions as one of the supply rails, and an "artificial ground" or "signal ground" is synthesized with a resistive voltage divider for reference purposes. This provides the required symmetry to the circuit.

Each type of supply has advantages and disadvantages. A bipolar supply furnishes a signal ground that is at true ground potential. This simplifies circuit design and eliminates at many points the need for capacitive coupling. However, a bipolar supply is more complex than a single-ended one and is more expensive to construct. A single-ended supply is simpler but usually makes the circuit to be powered slightly more complex. Let's examine some basic supplies of each type and see how they can be used to power op-amp circuits.

Basic Power Supplies. Appearing in Fig. 1 are simple single-ended (A) and bipolar (B) power supplies. In the single-ended supply, bridge rectifier *D1* through *D4* delivers pulsating dc to filter capacitor *C1*, which provides a smoothed dc output. Resistor *R1* is a bleeder component. A voltage divider comprising *R2* and *R3* synthesizes an artificial signal ground at half of the positive dc output voltage (assuming *R2* = *R3*) or approximately +17 volts. The op amp's positive power-supply terminal is connected to V+ and its negative supply terminal is connected to V−, which is actually true ground. An amplifier powered by this supply can process an ac signal symmetrically if the signal input is at ARTIFICIAL GROUND and the constraints of the power supply are not exceeded. The use of a blocking or coupling capacitor at the output of the amplifier permits the recovery of a pure ac signal with no dc component.

A basic bipolar power supply appears in Fig. 1B. The major differences between it and the single-ended supply just described lie in the transformer used, the need for a second filter capacitor, and the lack of a ground-synthesizing voltage divider. A transformer with a center-tapped secondary is needed. The bridge rectifier comprising *D1* through *D4* simultaneously charges filter capacitor *C1* positively and *C2* negatively. The GROUND at the output of the supply is connected to the transformer's center tap, and the positive and negative output voltages are symmetrical with respect to it. Note that the *differential* voltage between the positive and negative supply rails in each supply is the same even though the actual voltages on each of the rails with respect to true ground are not the same.

As a rule, operational amplifiers consume small amounts of current. This points to a disadvantage of the bipolar supply shown in Fig. 1B. Because only a small amount of output current is required, compact transformers rated at 300 mA or less are particularly attractive. Unfortunately, small transformers with center-tapped secondaries are not as widely available as ones lacking a center tap. The bipolar supply shown schematically in Fig. 2 offers a solution to this problem.

A glance at this supply reveals that it delivers positive and negative output voltages by means of a transformer lacking a center-tapped secondary. Also, note that the voltage rating of the secondary is half of that of the transformer shown in Fig. 1B. This supply can be thought of in one of two ways—either as two half-wave supplies, one positive and one negative with a common ground, or as a full-wave voltage doubler. In any event, it provides positive and negative voltages approximately equal to those produced by the supply shown in Fig. 1B. Also, the GROUND at the output of the supply is true ground, not an artificial one.

In practice, the true grounds of Figs. 1 and 2 are often connected to earth ground for shielding purposes. A fundamental difference between the bipolar supplies of Figs. 1B and 2 is that larger filter capacitors are required in the circuit shown in Fig. 2 for the same amount of ripple rejection. This is because the ripple frequency is lower (60 Hz as opposed to 120 Hz). Therefore, twice the capacitance is required if the capacitive reactance of the ripple shunt path to ground is to be kept at the same value as before.

Electronic Filtering. If the current drain from any of the power supplies that have been described is very low, and if the values of the filter capacitors are sufficiently large, only a small amount of ripple will be present in the dc output. However, in some applications even a low-level ripple component can be troublesome. An excellent safeguard against ripple is the use of electronic filtering such as that provided by a zener diode.

If a zener diode or similar component or electronic filtering network is connected to the output of a simple power supply, ripple can be almost entirely suppressed. The diode will provide not only the equivalent of several thousand or tens of thousand microfarads of filter capacitance in a very small space, but also a high degree of voltage regulation, which is very beneficial.

A basic electronic filter for positive-voltage applications is shown schematically in Fig. 3. When a positive unregulated voltage is initially applied to the input of the filter, capacitor *C1* begins to charge up to the input voltage. Zener diode *D1* clamps the voltage across the capacitor when the zener knee of its characteristic curve is surpassed. The voltage applied to the base of transistor *Q1* is thus kept at a fixed level. This transistor effectively performs two functions. It multiplies the capacitance of *C1* by its dc beta and behaves as an emitter follower, presenting a voltage at its emitter equal to the zener voltage less

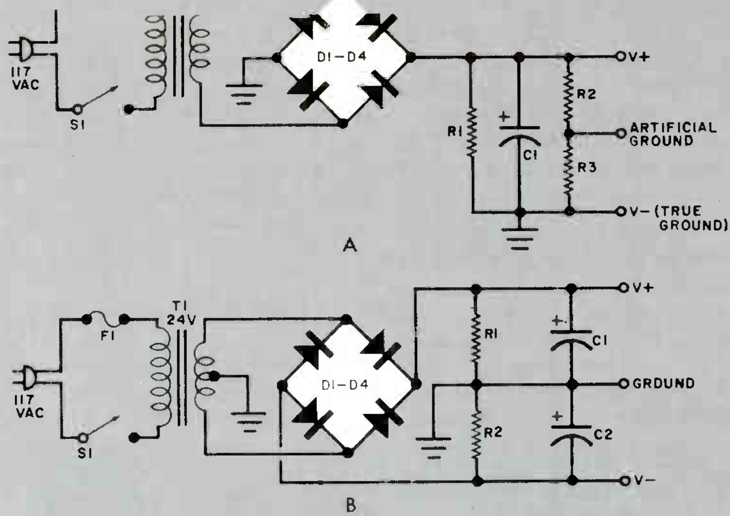


Fig. 1. Single-ended dc power supply for op-amp (A). Bipolar dc power supply that employs a center-tapped transformer (B).

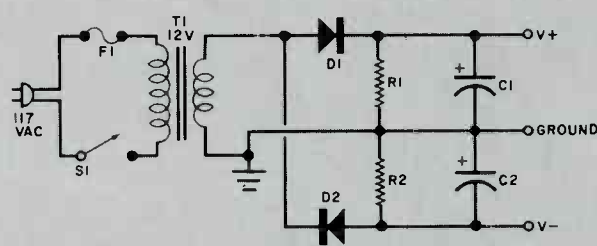


Fig. 2. A bipolar dc supply whose transformer does not have a center tap.

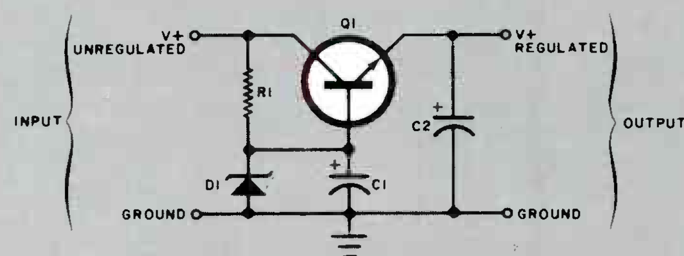


Fig. 3. This electronic filter provides a regulated positive dc output.

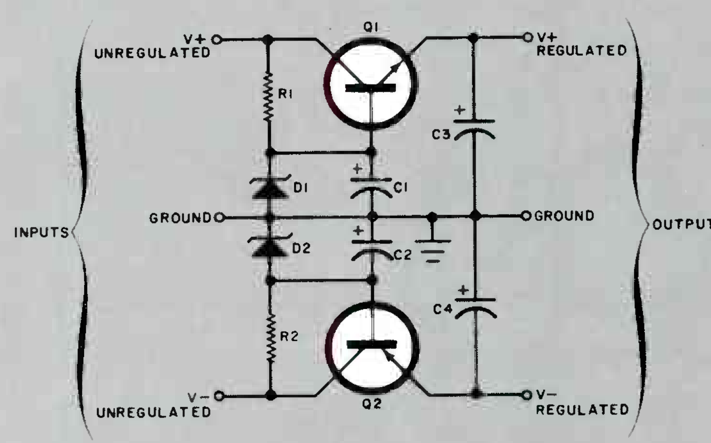


Fig. 4. An electronic filter for use with bipolar dc supplies.

the forward voltage drop across the base-emitter junction. Capacitor *C2* improves the performance of the electronic filter by helping to absorb transients. The time constant *R1C1* results in a slow turn-on characteristic that eliminates potentially troublesome switching transients (clicks) from the supply rails.

The filter shown in Fig. 3 is designed for use with positive-output (negative-ground), single-ended power supplies. It can be adapted for negative-output applications by inverting the polarities of *C1*, *C2*, and *D1* and employing a pnp instead of an npn pass transistor. The unregulated negative dc voltage would then be applied to the node *R1*-collector of *Q1* and the regulated negative voltage would appear at the emitter of *Q1*. This technique is employed in the bipolar electronic filter shown schematically in Fig. 4. The top portion of this circuit is essentially the same as that shown in Fig. 3, and the bottom is a mirror image of the top—that is, a negative-output electronic filter.

Practical Supplies. A complete bipolar regulated power supply for op-amp audio applications appears schematically in Fig. 5. It is basically an amalgam of Figs. 2 and 4 with a few additional elements included. Hum and ripple components in its bipolar outputs are so low in level that they can be ignored in most applications, even where op amps are operating at high gain. The one precaution that is necessary is careful placement of transformer *T1*. This component should be located as far from high-gain stages as is practicable, and it should be physically oriented to keep induced hum signals as small as possible.

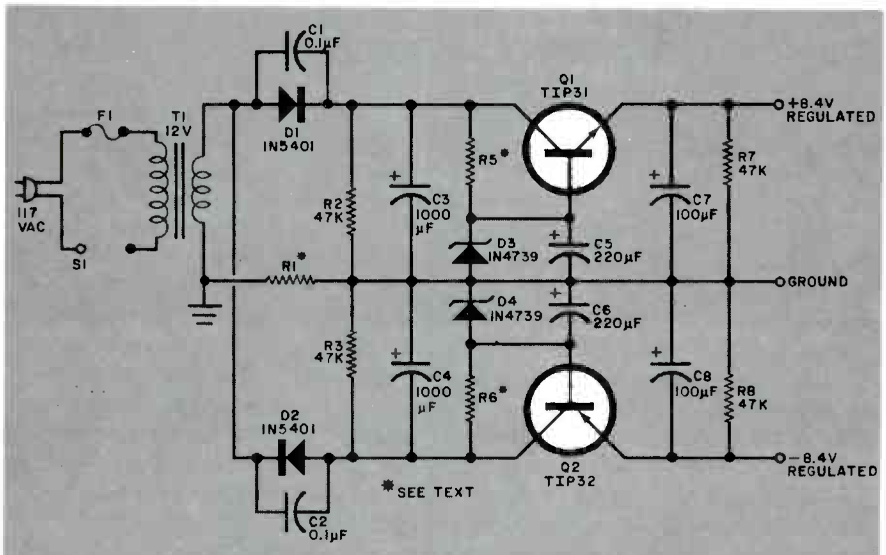


Fig. 5. Complete regulated bipolar supply for op-amp circuits. Transistors Q1 and Q2 might require heat sinking.

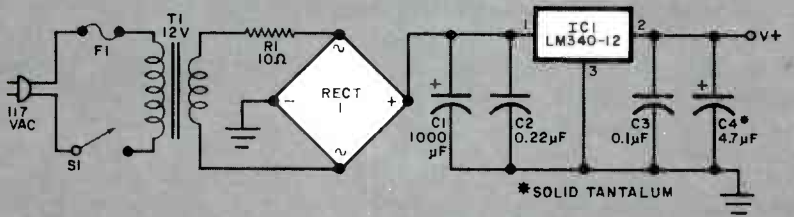


Fig. 6. Regulated single-ended dc supply for powering operational amplifiers.

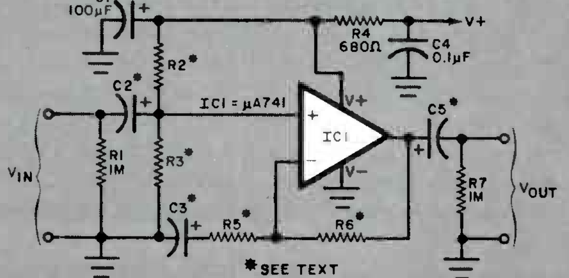


Fig. 7. Typical noninverting op-amp stage designed for use with a single-ended supply.

Rectifiers *D1* and *D2* have forward current ratings of three amperes rms. This high current rating, together with the current-limiting action of *R1*, prevents damage to the diodes by excessive charging current to the capacitors when ac power is first applied to the supply. Actually, the inherent resistance of the 300-mA transformer secondary is great enough to prevent the initial charging current from damaging three-ampere diodes. However, if one-ampere diodes or a transformer with a larger secondary-current rating (and thus less winding resistance) are used, or both, it would be wise to include resistor *R1* in the circuit.

The value of this resistor can be determined by measuring the resistance of the secondary and then solving Ohm's law for the resistance necessary to limit the current through the diodes to the rms rating. The peak voltage delivered by the secondary (1.414 times the rms voltage) should be used in this calculation, and the electrolytic capacitors should be considered dead shorts. Thus, only the inherent secondary resistance and any supplemental resistance provided by *R1* will be available for current limiting. If the resistance value obtained by this calculation is larger than the resistance of the secondary winding, *R1* should be included. Its value is simply the remainder obtained by subtracting the secondary resistance from the total resistance required. This results in a greater degree of protection for the diodes than is really necessary, but ensures trouble-free diode performance.

Note that 0.1-µF disc ceramic capacitors are shown in parallel with each rectifying diode. The function of these components is to suppress the spikes that are generated each time the diode junction breaks into and out of conduction. Fourier analysis of the waveform generated by the diode reveals the presence of significant high-order harmonic components. These harmonics can be troublesome to high-gain op-amp audio stages as well as a source of radio-frequency interference to AM or FM tuners.

Resistors *R5* and *R6* provide current limiting for zener diodes *D3* and *D4*. Values of these components are best determined empirically after performing an initial calculation. First, the rated zener voltage sould be subtracted from the voltage appearing across *C3* or *C4*. The remainder is the voltage drop across the current-limiting resistor. Then Ohm's law should be solved for that value of resistance that results in a current flow of two milliamperes through the resistance. Using this as a starting value, connect a suitable component to the rest of the circuit and temporarily connect a load resistor between the regulated output and ground. The load resistance should be such that the supply will be required to source two or three times the amount of current drawn by the op-amp circuit to be powered under worst-case (maximum current) conditions.

Apply power to the circuit and measure the voltage across the load resistor. Next, disconnect the load from the output of the supply and measure the open-circuit output voltage. If the difference between the loaded and unloaded output voltage is greater than a few percent at most, decrease the value of the current-limiting resistor to the next smaller commercial value and repeat the procedure. (Alternatively, employ a trimmer potentiometer in place of fixed resistors.) When the supply voltage has sufficient regulation, permanently install a fixed resistor of the *next smallest* commercial value with respect to the resistance value that has been empirically determined. This will provide an extra margin of voltage regulation.

The use of this empirical method, though somewhat crude, is justified by the fact that many experimenters purchase surplus zener diodes and transistors whose parameters might be unknown or considerably different from their rated values. Parameters such as a transistor's dc beta and the sharpness of a diode's zener knee will have a significant influence on the appropriate values of the current-limiting resistors. If this method does not produce the desired result, that is, if adequate voltage regulation cannot be obtained, either the zener diode or transistor (or both) should be replaced with another component of the same type. Deficiencies in either device can cause this problem.

Some readers might question the choice of the bipolar output voltage, ±8.4 volts, as opposed to the more common ±12 or ±15 volts. The author was more interested in extended, reliable op-amp performance than in large output-voltage swings. A lower supply voltage places less strain on an op amp and can also help prevent it from becoming noisy. The lower supply voltage does *not* affect stage gain. However, if a higher differential supply voltage is desired, simply use higher-voltage zener diodes for *D3* and *D4* and follow the same resistance-selection procedure that has already been outlined.

Keep in mind that the output voltage will be approximately 0.7 volt less than the zener voltage of the diode and that decreasing the differential input-to-output voltage (V_{CE} of the pass transistor) can degrade voltage regulation when large amounts of current are drawn from the supply. A ±8.4-volt prototype supply can simultaneously power four op-amp audio stages with fine regulation and lack of hum.

A complete single-ended supply for op-amp applications is shown in Fig. 6. It generates a regulated +12-volt output referenced to ground and employs a 100-PIV modular bridge rectifier and an integrated 12-volt regulator. Resistor *R1* limits the surge current through the bridge during power-up. Capacitors *C2* and *C3* are disc ceramic components that should be placed close to the regulator IC package. Solid tantalum capacitor *C4* improves the transient response of the regulator IC. Alert readers might have noted that no spike-suppressing capacitors are shown connected across the bridge's diodes. The capacitors might not be necessary, but any reader who plans to duplicate this circuit should leave space for them if actual performance indicates a need for them. Four capacitors would then be installed—one across each diode forming the bridge.

The +12-volt output is usually sufficient for most op-amp applications. It permits the output of an operational amplifier to swing almost 12 volts peak-to-peak without clipping. If a greater output swing is desired, a higher-voltage regulator IC and either a diode-capacitor voltage multiplier or a transformer with a smaller step-down ratio can be used.

Figure 7 is the schematic diagram of an op-amp audio amplifier that the author has powered with the single-ended supply just described. Resistors *R2* and *R3* form a voltage divider across the supply rails. The values of these components are identical (typically 100,000 ohms) so that the noninverting input of the op amp, the one to which input signals are applied via coupling capacitor *C2*, is at exactly half the supply voltage. This artificial signal "ground" potential permits the op-amp output to swing symmetrically in response to ac excitation. Components *C1* and *R4* decouple the supply line that feeds the biasing resistors to ensure good performance.

The bias level applied to the noninverting input of the op amp causes the output of the amplifier to remain at this same level during quiescence due to the effectively infinite dc feedback provided by *R6*. No dc amplification can occur, however, because *C3* prevents any dc voltage division by *R5* and *R7*. Resistors *R1* and *R7* provide dc return paths at the input and output of the stage.

The amplifier's voltage gain equals the quantity ($1 + R6/R5$) because the stage is noninverting. Selection of these resistor values is made to obtain the required voltage gain. The capacitance of *C3* should be large enough that the component's capacitive reactance should be low at the lowest frequency to be amplified. One hundred microfarads or more should be sufficient for most audio applications, especially if the gain-determining resistances are on the order of kilohms or more.

Electrolytic capacitors *C2* and *C5* couple ac signals into and out of the amplifier, respectively. Their values have an influence on the frequency response of the amplifier. As a rule, the capacitance of *C5* must be higher than that of *C2* for a given low cutoff frequency because the output impedance of the amplifier is much lower than the input impedance. Practical audio circuits of similar design commonly employ tens of microfarads or more capacitance for input coupling and hundreds or thousands of microfarads for output coupling. The optimum values for a given application depend on the lowest frequency to be amplified, the load impedance, etc.

Some audio circuits employing electrolytic capacitors and op amps powered by bipolar supplies have appeared previously in the literature. These circuits have one principal disadvantage—there is no dc polarizing voltage impressed across the coupling capacitors. During one half of the ac signal cycle, the capacitors are reverse-polarized and a reverse current flow exists. At best, this can result in varying circuit impedances and shortened capacitor useful lifetimes. At worst, it can cause catastrophic capacitor failure and the application of dc levels from a previous stage to a subsequent one. In the op-amp circuit we have just described, all electrolytic capacitors are properly dc-polarized.

In Conclusion. Operational amplifiers are among the most useful devices available to the electronics experimenter. For best performance, their relatively modest power requirements should be satisfied through the use of stable sources of clean dc. To that end, a number of power-supply design ideas and practical circuits have been presented in this article. The experimenter can use them for guidance in the construction of power supplies that will enable him to derive the best possible results from his op-amp projects. ◇

VOCAL ZAPPER MAKES YOU A "SUPERSTAR"

Cancels the "phantomed" center channel of a stereo record and lets you substitute your own voice

BY CRAIG ANDERTON AND DAVID KARR

WHETHER to practice singing, have fun at parties, or just feel like a rock star, the Vocal Zapper may be just what you want. This inexpensive device lets you remove a lead singer's voice during playback of most stereo records and substitute your own voice. The Zapper is effective only with stereo records and most effective with those in which the lead vocalist (and bass instruments, if used) occupy center-stage, with vocal and nonbass-instrumental accompaniment mixed more toward the left or right of the stereo spread. (This type of mix is common in popular music.)

To create the center-channel effect, the sound engineer generally mixes equal amounts of in-phase lead-vocal (and bass) signal with the directional left- and right-channel signals. When a stereo record mastered in this manner is played back, the mix psychoacoustically places the lead vocalist stage-center, with accompanying voices and instruments to the left and right of the stereo spread.

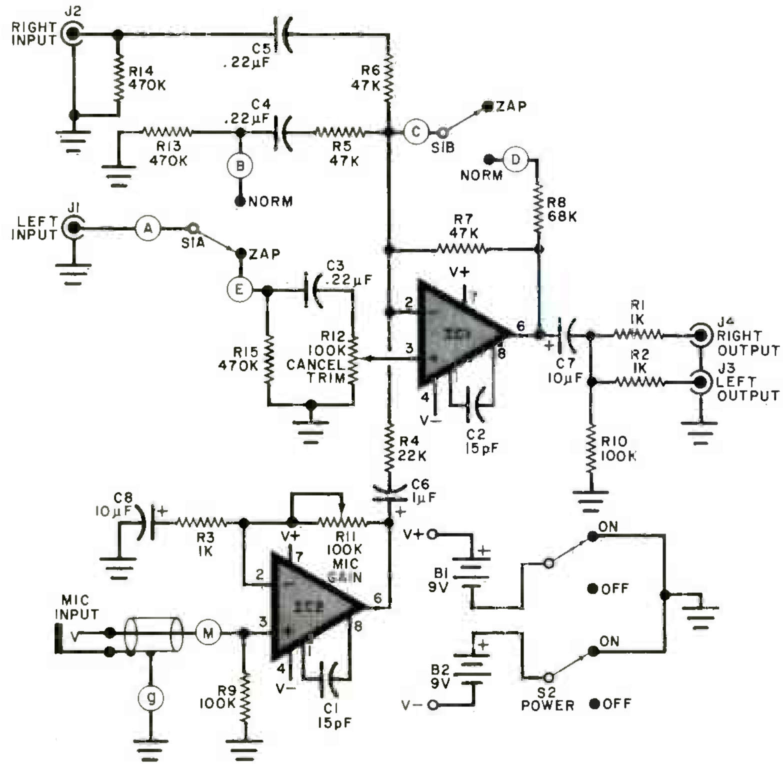
In the ZAP mode, the Zapper subtracts the left and right stereo signals fed to its inputs in a differential amplifier. The result is that all common-mode (equal-amplitude, in-phase) signals in both channels—in this case, the lead vocalist—are cancelled out. What emerges from the amplifier and is fed back into the stereo system is a single mono signal with all the original left- and right-of-center information, including any reverb that may have been added to the lead vocal, but no lead vocal. The residual reverb will generally be of a low enough level to be unobjectionable if you replace the lead vocal with your own voice. In fact, you may even find it desirable, since it adds depth to the sound.

About the Circuit. The heart of the Vocal Zapper, shown schematically in Fig. 1, is differential amplifier *IC1*. This IC and microphone preamplifier *IC2* can be an LM301, LM748, or any equivalent uncompensated operational-amplifier integrated circuit.

With *S1* set to NORM, both the left input at *J1* and the right input at *J2* are mixed together and fed to the negative, inverting input of *IC1*. Since in this mode only one input of *IC1* has a signal applied to it, no differential amplification occurs. In this event, *IC1* simply passes on *all* the signal information, including common-mode vocal in mono form, to both *J3* and *J4*, the left and right outputs, respectively. If a microphone is plugged into *J5* in the NORM mode, its signal would be amplified by microphone preamplifier *IC2* and mixed with the left and right input signals to provide a "duet" signal capability. (Microphone gain is set as desired with potentiometer *R11*.)

Setting *S1* to ZAP (common-mode cancel) causes the left-channel input signal to feed the positive noninverting input of *IC1*, while the right-channel signal continues to feed the negative input. Once the two signals enter *IC1*, one of them is inverted (phase shifted by 180°) so that common-mode information cancels. The music at this point would be lower in volume than in the NORMAL mode. During zapping, you can add your own voice in place of the vocal being cancelled simply by singing into a microphone.

Power for the circuit is supplied by a pair of 9-volt transistor batteries, *B1* and *B2*. Since the circuit requires a bipolar source, *B1* and *B2* are ar-



PARTS LIST

B1,B2—9-volt transistor battery
C1,C2—15-pF disc capacitor
C3—0.01-µF, 15-V disc or Mylar capacitor
C4,C5—0.22-µF, 15-V disc or Mylar capacitor
C6—1-µF, 15-volt electrolytic or tantalum
C7,C8—10-µF, 15-volt electrolytic or tantalum
IC1,IC2—LM301, LM748 or equivalent op amp (see text)
J1 through J4—Phono jack (see text)
J5—Microphone jack (see text)
Unless otherwise specified the following are ¼-watt, 10% tolerance fixed resistors
R1,R2,R3—1 kΩ
R4—22 kΩ
R5,R6,R7—47 kΩ
R8—68 kΩ
R9,R10—100 kΩ
R11,R12—100-kΩ upright pc-type trimmer potentiometer
R13,R14,R15—470 kΩ
S1,S2—Dpdt switch
Misc.—Printed-circuit or perforated board; IC sockets (optional); sheet aluminum for front and rear panels; L brackets; No. 6 machine hardware; dry-transfer lettering kit; hookup wire; solder; etc.

Fig. 1. Schematic diagram of the Zapper. IC1 and IC2 can be any uncompensated op amp ICs similar to the LM301.

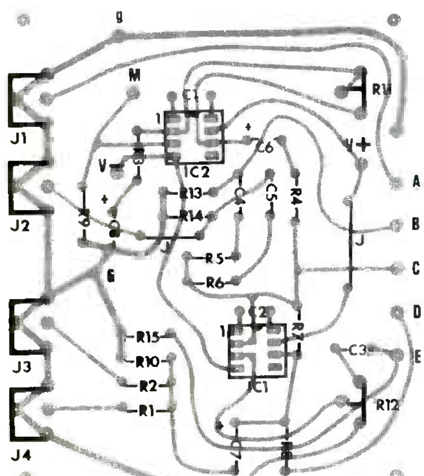
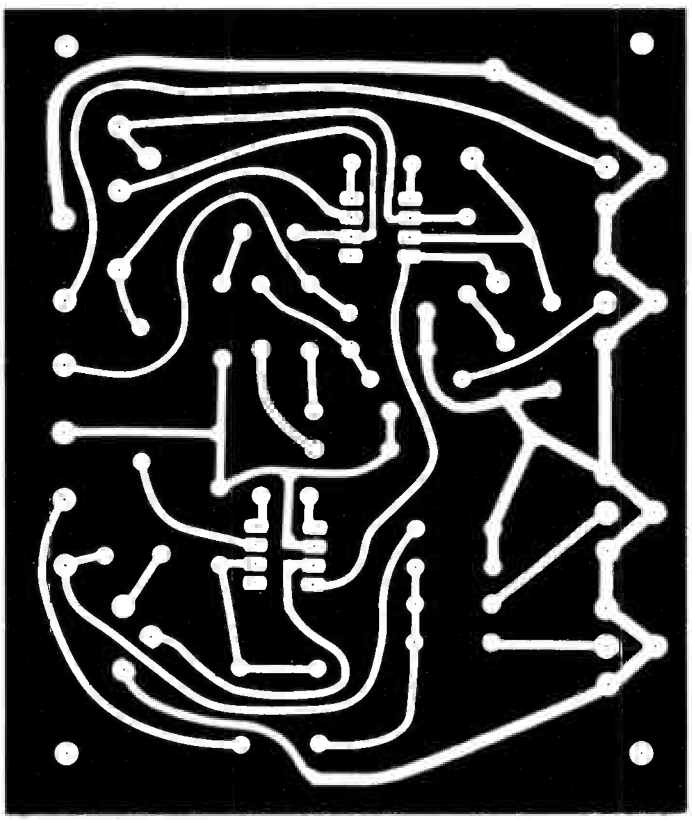


Fig. 2. Actual-size foil pattern for a pc board is at right; component layout above.



KIT ORDERING INFORMATION

The following is available from PAIA Electronics, Inc., P.O. Box 14359., Oklahoma City, OK 73116: complete kit of parts No. 6730K, including front panel for $24.95 plus $3 postage. Also available separately: pc board No. 6730pc for $9.95. Add $5 handling charge for foreign orders.

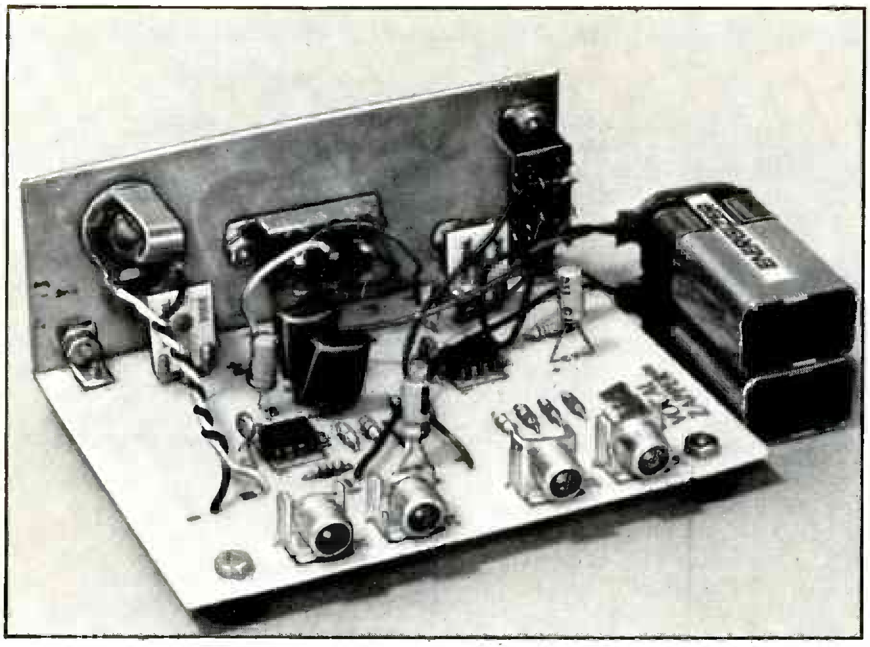


Fig. 3. Photo of the interior of the author's prototype. Right-angle pc-mount jacks were used for J1 through J4.

ranged to supply ±9 volts, referenced to signal ground.

Construction. The Zapper is best assembled on a printed-circuit board (see Fig. 2) or perforated board with solder clips. In either case, sockets are optional, but recommended, for *IC1* and *IC2*.

Mount the resistors, capacitors, trimmer potentiometers, and ICs (or their sockets) as shown in the component-placement guide. Don't forget to install the two jumpers at the locations labelled *J*. You have the option with *J1* through *J4* of using either right-angle pc-mount jacks (see Fig. 3) or standard panel-mount jacks.

Referring to the lead photo, prepare a front panel to accommodate POWER and NORM/ZAP switches *S1* and *S2* and MIC jack *J5* and to provide access to CANCEL TRIM and MIC GAIN controls *R12* and *R11*. (Note: Select a jack that mates with the connector on the microphone you plan to use with the Zapper and drill a hole just large enough to accommodate it.) Then mount the panel to the pc assembly edge with the letters A through E on it with a pair of small L brackets.

Loosely twist together two lengths of different colored insulation hookup wire or substitute a length of shielded cable and solder one end to the lugs on the MIC jack. Being careful to maintain proper polarization, connect and solder the other end of the twisted pair or shielded cable to points M (hot) and g (signal ground) on the pc board. This step and the remainder of off-board wiring are shown in Fig. 4.

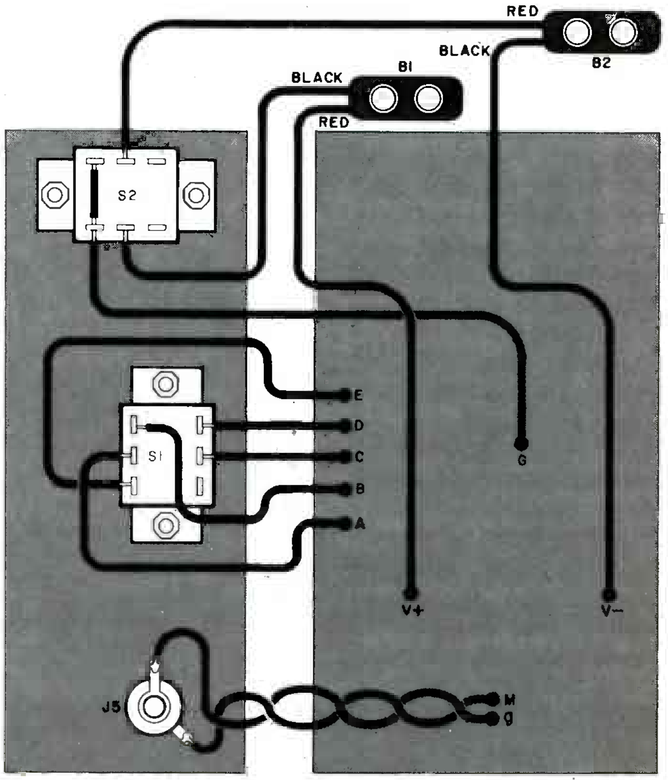


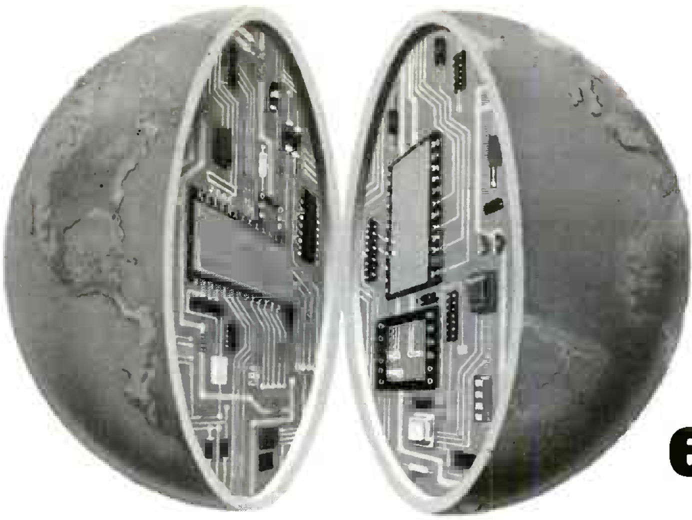
Fig. 4. Follow this wiring diagram to connect the front panel to the components on the pc board.

Installation and Use. Snap a pair of batteries into their connectors, but leave the POWER switch off. Then connect the Zapper into your stereo system's TAPE OUT/TAPE MONITOR loop. From now on, when you wish to use the Zapper, all you do is activate the receiver or amplifier tape-monitoring function.

After installation, turn on power first to the Zapper and then to the stereo sytem. Set your stereo system's input selector to PHONO but leave the TAPE MONITOR switch in the out position. When you play a stereo record, you should now hear normal stereo sound. Set the Zapper to NORM and switch in the stereo system's tape-monitor function. The stereo spread should now disappear and be replaced by mono sound. You might also note a slight drop in overall volume.

Now switch to the ZAP mode and listen to the sound. The lead vocal should be absent, but the stereo spread should remain. If you can hear the lead vocal (don't confuse this with any reverb that may have been added), adjust the CANCEL TRIM control for maximum cancellation, which should occur somewhere near the center of the pot. The CANCEL TRIM control need not be touched again.

Once the Zapper is operating properly, plug headphones into the amplifier and then a microphone into the Zapper. (Don't attempt to listen through speakers with a live microphone. If you do, acoustic feedback can damage your system.) As you sing into the microphone, adjust the MIC GAIN control for the proper blend between microphone and program material. At first, you might tend to set mike gain too high, which could result in distortion. With a little practice, you'll soon be using the MIC GAIN control with the proper "touch." ◇



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EH-32

BY JOHN D. RICHARD

PROTECT YOUR PROPERTY WITH A CMOS GUARDIAN

Lets you know if an unauthorized person has used any electric machines when you weren't present

Wouldn't it be nice to have a device that would tell you when someone has operated any line-powered electrical device in your home or office without your permission? Well, the Sentinel described here does just that. Once coupled to any 117-volt ac line-operated equipment or lighting circuit, the Sentinel constantly monitors the ac power. To determine if the ac circuit has been switched on since the last time you checked, you simply push a button. No telltale lights or alarms sound when unauthorized use occurs; to find out, you must close a switch.

About the Circuit. Although *IC1* in the illustration contains four 2-input NAND gates, the two inputs of each gate are wired in parallel to form four inverters. Gates A and B are wired in a set/reset flip-flop configuration.

A low input to gate B generates a high condition at its output. Because this signal is also present at the input of gate A, its output is forced low. The circuit is completed by feeding the low output of gate A to the input of gate B. Output current from gate A is limited by *R3* during changeover.

The high output from gate B is also routed to the input of gate D, forcing the latter's output, which is connected to *LED1*, low. The low output from gate A is inverted by gate C whose output, connected to *LED2*, goes high. Hence, if *S3* is pressed (closed) at this time, only *LED2* (which is green) can come on. If the input to gate B is forced high, the flip-flop changes states. Now only *LED1* (red) can come on when *S3* is pressed.

In the flip-flop's "normal" state, with no power applied to *T1*, closing *S2* places the flip-flop in the state where only *LED2* can light when *S3* is pressed.

The primary of *T1* connects to either the power line or the primary of the power supply (after the power switch) of the device to be monitored. If *T1*'s primary is energized, the *C1/D1* circuit creates a positive voltage that is applied to the input of gate A via current-limiting resistor *R2*. When this voltage exceeds the switching level of gate B, the flip-flop changes states. Then, pressing *S3* causes *LED1* to light.

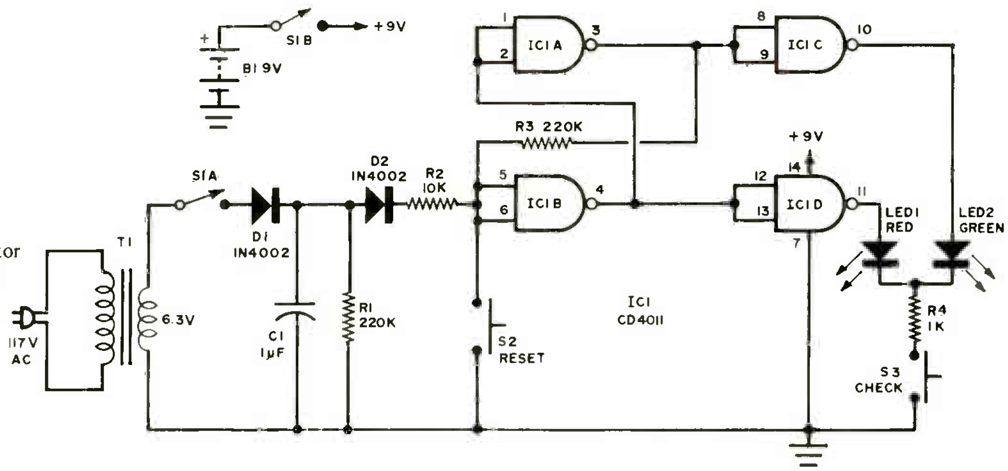
Momentary application of power from the ac line produces enough dc voltage for the flip-flop to change states. When the ac is removed, *R1* discharges *C1*, but *D2*, now reverse biased, keeps the flip-flop from changing states. Once tripped, the circuit does not go into automatic reset.

Once *S2* is pressed to reset the Sentinel, operating *S3* will cause only the green LED to come on. If you press *S3* later and the red LED comes on, someone has applied ac power to the device being monitored. Both ac-line and 9-volt dc power can be disconnected from the sentinel by opening *S1*.

Construction. Although the Sentinel can be assembled with just about any wiring technique, it is best assembled on a piece of perforated board or a printed-circuit board of your own design. Component placement and orientation, wire routing, and lead dress are not critical. Just arrange the circuit neatly. Then house it in an appropriate-size box that is predrilled for the three switches and two LEDs. ◇

PARTS LIST

- B1—9-volt battery
- C1—1-μF polyester capacitor
- D1, D2—1N4002 diode
- IC1—4011 quad 2-input NAND gate
- LED1—Red light-emitting diode
- LED2—Green light-emitting diode
- R1, R3—220,000-ohm ¼-W 10% resistor
- R2—10,000-ohm, ¼-watt 10% resistor
- R4—1000-ohm, ¼-watt, 10% resistor
- S1—Dpst switch
- S2, S3—Normally open pushbutton
- T1—6.3-V transformer
- Misc.—9-volt battery and holder; suitable enclosure; machine hardware; line cord; hookup wire; etc.



In normal state of flip-flop IC1/IC2, LED2 glows when S3 is pressed. If flip-flop is toggled, LED1 glows.

Audio Time Delay System

A Low-Cost Analog Audio Delay Line

BY JOHN ROBERTS

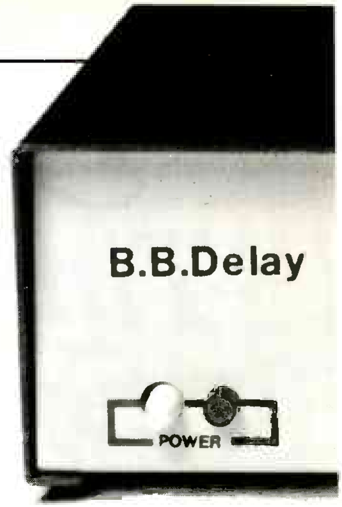
Analog system employs a bucket-brigade device and compansion to provide adjustable delays and wide dynamic range

THE AUDIO BUFF is constantly seeking ways to make the sound from his audio system more realistic. That's why there's been a high level of interest in a family of audio components known as audio delay lines or "room expanders." Such a component is intended to create an auditory illusion that simulates the environment in which music is ordinarily performed—a large concert hall, a night club, etc.—rather than the sense of being reproduced in a small listening room. To provide you with a component that will achieve this objective with any hi-fi system, we present here an analog audio delay line, that can be built by a technically inclined audiophile for a relatively moderate cost. The delay line described is analog in design.

THE analog audio delay line described here employs a high-performance, "bucket-brigade" analog shift register and a 2:1 compansion system to preserve as much of the input signal's dynamic range as possible. According to its designer, it offers an adjustable delay time of from 5 to 68 ms, a frequency response of 30 to 12,000 Hz (+0, −1 dB), an output noise rating ("A" weighted) of −91.5 dBm at 5-ms delay, and a THD + N content of 1% at 10 kHz. A complete stereo delay-line kit including an ac or dc power supply and a custom enclosure is available for $250.

Delay Lines and Reverberation. Perhaps the most significant difference between a large concert hall and the typical home listening room lies in their reverberation times. Reverberation time can be defined as the amount of time it takes for a steady-state sound field to decay to −60 dB relative to the level that existed before the sound source was deactivated. The size of a room and the materials used to construct it affect its reverberation time.

Because the speed of sound in air is relatively constant (approximately one foot or 0.3 meter per millisecond) for given atmospheric conditions, sound waves travelling in a very large room will experience fewer energy-absorbing collisions with the walls, floors, and ceiling per unit time than will similar sound waves travelling in a small room. Accordingly, sound waves in the large room decay less rapidly.



A listener in a reflective room receives a series of sound waves starting with the wave that reaches him on a direct path from the source. The reflected waves arrive at some time after the direct signal. The human ear derives from these differences in arrival times clues as to the size of the listening space.

When the reflections arrive so soon after the direct wave that they merge with it, the room "sounds" small. By contrast, larger differences in arrival times and more protracted reverberation tell the listener that he is in a large hall.

In operation, an audio delay line accepts signals from the main audio channels, stores them for a given amount of time, and then presents them to a power amplifier which drives one or more speaker systems. The speakers driven by the main-channel signals are placed in front of the listener, and the speaker(s) driven by the delayed information is (are) placed behind him or off to the sides. The goal is to synthesize the reverberative characteristics of the type of environment in which the recorded program material would ordinarily be performed.

Delaying the Signal. Various means, electromechanical and electronic, are available for providing delayed signals; but cost, complexity, and space requirements make most of these impractical for use in the home. It seems fair to say that use of delayed signals to enhance home music reproduction was brought about by the availability of purely electronic delay systems.

State-of-the-art reverberation synthesizers derive suitable audio delays by means of analog or digital shift registers. In either method, the audio signal is divided at a given rate into samples that describe its instantaneous amplitude. These are sequentially deposited in a shift register that stores them for a given amount of time. The samples are clocked through the register, the end of which is connected to a circuit that reconstructs a smoothly varying analog signal out of the series of discrete samples applied to it.

The difference between analog and digital delay lines lies in the manner in which the input signal is sampled, stored, and reconstructed. In an analog system, the input signal is sampled and its instantaneous amplitude is applied to the input of an analog shift register. What happens next depends on the type of analog shift register that is employed.

If the register is a *bucket-brigade de-*

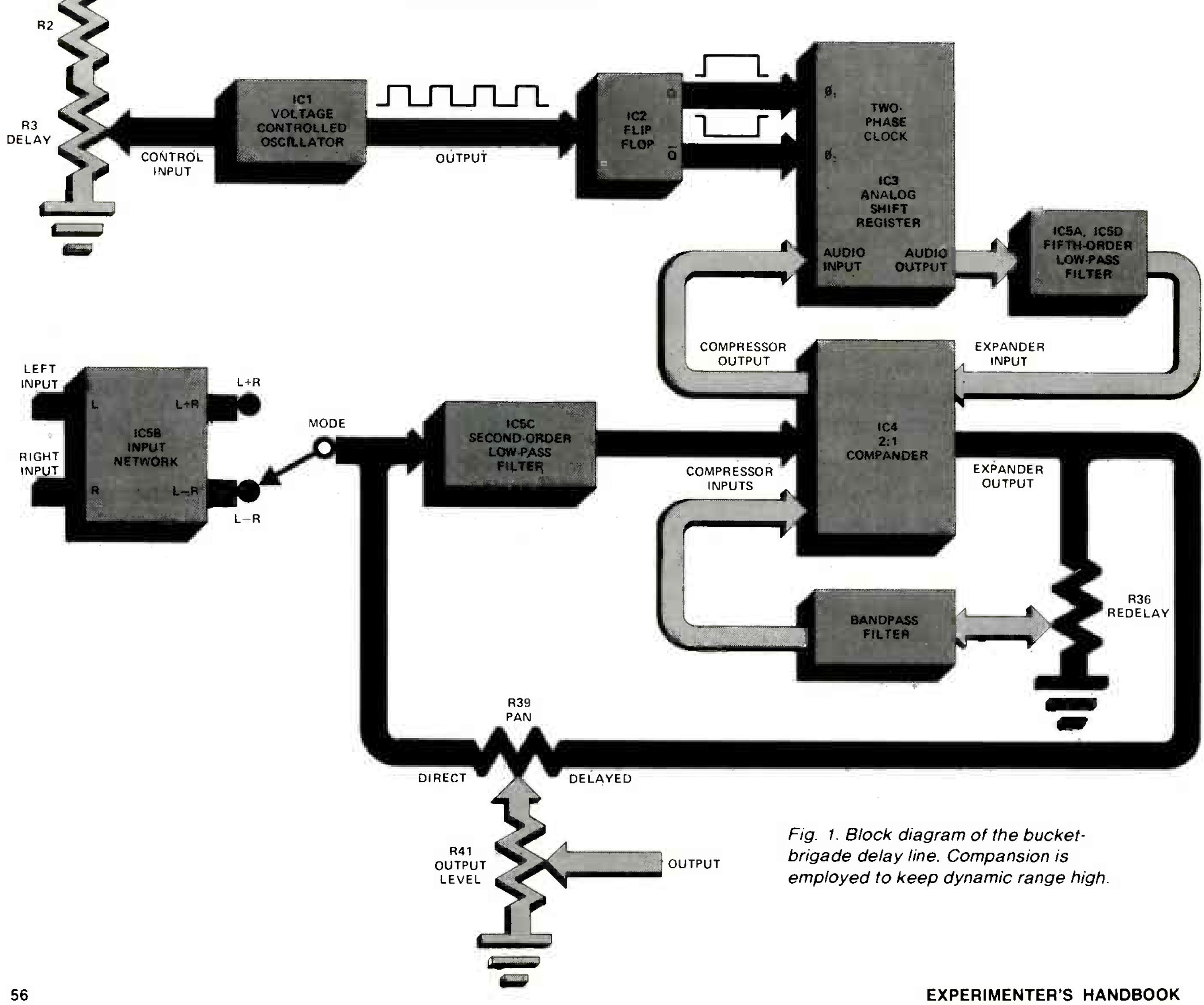
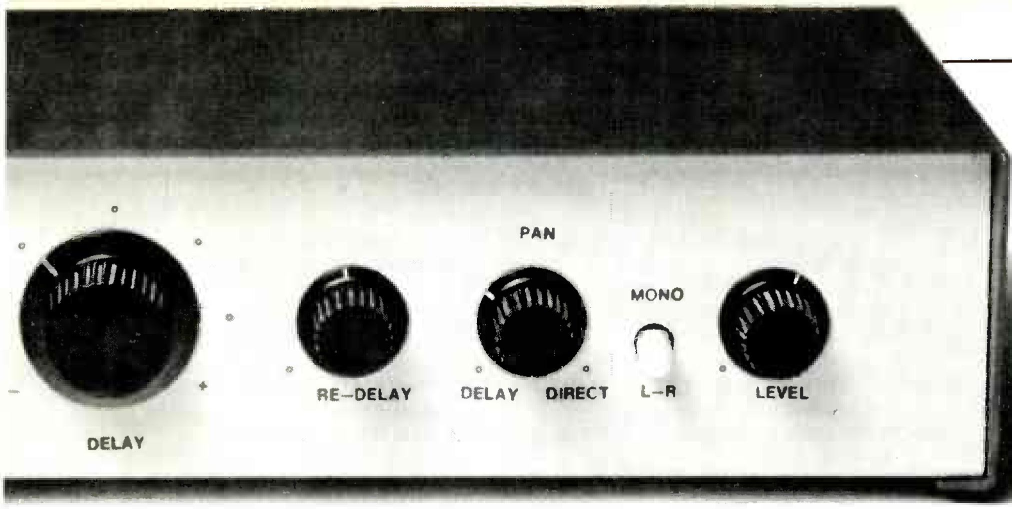


Fig. 1. Block diagram of the bucket-brigade delay line. Compansion is employed to keep dynamic range high.



Photograph of the author's prototype. The large control knob adjusts vco frequency and, hence, delay time.

vice, the sampled voltage charges a small input capacitor. This charge is then transferred to the first of a long series of storage capacitors by means of a voltage-controlled switch (a FET driven by one component of a two-phase clock). Next, a new sample charges the input capacitor and the first sample is transferred to the second in the string of storage capacitors. The sample in the input capacitor is then transferred to the first storage capacitor; the input capacitor receives a new sample; the sample in the second storage capacitor is transferred to the third while that in the first is transferred to the second; and so on.

This process goes on continuously and the analog samples of the input waveform make their way down the bucket-brigade device in the form of packets of charge being shifted from one capacitor to the next. At the end of the register, a low-pass filter integrates the stacatto sequence of samples delivered to it into a smoothly varying replica of the input waveform.

The second type of analog shift register, the *charge-coupled device*, functions in a similar manner but employs a different method of storing and transferring the analog samples of the input waveform. Instead of using actual capacitors to store the charge packets, a charge-coupled device or CCD employs the equivalent capacitances of a series of MOSFET channels which form under gate structures biased by voltages greater than the MOS threshold.

The MOS elements of a CCD are close enough to each other that the free charge consisting of minority carriers stored in the inversion layer associated with one MOS capacitor (the channel) can be transferred to the channel region of the adjacent device. The transfer of charge is governed by the multi-phase clock voltages applied to the gate structures of adjacent MOS devices. In a CCD, an analog sample of the input signal is stored as a channel charge. Because CCD gates are very small (typically a few square micrometers in area), tiny amounts of charge are involved—usually from approximately 10 electrons (!) to 10^7 electrons.

In an analog delay line, the amount of delay that is obtainable depends on both the rate at which the samples are clocked through the shift register and the number of storage elements in the register. Current IC fabrication techniques have made possible the construction of BBD or CCD delay lines containing hundreds and even thousands of storage elements. Such devices offer delays as long as 100 milliseconds or more—longer than necessary for most reverberation synthesis applications.

The faster the clock frequency, the shorter the delay and, for a given device, the more closely the output signal resembles the input signal. As a rule, longer delays result in some loss of high frequencies and degradation of dynamic range. Advanced delay-line ICs offer impressive performance in spite of these limitations. For example, the Reticon SAD-4096 employed in the project to be described here has 2048 storage elements, a clock-frequency range of 8 kHz to 2 MHz, and a delay range of 1 millisecond (2-MHz clock) to 250 milliseconds (8-kHz clock). The dynamic range of its output is 65 dB when the clock frequency is a relatively low 20 kHz. The use of compansion can provide even greater dynamic range.

In a digital system, the input waveform is sampled at an appropriate rate. Each sample is applied to an A/D converter which transforms it into a sequence of bits describing its instantaneous amplitude in digital form. Each digital word describes a specific sample and is applied to either a digital shift register or to a RAM, depending on the design of the delay line. If a shift register is employed, the words are clocked through the register at a specific clock rate and eventually appear at its output. If a RAM is used, the words are written into specific memory locations, stored in them for a certain period of time, and then read out of the memory locations in the appropriate order.

As the digital words stream out of the register or are read out of the RAM, they are applied to the input of a D/A converter which changes them back into analog form. Low-pass filtering smooths out the reconstructed analog waveform. The total delay provided by a digital system depends on the length of the shift register and the rate at which data is clocked through it or on the size of the RAM and the rate at which digital data is written into and read out of it.

Some delay line designs employ *delta modulation*. That is, the input waveform is sampled continuously and compared to the previous sample. The circuit that processes the input waveform generates an output signal that describes the result of this comparison—whether the input signal has decreased or increased in amplitude, or remained constant. If this is done, only "change" information need be clocked through a register or written into memory, rather than information completely describing the instantaneous amplitude of the input signal at each moment that it is sampled. At the output of the storage circuit, a demodulator reconstructs an analog replica of the input waveform that is low-pass filtered to remove abrupt level changes introduced by the delta modulator.

Design Considerations. A digital system's greatest advantage is that the signal degradation it introduces is fixed and independent of the length of the delay. Once a signal sample has been converted into digital form, it can be manipulated any number of times without loss. The quality of the output signal is affected only by the linearity and dynamic range of the A/D and D/A converters at the input and output.

The dynamic range of a digital system in which the digital words directly describe the corresponding input samples is approximately 6 dB per bit. A 16-bit linear digital system thus offers a dynamic range of approximately 96 dB, but is horrendously expensive. To obtain an acceptable dynamic range using fewer bits, various "nonlinear" coding schemes have been developed.

Analog delay systems bypass the complexities of A/D and D/A conversion but degrade signals more as delays become longer. Because analog shift registers are more-specialized, lower-volume devices than their digital counterparts, analog registers are considerably more expensive. In the author's opinion, analog systems offer superior price/performance ratios for delays of less than 100 milliseconds. For longer delays, he would give digital systems the nod. As 100 ms was considered a suitable upper limit for delay time in the system, the analog approach was used.

The length of delay required depends on the reverberation times that the designer is attempting to synthesize. In the author's opinion, audibly believable reverberation can be generated by feeding the output signal of the delay device back to the input. The resulting multiple repetitions simulate the arrivals of reflected sounds along paths of different lengths. In such a system, the reverberation time can be calculated from the length of the delay and the gain of the feedback loop. For example, if the signal is delayed 50 ms and the gain of the loop is −3 dB, it will take 20 recirculations of the signal before the output level decays to −60 dB relative to its initial amplitude. The reverberation time is thus one second.

Natural-sounding reverberation can be achieved with a maximum shift-register delay of 40 to 60 ms as long as the recircu-

PARTS LIST
DELAY CIRCUIT

C1, C18, C19, C32—0.1-μF, 50-V disc ceramic capacitor
C2—100-μF, 16-V radial-lead electrolytic
C3, C13, C16, C25, C27—4.7-μF, 16-V radial-lead electrolytic
C4—0.01-μF, 5% Mylar capacitor
C5, C11, C21, C22, C24—100-pF, 5% polystyrene capacitor
C6, C7, C8, C12, C17—1-μF, 25-V radial-lead electrolytic
C9, C14—5-pF, 50-V disc ceramic capacitor
C10—2200-pF, 5% polystyrene capacitor
C15, C26—0.47-μF, 25-volt radial-lead electrolytic
C20—1000-pF, 5% polystyrene capacitor
C23—510-pF, 5% polystyrene capacitor
C28—0.0022-μF, 5% Mylar capacitor
C29, C30—470-pF, 50-V disc ceramic capacitor
D1, D2—1N914 diode
IC1—CD4007AE dual complementary pair plus inverter
IC2—CD4013AE dual D flip-flop
IC3—SAD-4096 bucket-brigade analog shift register (Reticon)
IC4—NE570N compander
IC5—TL074CN quad BiFET op amp
J1, J2, J3, J4—phono jacks

The following, unless otherwise specified, are 1/4-watt, 5%, fixed carbon-composition resistors.
R1, R6, R7—1000 ohms
R2, R10 through R15, R22, R31, R32, R34—100,000 ohms
R3, R36, R41—100,000-ohm, linear-taper potentiometer
R4, R25, R26—3300 ohms
R5—300,000 ohms
R8, R40—100 ohms
R9—75,000 ohms
R16, R17—22,000 ohms
R18, R35—68,000 ohms
R19, R20, R37, R38—43,000 ohms
R21—10 ohms
R23—36,000 ohms
R24, R27, R28—15,000 ohms
R29—62,000 ohms
R30—180,000 ohms
R33—20,000 ohms
R39—10,000-ohm, linear-taper potentiometer
S1—Dpdt pc-mount push-on/push-off switch
Misc.—Printed circuit board, IC sockets or Molex Soldercons, circuit board standoffs, control knobs, suitable enclosure, shielded patch cords, hookup wire, etc.

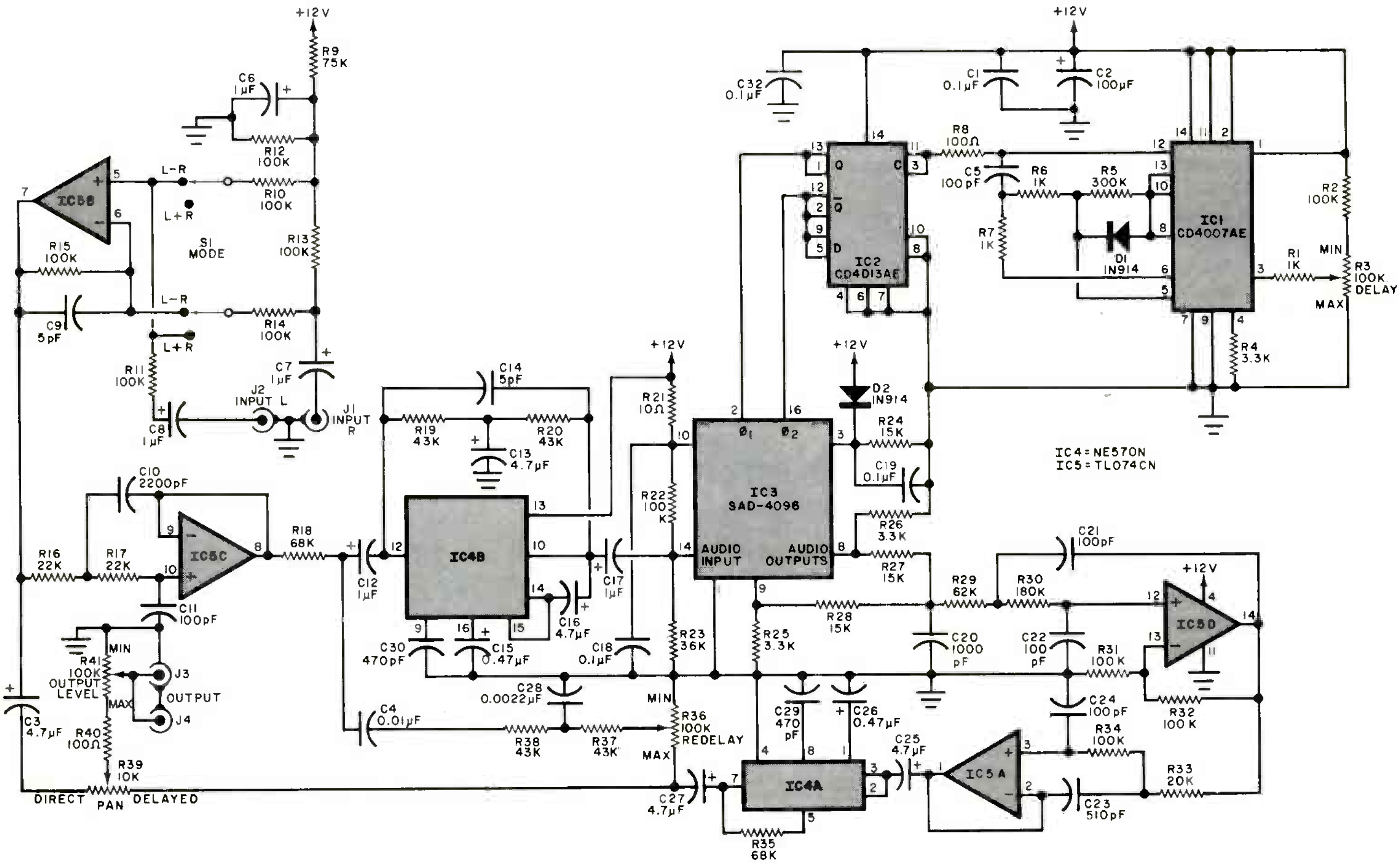


Fig. 2. Schematic diagram of the delay line. Two audio input channels are combined by IC5C into a single channel which is delayed by IC3.

lation loop gain is well below 0 dB. A loop gain of more than 0 dB will make the system unstable.

The bandwidth of the delay line and the rate at which its input signal is sampled are intimately related. Although standard high-fidelity practice would dictate a flat frequency response between 20 and 20,000 Hz, a narrower bandwidth is appropriate for a delay line. The principal reason for this is that natural reverberation generally causes high-frequency attenuation.

Sampling theory indicates that a signal must be sampled at least twice every period if it is to be reconstructed into continuous form without error. The sampling frequency thus should be at least twice that of the highest frequency in the signal. Furthermore, a rolloff caused by the reconstruction process itself results in a response 3 dB down at approximately one-third of the sampling frequency. (This rolloff is in addition to any due to a smoothing filter at the output.)

Any signal frequency greater than one-half of the sampling frequency will stimulate the production of aliases or beat tones that fold back into the useful passband. For example, if a 22-kHz signal is sampled at a rate of only 40 kHz, an alias will appear at 18 kHz. Accordingly, for all of the above reasons, it is good design practice to band-limit the signal to be sampled to about one-third of the sampling rate.

About the Circuit. The Analog Audio Delay Line appears in block-diagram form in Fig. 1 and schematically in Fig. 2. The block diagram shows the principal function stages of the project.

A voltage-controlled oscillator generates a train of pulses at a rate determined by the setting of the DELAY potentiometer. The oscillator drives a flip-flop which provides a two-phase clock signal by means of its complementary (Q and $\overline{Q}$) outputs. This two-phase clock governs the transfer of signal samples within the analog shift register.

An op-amp input stage accepts signals from the two main stereo channels and generates either an L+R or L−R output, depending on the position of the MODE switch. A considerable saving in system cost and circuit complexity can be realized by combining the main stereo channels to form one channel of delayed information.

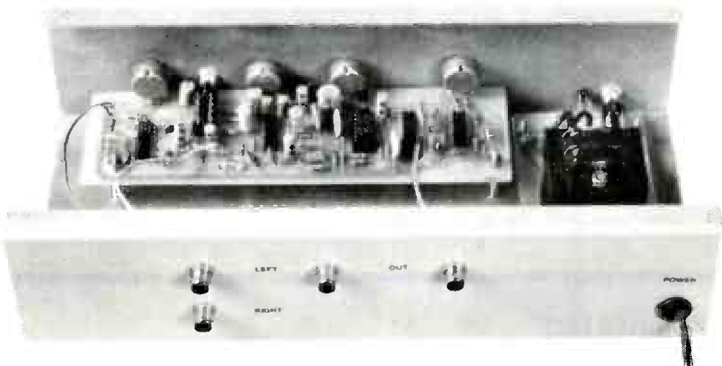
Summing the two main channels before delaying them results in a conventional monaural signal that is then delayed, amplified and reproduced by a single loudspeaker. The usefulness of the L−R mode can be dramatically demonstrated by listening to a stereo FM broadcast. During the musical portion of the broadcast, relatively high levels of L+R or stereo reverberation can be introduced to provide a pleasing audio effect. When the announcer's voice is heard, it sounds as if he is talking from the bottom of a well. This can also happen when a centered vocal or instrumental soloist predominates.

The L−R mode, in which the direct center components are cancelled out, can prevent this from happening. An additional benefit provided by the L−R mode is realized because of the common mixdown practice of placing room or ambience microphones and studio reverberation unit output signals away from center. Although it is not possible to completely characterize the differences in sound quality provided by the two modes, the author's experience is that L−R reverberation sounds "softer" or more subtle. The type of music and the particular mix-down will determine which mode is more pleasing.

The signal from the input network is applied to a second-order active low-pass filter with a cut-off frequency of 15 kHz. This prevents foldback/aliasing problems that might otherwise occur. A 2:1 IC compressor acts on the filter output before it is applied to the analog shift register. Also applied to the compressor input is a signal component that is provided by the recirculation loop.

Delayed audio signals appearing at the output of the analog shift register are treated by a fifth-order active low-pass filter before being processed by a 1:2 IC expander. This filter smooths out the signal provided by the delay line and suppresses any ultrasonic clock energy contained in it. One portion of the expander output makes its way back to the compressor input by means of a recirculation loop. This loop comprises *R36*, the REDELAY potentiometer, which permits adjustment of the amount of delayed signal fed back to the input compander, as well as a passive bandpass filter (*R37*, *R38*, *C4* and *C28*). The bandpass filter provides additional high-frequency rolloff for each recirculation of the signal and some low-frequency rolloff. The accelerated absorption of high-frequency components simulates the treble loss of natural reverberation; the low-frequency attenuation prevents the reverberant signal from sounding muddy.

Complementary compression and expansion make it possible for the delay line project to have an impressive dynamic range. The rated S/N of the SAD-4096 analog shift register varies from more than 75 dB for its shortest delays to approximately 65 dB for its longest delay time. The compansion employed in this project allows the delay system to have a very large dynamic range. As measured by the author, the IHF "A" weighted noise at the project's delayed output is −91.5 dBm at 5 milliseconds and −89 dBm at 100 milliseconds. Input-level adjustments are therefore unnecessary.



This photograph of prototype shows how author housed main pc board and ac supply inside custom enclosure.

Output signals are presented to PAN control *R39*. This potentiometer allows the user to drive the subsequent stages in the signal chain with a fully undelayed audio signal (when the wiper is set to the DIRECT extreme of its travel), a fully delayed signal (when the wiper is set to the DELAYED extreme of its travel), or with a mixture of the direct and delayed versions of the input signal (when the wiper is set between the two extremes of its travel). Potentiometer *R41* can be adjusted for the desired balance of front to back sound levels.

(Continues on next page.)

Power Supply. The analog delay line project requires modest electrical power. Its basic requirement can be obtained from any single-ended supply capable of delivering 12 volts at 20 mA. This modest amount of power can be provided from the ac power line with the ac power supply shown schematically in Fig. 3. This supply employs a center-tapped step-down transformer (*T1*), a full-wave rectifier (*D1* and *D2*), four capacitors (*C1* through *C4*), and a 12-volt regulator integrated circuit (*IC1*). Light-emitting diode *LED1* is a convenient power-on indicator.

In mobile and many other applications, however, a source of 117-volt sinusoidal ac power is not readily available. In such situations, the project can be powered by the dc power supply shown schematically in Fig. 4. This power supply employs a zener diode (*D3*) as a voltage reference for an LM301 operational-amplifier integrated circuit (*IC1*), which, in turn, governs the operation of a pass transistor (*Q1*). This pass transistor acts as the regulated source for the delay circuit. The dc supply can be used with virtually any unregulated source capable of delivering +12 to +30 volts dc. Again, *LED1* serves as a convenient power-on indicator.

Construction. The use of printed-circuit construction techniques is strongly recommended. Full-size etching and drilling guides of suitable pc boards for the main

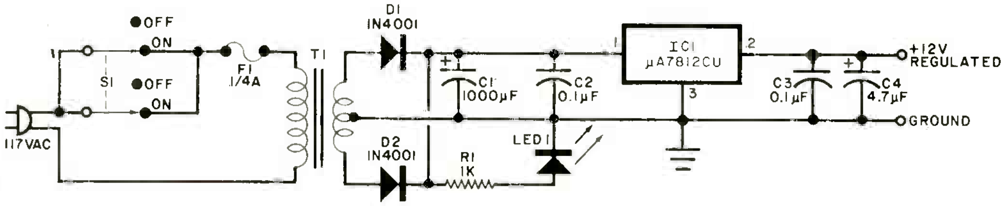


Fig. 3. This full-wave line-powered supply furnishes regulated +12 volts for the audio delay circuit.

PARTS LIST
AC POWER SUPPLY

C1—1000-µF, 25-V radial-lead electrolytic
C2,C3—0.1-µF, 50-V disc ceramic capacitor
C4—4.7-µF, 16-volt radial-lead electrolytic
D1,D2—1N4001 rectifier diode
F1—¼-ampere fast-blow fuse
IC1—µA7812UC 12-volt regulator
LED1—Light-emitting diode
R1—1000-ohm, ¼-watt, 5% fixed carbon composition resistor
S1—Dpdt pc-mount push-on/push-off switch or spst toggle switch
T1—20-volt, 250-mA center-tapped stepdown transformer (Signal Transformer Co. No. ST-4-20 or equivalent)
Misc.—Printed circuit board; fuse clips; line cord; strain relief; circuit board standoffs; machine hardware; hookup wire; solder; etc.

PARTS LIST
DC POWER SUPPLY

C1,C5—0.1-µF, 50-V ceramic disc capacitor
C2—100-µF, 16-V radial-lead electrolytic
C3—4.7-µF, 16-V radial-lead electrolytic
C4—100-pF, 50-V ceramic disc capacitor
D1,D2—1N914 diode
D3—6.2-volt, 1-watt zener diode (1N4735 or equivalent)
F1—¼-ampere fast-blow fuse
IC1—LM301AN operational amplifier
LED1—Light-emitting diode
Q1—2N3906 pnp silicon transistor
The following are ¼-watt, 5%, fixed carbon-composition resistors:
R1,R7—510 ohms
R2,R5—30,000 ohms
R3,R4—10 ohms
R6—33,000 ohms
R81500 ohms
S1—Dpdt pc-mount push-on/push-off switch or spst toggle switch
Misc.—Printed circuit board; fuse clips; strain relief; circuit board standoffs; hookup wire; solder; hardware; etc.

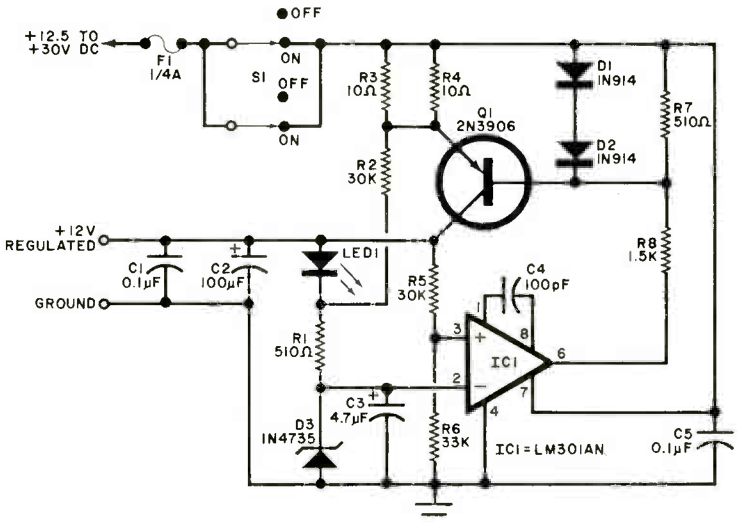
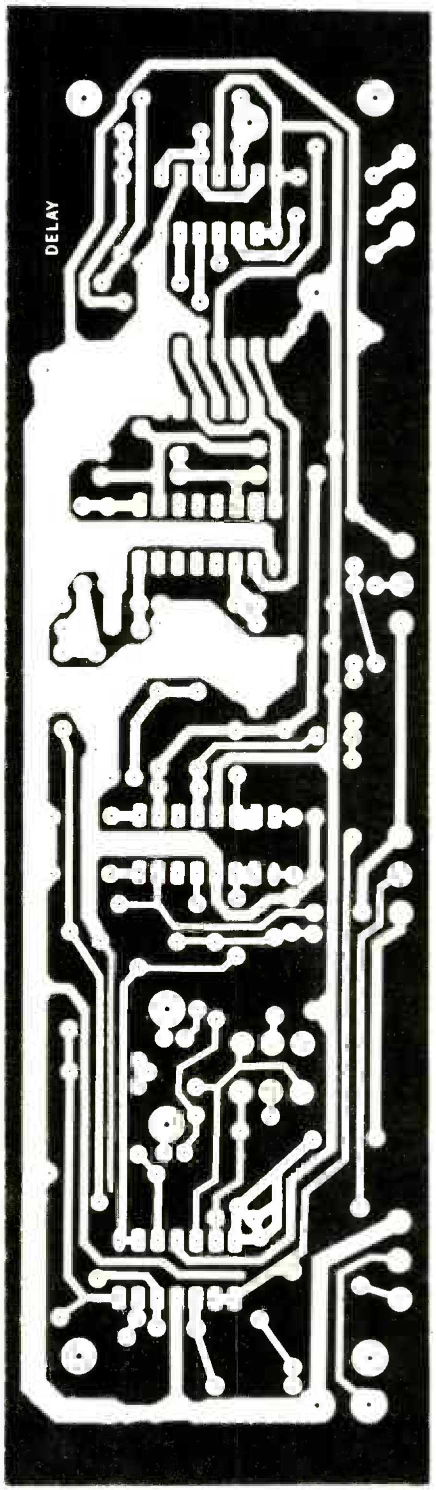


Fig. 4. This supply should be used for remote or mobile applications when ac line power is not available.

delay circuit, the ac power supply, and the dc supply appear in Figs. 5, 6, and 7, respectively. Component-placement guides for these boards appear in Figs. 8, 9, and 10. The main circuit board has been laid out to keep power and ground bus runs as short and direct as possible, and to prevent objectionable leakage of ultrasonic clock energy into the audio-frequency signal path.

Sockets or Molex Soldercons should be used when mounting ICs on the main circuit board, especially for *IC3*—any device costing that much deserves special handling. When mounting semiconductors and electrolytic capacitors, be sure to observe polarity and pin basing. Use the minimum amount of heat and solder consistent with the formation of good solder joints. Those components mounted off the board can be connected to it by means of suitable lengths of stranded, insulated hookup wire.

When assembly of the circuit boards is complete, carefully inspect them for cold solder joints, solder bridges between adjacent foils, reversed polarities, etc. Then interconnect the main board with the power supply board that has been assembled, using short lengths of stranded, insulated



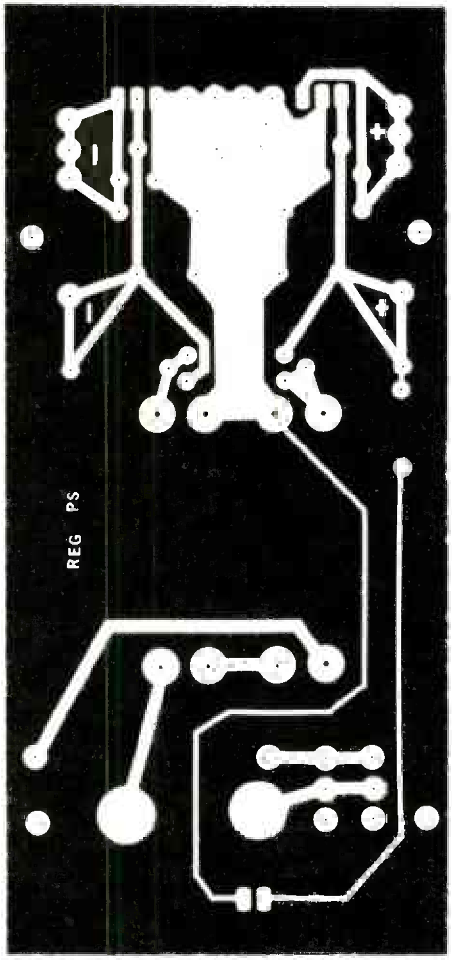


Fig. 6. Etching and drilling guide for the ac power supply printed-circuit board.

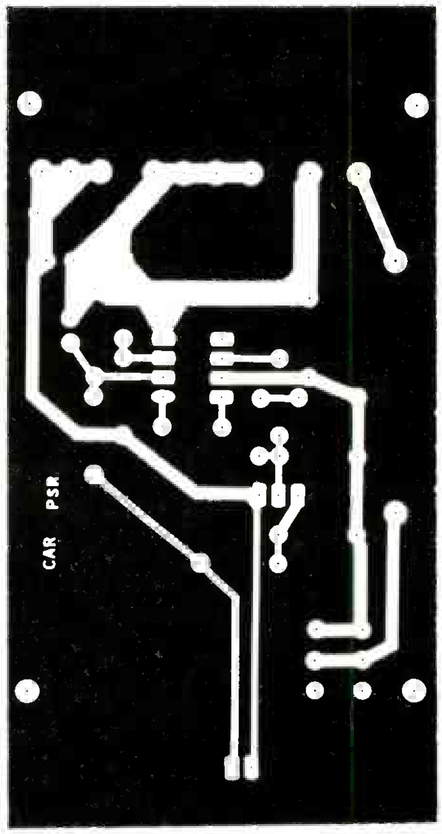


Fig. 7. Etching and drilling guide for the dc power supply printed-circuit board.

Fig. 5. Full-size etching and drilling guide for the main printed circuit board.

hookup wire. Finally, mount the boards in a suitable enclosure, with spacers to insulate the boards from the metallic surfaces of the cabinet.

Adding It to Your System. Use shielded audio patch cords of appropriate lengths to interconnect the project with your existing audio system. The main stereo channels should be tapped at some point at which the signals are at line level. If the signals are tapped at the output of the preamplifier, the project's output level potentiometer can be used as a front-to-back balance control. If the signals are tapped before the preamplifier's volume control, the project's output level potentiometer will have to be readjusted every time the level of the front channels is changed.

A single channel of delayed audio information calls for a monophonic power amplifier and one speaker system. However, the author's prototype includes two output jacks wired in parallel so that both

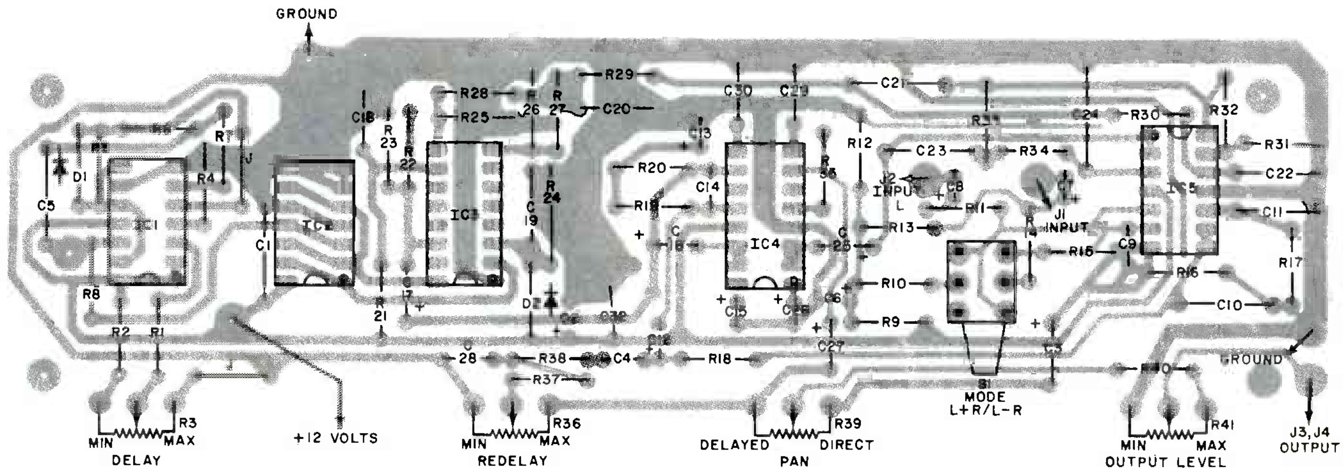


Fig. 8. Component-placement guide for the audio delay line's main pc board.

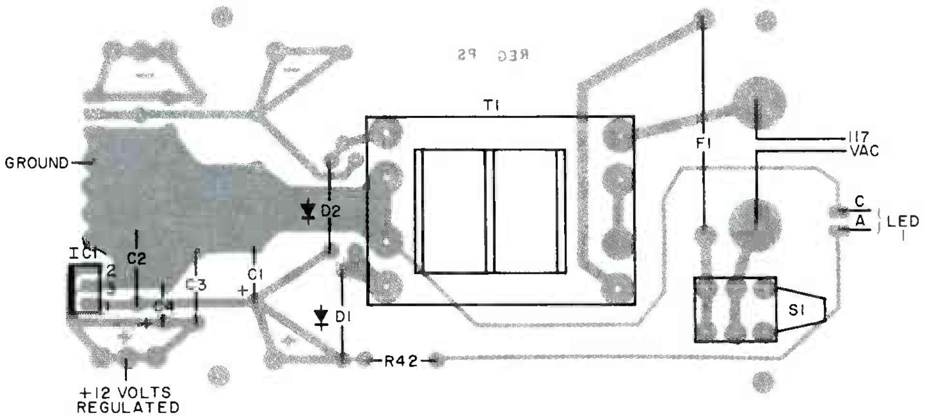


Fig. 9. Component-placement guide for the ac power supply of the project.

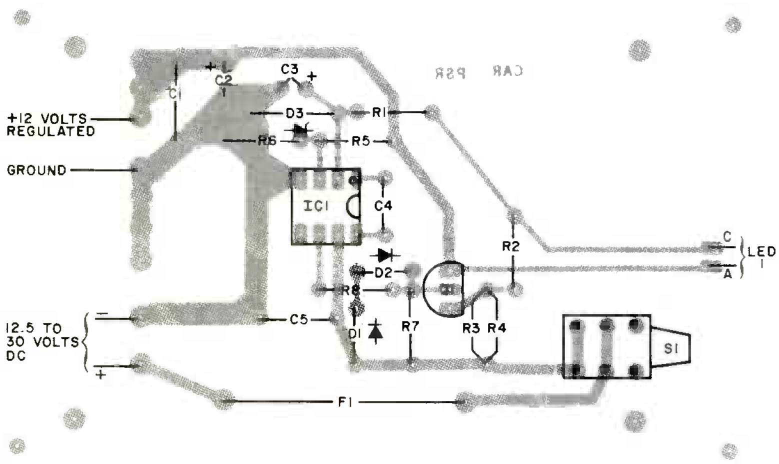


Fig. 10. Component-placement guide for the regulated dc-powered supply for the audio delay line.

channels of a stereo amplifier can be driven by the same signal if desired. The rear-channel amplifier can have a power rating as low as one-fourth that of the front-channel amplifier. Excellent performance has been obtained with as little as 20 watts of rated amplifier power for the rear channel.

Similarly, the speaker system associated with the rear channel need not be as sophisticated as those used in the main (front) stereo channels. Deep bass response and extended high end are simply not needed. A speaker system with clean midrange response and a power-handling capacity compatible with the rear-channel amplifier output power will suffice.

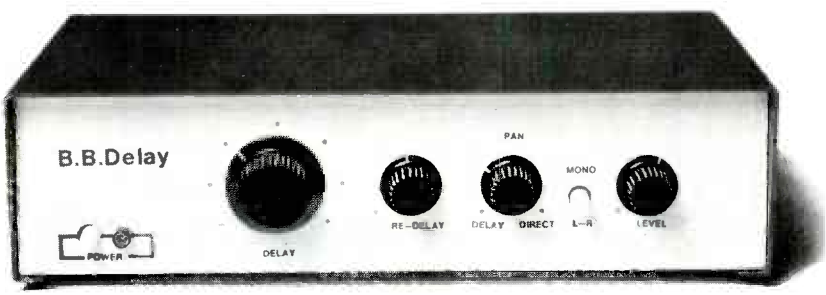
There are no "correct" delay-unit control settings. These adjustments should be guided by the type of music being reproduced and the personal taste of the listener. Also, the amount of reverberation that will have to be instroduced to achieve a desired effect will depend on the individual recording of a given piece of music.

Two discrete delay channels can share a common enclosure and power supply. Such a configuration is available in kit form and can be connected to the main stereo channels in such a way that monaural addition or subtraction will not take place. If desired, one clock can be be used to drive both stereo delay lines so that the delay times track each other. A richer sound may result if each channel has an independent, adjustable clock.

KIT AND PARTS AVAILABILITY

The following are available from Phoenix Systems, 91 Elm St., Manchester, CT 06040: Complete kit of parts, including enclosure, for a single-channel, dc-powered delay line, No. P-25-DLC, for $145; complete kit of parts, including enclosure, for for a single-channel ac-powered delay line, No. P-25-DL, for $150; complete kit of parts for two-channel ac- or dc-powered (specify) delay line, No. P-25-SDL, for $250. The following are also available separately from the same source: SAD-4098 bucket-brigate analog shift register IC, No. P-SAD-4096 for $40.00; etched and drilled main printed-circuit board, No. P-25-DB, for $8.00; NE570N compander IC, No. P-NE570N, for $4.50; Signal Transformer Co. No. ST-4-20 step-down transformer, P-94-T, for $6.50; etched and drilled ac power-supply printed-circuit board, No. P-25-PSB, for $5.00; dc power-supply board, No. P-25-PSBC, for $5.00; TL074CN high-performance quad biFET operational amplifier, No. P-TL047CN, for $2.50; μA7812UC 12-volt regulator IC, No. P-7812UC, for $1.50; 100,000-ohm linear-taper, pc-mount potentiometer, No. P-100KB, for $1.00; 10,000-ohm, linear-taper, pc-mount potentiometer, No. P-10KB, for $1.00; push-on/push-off pc-mount dpdt switch, No. P-2PDT, for $1.00. Add $1.00 handling charge for orders less than $10. All items postpaid within continental U.S. COD orders subject to $2.00 surcharge. Connecticut residents, add state sales tax.

In Conclusion. Psychoacoustics is still as much an art as a science and remains a fertile field for experimentation. The analog delay line that has been presented here is designed with the adventurous, inquisitive audiophile in mind. It is, therefore, well suited for those readers who want to experiment with time-delay techniques.



External (above) and internal (below) views of author's prototype.

HIGH-SPEED **ELECTRONIC FUSE**

"Blows" within microseconds to protect sensitive components

BY CHARLES M. LENNY AND CHESTER DAVENPORT

FUSES, in many cases, blow too slowly to prevent damage in solid-state circuits. Power transistors, which are prone to thermal runaway when passing excessive currents, are especially vulnerable to slow-opening fuses. The electronic "fuse" shown in the schematic is a basic crow-bar circuit that operates in a hundred microseconds or so—more than fast enough to save low-power transistors—and can safely handle load currents up to 60 amperes.

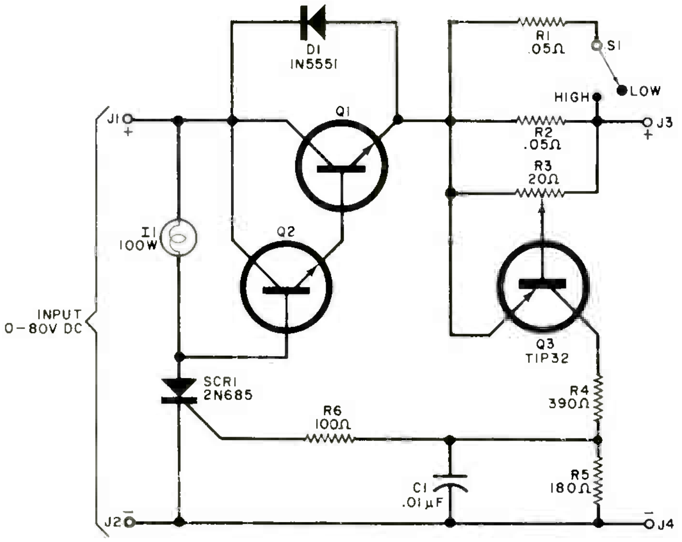
How It Works. When an overcurrent triggers *SCR1* into conduction, base drive is diverted from series-pass transistors *Q1* and *Q2*, which cut off and stop the flow of current to the load. Incandescent lamp *I1* has about a 10-ohm resistance when cold, and drops very little voltage. When *SCR1* fires, the lamp glows, and the filament resistance increases to about 100 ohms, minimizing the load on *SCR1* and acting as an indicator to show that the circuit has tripped.

Potentiometer *R3* establishes the desired trip current. When the current passing through *R2* (and *R1* when *S1* is set to HI), exceeds the desired limit, transistor *Q3* turns on. The resulting positive voltage generated across *R5* turns on *SCR1*. Resistor *R6* limits the SCR gate current to a safe value. Diode *D1* permits operating the electronic fuse with an inductive load, removing any probability of punch-through of *Q1* or *Q2*.

Construction. At 60 amperes, resistors *R1* and *R2* can dissipate 45 watts each and should be provided with suitable heat sinking. A similar heat sink should be used for *Q1*, *Q2* and *SCR1*. These two heat sinks should be mounted on two exterior sides of the selected chassis. A socket for *I1* can be mounted on top of the chassis. Input and output power connectors *S1*, and *R3* can be mounted on an empty side as desired. The Solitron SDT96306 can handle 70 amperes at 325 volts. A 2N3055 that can handle 15 amperes at 60 volts is an acceptable substitute.

Calibration of *R3* is performed by using various resistive loads to draw specific currents, with *R3* adjusted so that the lamp glows when the specific current is reached. A dial plate on *R3* is used to identify the calibration points. Remember that the trip current must be within the pass transistor's rating.

Since the SCR is powered by dc, once it fires it will remain in the conductive state until the applied dc voltage is removed. This can be done either by installing a series switch in either of the supply leads or by turning off the driving power supply. ◇



PARTS LIST

C1—0.01-µF disc capacitor
D1—1N5551 diode
J1 through J4—5-way binding post, color coded
I1—100-W incandescent lamp
Q1, Q2—SDT96306 (70 amperes) or 2N3055 (15 amperes)
Q3—TIP32 or any silicon transistor
R1, R2—0.05-Ω, 50-W resistor
R3—20-Ω, 5-W potentiometer
R4—390-Ω, 10-W resistor
R5—180-Ω, 1-W resistor
R6—100-Ω, 1/2-W resistor
S1—Spst switch
SCR1—2N685 or similar SCR
Misc.—Suitable heat sinks (2), socket for I1, enclosure, terminal strips, mounting hardware.

Do-It-Yourself LOGIC CHIPS

By Forrest M. Mims

IN THIS day of ultra-sophisticated semiconductor technology, large-scale and very-large-scale integrated circuits (LSI and VLSI respectively) containing hundreds or even thousands of logic gates have become commonplace. Nevertheless, examine any board containing one or more LSI or VLSI chips and you'll probably find an assortment of small- and medium-scale integrated circuits (SSI and MSI) with relatively few gates or flip-flops package.

Circuit designers have long wanted to combine in a few packages the relatively small number of gates and flip-flops required to support most LSI and VLSI chips. Custom ICs are usually out of the question because of their high price and long development time. And what happens if a design change is necessary?

Semi-custom integrated circuits are a better choice. These chips contain arrays of gates which have not been *metalized*. In other words, the gates are independent of one another since they've not yet been connected together electrically by a metalization pattern on the top surface of the chip. The customer tells the custom IC house how he wants the gates interconnected, and the gate chips are then metalized according to the customer's specifications and installed in DIPs.

This procedure is faster and cheaper than the custom IC route, but it's still relatively expensive since the customer usually must agree to buy a thousand or more chips. And as in the case of the custom IC, what happens if a design change is necessary?

A third alternative is the do-it-yourself logic chip. Included in this category are *field programmable logic array* (FPLA) and *programmable array logic* (PAL, a trademark of Monolithic Memories, Inc.) chips. These chips contain arrays of logic gates interconnected via the same kind of fusible links used to make programmable read-only memories (PROMs). By selectively applying high-current pulses to the programming pins of an FPLA or PAL, fusible links can be opened in various patterns to produce a customized integrated circuit.

The PROM is itself a versatile do-it-yourself logic chip since it can be used to implement any truth table for which it has sufficient inputs and outputs.

You can better understand the operation and compare the differences of PROMs, FPLAs and PALs be referring to Figs. 1, 2 and 3. They show the internal circuitry of ultra-simple, hypotheti-

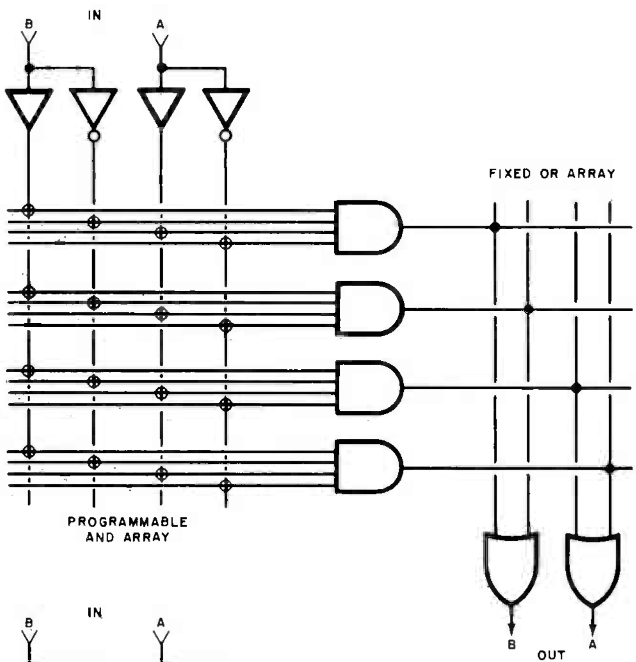


Fig. 2. A hypothetical PAL of two four-bit words. It is a backward PROM since the AND array is programmable while the OR is fixed.

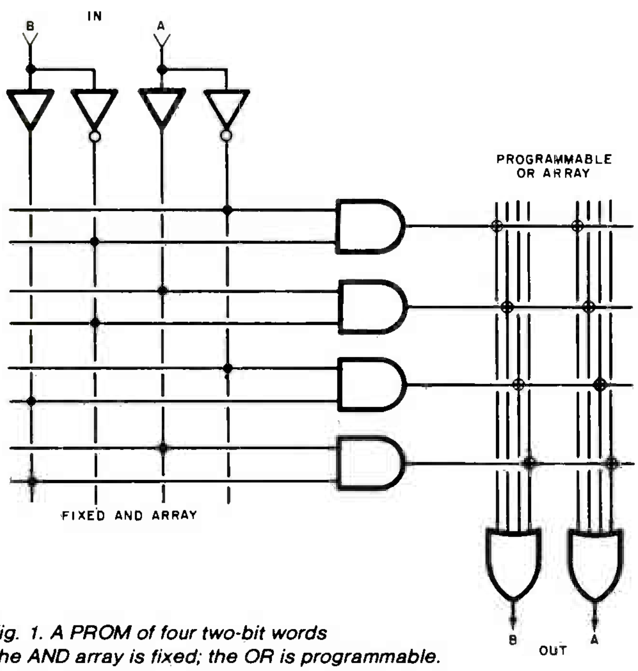


Fig. 1. A PROM of four two-bit words The AND array is fixed; the OR is programmable.

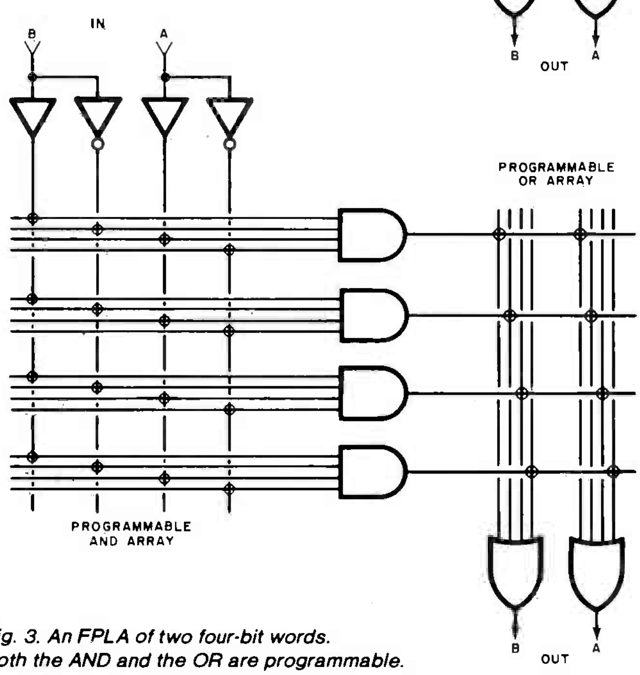


Fig. 3. An FPLA of two four-bit words. Both the AND and the OR are programmable.

cal versions of each of these three kinds of programmable logic arrays.

As is readily apparent from these figures, all three circuits contain an AND array followed by an OR array. The input word applied to the AND array can be considered an address, data word or bit pattern. In any case, the effect is the same since a particular input switches the output of one of the AND gates from low to high. The outputs then reflect whether or not connections are present at the junction of the output line from a selected AND gate and thc input lines to the OR gates.

A solid dot at the intersection of two array lines means the connection was unalterably programmed when the chip was made. User programmable fusible links are indicated by small circles at intersection array lines.

In the PROM (Fig. 1), the AND array is permanently programmed or *fixed* while the OR array is programmable. The AND array in Fig. 1 is programmed to address in turn each of the AND gates from top to bottom according to a standard 00, 01, 10, 11 input sequence.

The PAL (Fig. 2) is a backward PROM since the AND array is programmable while the OR array is fixed. In real PALs the OR array is factory programmed to give some of the most commonly used logic functions.

The FPLA (Fig. 3) is the ultimate do-

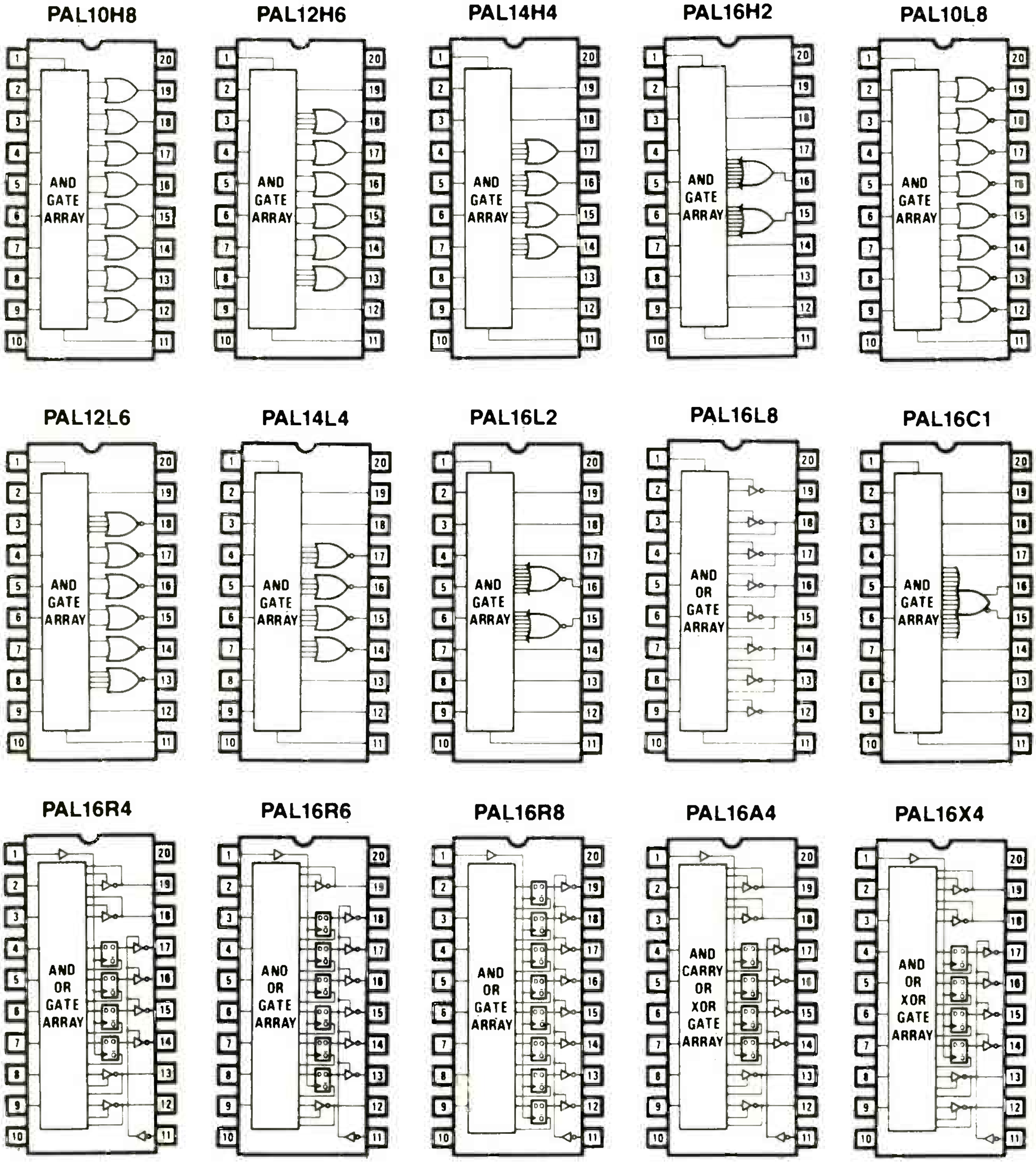


Fig. 4. Pin outlines and internal block diagrams of the PAL family of chips.

it-yourself logic chip since *both* the AND and OR arrays are programmable. While this provides the highest degree of flexibility, in practice the FPLA is much more dificult to use and more expensive than either the PROM or the PAL. All three kinds of chips can be programmed using standard PROM programmers, but the programming procedure for the FPLA is at least twice as cumbersome since both the AND and OR arrays must be programmed.

Some PALs and FPLAs include flip-flops to store output states and feed results back to the inputs. This makes possible such functions as counting, shifting and sequencing.

PALs without flip-flops can perform virtually any task now accomplished with SSI and MSI logic chips up to and including a 4-bit arithmetic logic unit! In many applications a single PAL can replace up to ten SSI/MSI packages.

A clever feature of PAL chips is a data security fuse. After the PAL has been programmed, the security fuse is blown to disable the circuit's internal verification logic. This prevents the internal program from being read out by a potential copier, thereby making the chip proprietary.

The PAL concept was pioneered by John Birkner of Monolithic Memories, Inc., and that firm now makes a family of fifteen PAL chips with National Semiconductor as a second source. Figure 4 shows the pin outlines and internal block diagrams for all fifteen chips. As you can see, considerable flexibility is provided by this lineup.

Information about PALs and FPLAs is not too abundant. The best way to learn more about PALs is to contact a Monolithic Memories or National distributor or representative. Try to obtain a copy of the excellent "PAL Programmable Array Logic Handbook" published by Monolithic Memories (1165 E. Arques, Sunnyvale, CA 94086).

Signetics (P.O. Box 9052, Sunnyvale, CA 94086) is a major maker of FPLAs. Their "Bipolar and MOS Memory Data Manual" contains FPLA data sheets and related information. Two Signetics engineers, Napoleone Cavlan and Stephen J. Durham, have written an excellent two-part article of the subject for *Electronics* (July 5, 1979, pp. 109-114 and July 19, 1979, pp. 132-139). In an article for *Computer Design* (April 1980, pp. 141-147), Mr. Durham described a complete 60-character keyboard encoder complete with key debouncing and made from a *single* Signetics 82S105 FPLA!

You can find the aforementioned articles in any good public or university library. For manufacturer's literature, check the yellow pages and call local electronics distributors or reps. If they can't help you, ask for the phone number of an authorized rep in any nearby city or state. If necessary, call the company direct. The cost of a few long distance calls may be well worth the results you'll harvest.

Do-it-yourself logic chips require careful design procedure and a PROM programmer so they're not necessarily suited for the typical hobbyist or experimenter. But if you want to greatly simplify a favorite logic circuit while learning about one of the latest trends in digital circuit design, get your hands on some manufacturer's literature and warm up your PROM zapper.

WIRELESS AD*ZAP TURNS OFF TV COMMERCIALS

A beam of infrared shuts off video and/or sound for a preset period

HAS a television commercial ever made you feel like shooting your receiver? Now you can "blow away" commercials without destroying the TV set. The AD•ZAP TV Commercial Killer presented here employs "bullets" of infrared light to kill the sound and/or picture during an annoying advertisement. The project is relatively simple and can be connected to virtually any television receiver with only minor work.

When assaulted by an undesirable commercial, the viewer points a remote transmitter (which can be assembled into a plastic toy pistol or a standard case) at a small photoelectric receiver attached to the TV set and momentarily closes a switch. The transmitter thereupon emits an infrared signal that silences the sound and causes the receiver to start its selectable timing interval (30 or 60 seconds). If a second infrared signal is received during the timing interval, the TV picture tube is darkened. At the end of the interval, normal television-receiver operation is automatically restored. Receipt of a third infrared pulse before the timing interval ends will restore normal TV operation. Since the TV receiver remains powered and in sync during the timing interval, the picture returns without rolling or tearing.

The transmitter is a small, self-contained, battery-powered wireless unit. Its companion receiver is housed in a small metallic enclosure that is generally positioned atop the TV set. The AD•ZAP receiver is powered by a small wall-mount transformer and is connected to the rear panel of the television receiver by means of a multi-conductor cable of convenient length. Disconnecting the AD•ZAP receiver from the TV set leaves the TV fully ready for normal operation.

About the Circuit. The schematic diagrams of two versions of the AD•ZAP transmitter are shown in Fig.1. At A is the transmitter circuit designed for installation in a plastic enclosure approximately the size of a pack of cigarettes.

BY DIETRICH SEAMAN

The circuit shown at B is almost identical and is designed to be mounted in a plastic-body six-shooter similar to the type used in some electronic target-practice games.

When switch *S1* is closed, battery power is applied to the astable multivibrator comprising 555 timer *IC1* and associated components. The multivibrator begins to oscillate and, when the output pulse causes pin 3 of *IC1* to be low (about 25% of the time), high-level current pulses flow through infrared emitter *LED1*. The LED radiates bursts of infrared at a rate of approximately 3.2 kHz. The exact pulse rate is determined by the setting of trimmer potentiometer *R2*. Capacitor *C3* ensures that enough current is available to the circuit during the time that *LED1* is conducting.

The schematic diagram of the AD•ZAP receiver is shown in Fig. 2. Pulsed infrared from the transmitter causes phototransistor *Q1* to turn on and off at around 3.2 kHz. Before infrared signals reach the phototransistor, they pass through an optical bandpass filter that attenuates much of the incident visible light that would otherwise affect the operation of *Q1*.

Voltage pulses developed across the phototransistor are amplified 60 dB by ac-coupled amplifiers *IC1F* and *IC1E*. These stages, as well as the high-Q, active state-variable filter that follows (*IC1A, IC1B, IC1C*), are part of a CD-4069 hex inverter. Although this CMOS chip is usually employed in a nonlinear operating mode, it is used here as linear amplifier inverter gates, much as low-gain op amps.

Also employed in this fashion is unity-gain buffer amplifier *IC1D*. This buffer supplies filtered pulses to the detector comprising *C6, C7, D1, D2,* and *IC3A*. Diode *D1* is a biased clamper that limits negative excursions of *IC1D*'s output to a level determined by the setting of THRESHOLD potentiometer *R16*. Half-wave rectifier *D2* passes pulsed positive dc to filter *R17C7*. After approximately 10 milliseconds, the voltage across *C7* increases to a level sufficient to trigger the Schmitt trigger—*IC3A, R19,* and *R20*. The output of *IC3A* thus goes to logic 1 when an infrared pulse reaches phototransistor *Q1*. Gate *IC3A*, together with *C8, R21* and *R23*, also acts as a debouncer that generates a clean logic pulse when manual control switch *S1* is closed.

The output of *IC3A* is applied to dual D flip-flop *IC2*. This chip is wired to function as a ÷3 counter. The first pulse applied to it causes pin 1 of *IC2A* (the Q output of the first flip-flop) to go to logic 1. As a result, relay driver *Q2* receives base drive from gate *IC3D* via *R29* and begins to conduct. Relay *K1* interrupts the circuit between the audio output stage of the TV set and the TV loudspeaker, and SOUND OFF indicator *LED1* begins to glow. Also, the logic-1 output of gate *IC3D* is inverted by *IC4A*, and the output of this NAND gate brings the RESET input of multistage counter *IC5* to logic 0. The counter then begins to tally the 60-Hz pulses

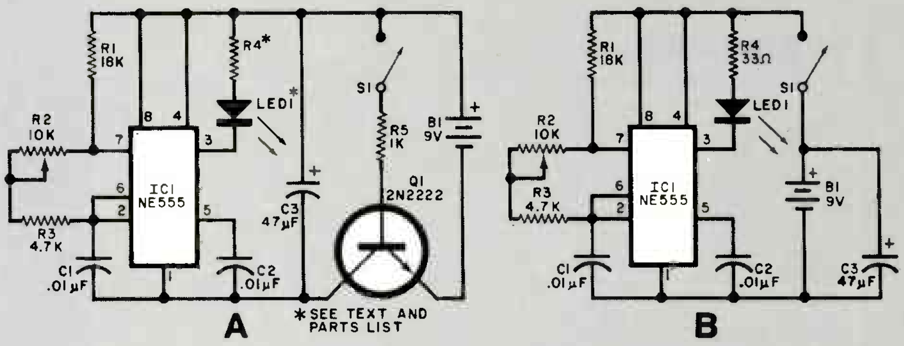


Fig. 1. Schematic diagrams of the box-style (A) and gun-style (B) infrared transmitters.

BOX-STYLE TRANSMITTER PARTS LIST

B1—9-volt transistor battery
C1—0.01µF, 10% tolerance Mylar capacitor
C2—0.01-µF disc ceramic capacitor
C3—47-µF, 10-volt radial-lead aluminum electrolytic or tantalum capacitor
IC1—NE555 timer
LED1—TIL32 unlensed infrared-emitting diode or TIL31 or LED55C lensed infrared-emitting diode
Q1—2N2222 npn silicon switching transistor
The following, unless otherwise specified, are ¼-watt, 10% tolerance, carbon-composition fixed resistors.
R1—18 kΩ
R2—10 kΩ, linear-taper horizontal pc-mount trimmer potentiometer
R3—4.7 kΩ
R4—33 Ω if *LED1* is a TIL32 unlensed diode, 15 Ω if *LED1* is a TIL31 or LED55C lensed diode
R5—1 kΩ
S1—Spst, normally open, momentary-contact pushbutton switch
Misc.—Mounting collar for *LED1*, lens for *LED1* if a TIL32 device is used, printed-circuit board, battery clip, suitable enclosure, solder, pc-board standoffs, suitable hardware, etc.

Note—Pushbutton switch S1 is a Panasonic No. EVQ-P1R component that is available from Digi-Key, Box 677, Highway 32 South, Thief River Falls, MN 56701.

GUN-STYLE TRANSMITTER PARTS LIST

B1—9-volt transistor battery
C1—0.01-µF, 10%-tolerance Mylar capacitor
C2—0.01-µF disc ceramic capacitor
C3—47-µF, 10-volt radial-lead aluminum electrolytic or tantalum capicitor
IC1—NE555 timer
LED1—TIL32 infrared-emitting diode
The following, unless otherwise specified, are ¼-watt, 5%-tolerance, carbon-composition fixed resistors.
R1—18 kΩ
R2—10 -kΩ, linear-taper vertical pc-mount trimmer potentiometer
R3—4.7 kΩ
R4—33 Ω
Misc.—Printed-circuit board, battery clip, plastic-body Coleco electronic-game gun with trigger-actuated switch (*S1*) and lens system, solder, etc.

Note—The Coleco gun is available from Meshna Electronics, Box 62, 19 Allerton Street, East Lynn, MA 01904.

that are derived from the ac power line, filtered by passive network *C2R34*, and squared up by Schmitt trigger *IC3B*.

If a second pulse appears at the output of *IC3A* due to either the receipt of another burst of infrared or a closure of switch *S1*, the Q output of *IC2A* (pin 1) returns to logic 0 and the Q output of *IC2B* (pin 13) goes to logic 1. The output of *IC3D* remains at logic 1, keeping *Q2* in saturation, but *Q3* begins to receive base drive from the Q output of *IC2B* via *R26*. As a result, relay *K2* becomes energized and PICTURE OFF indicator *LED2* begins to glow. The relay contacts are connected to the nodes of the television receiver's brightness-determining circuit. Closure of contacts D and F causes the screen to darken.

Both relays remain energized until either a third burst of infrared is received, switch *S1* is closed, or counter *IC5* has tallied 1800 pulses for a 30-second delay or 3600 pulses for a 60-second delay, depending on the setting of *S2*. If the counter runs through its cycle undisturbed, it will reset itself via *IC4B* and *IC4A* and will reset *IC2A* and *IC2B* via *IC4B*, *IC4A*, and *IC3C*. Both relays will then be deenergized and normal television reception will be reestablished. The counting cycle can be interrupted and the relay(s) deenergized at any time by a closure of *S1*. Passive components *C9* and *R24* generate a 100-millisecond pulse when power is first applied to the circuit. This pulse is routed to the RESET inputs of *IC2A* and *IC2B* via *IC3C* and ensures that both flip-flops are properly initialized and the relays deenergized in spite of any turn-on transients.

Power required by the AD•ZAP receiver is furnished by the simple supply shown in the lower right corner of Fig. 2. Unregulated dc provided by bridge rectifier *D3* through *D6* and filter capacitor *C11* powers the relay and LED indicator circuits. The CMOS logic ICs are powered by +5 volts regulated, which is furnished by integrated regulator *IC6*. This particular supply voltage was chosen for the CMOS ICs because such circuits when operated in the linear mode exhibit higher gains at lower supply voltages.

Construction. The use of printed-circuit construction techniques is recommended. Suitable full-size etching and drilling guides for the two versions of the AD•ZAP transmitter are shown in Figs. 3A and 3B. The receiver pattern is shown in Fig. 4. The full-size etching and drilling guide of the circuit board that accommodates relays *K1* and *K2* and protective diodes *D7* and *D8* appears in Fig. 5. This latter board should be mounted inside the TV receiver's cabinet. Corresponding component-placement guides for these boards appear in Figs. 6A, 6B, 7, and 8.

Most components mount directly on the boards or via sockets. Exceptions include phototransistor *Q1*, resistor *R1*, and plug-in wall transformer *T1*. To suppress feedback-induced oscillations, one end of *R1* is connected directly to the base lead of *Q1*. The other end of *R1* and the collector and emitter leads of *Q1* are connected to the appropriate pc foil pads via short lengths of insulated hookup wire. Similarly, *LED1* and *LED2* are connected to the board with insulated hookup wire.

It is good practice to install lengths of spaghetti or heat-shrinkable tubing on the exposed leads of all components that are mounted off the board to prevent accidental short circuits. The AD•ZAP receiver circuit board *must* be housed in a metallic enclosure.

Substitutions should not lightly be made for phototransistor *Q1*. For the device specified and the parameters of the circuit shown in Fig. 2, the phototransistor should function in the linear portion of its response curve for ambient light levels of up to 50 foot-candles of incandescent light or 150 foot-candles of daylight. Sensitivity of the device specified can vary over a 7:1 range. Therefore, the circuit incorporates means to compensate for such sensitivity variations. For example, it may be necessary to change the value of resistor *R3* or to even substitute another phototransistor of the same type. (Note that photodarlingtons have too much gain and will, therefore, not

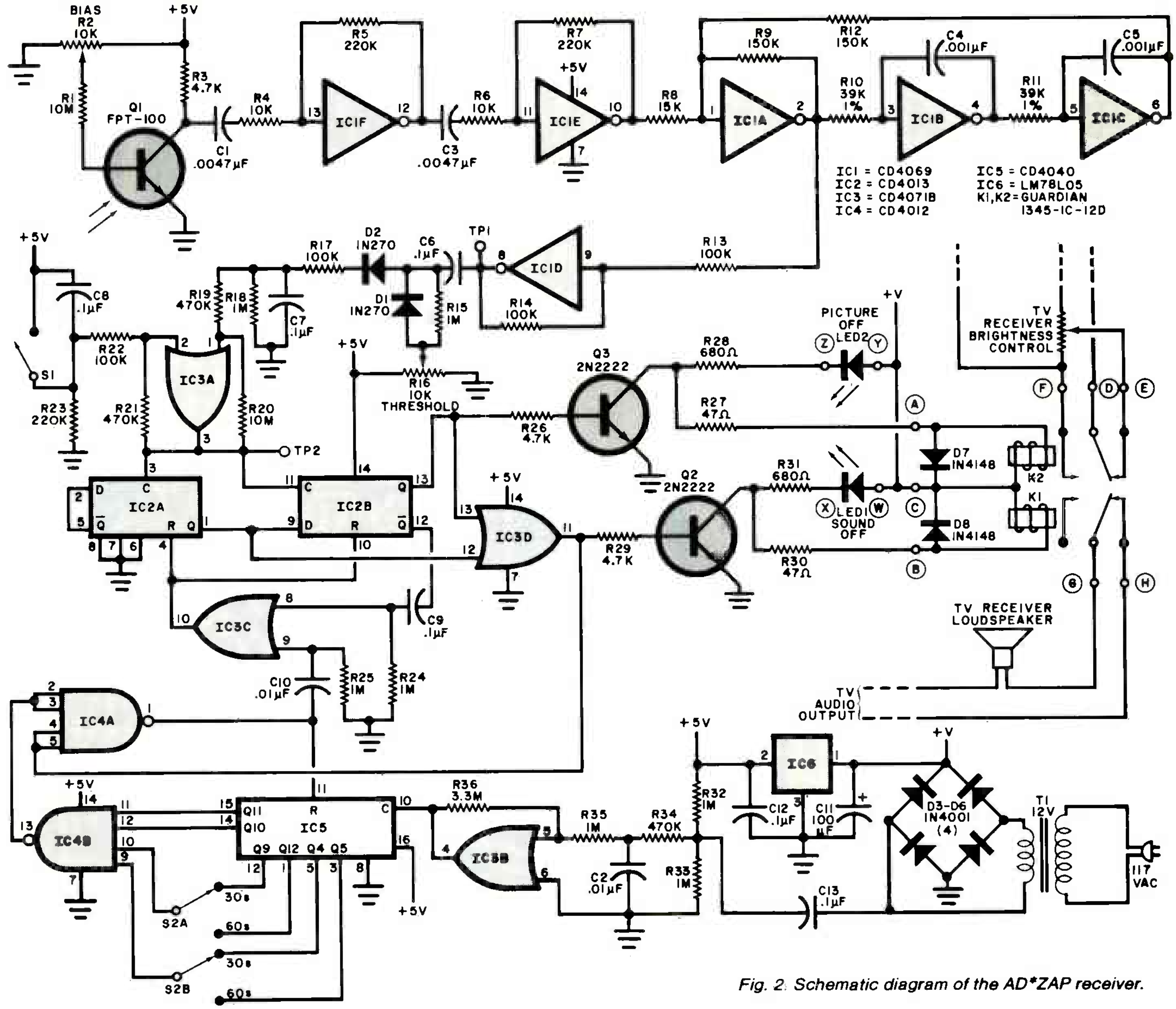


*Fig. 2. Schematic diagram of the AD*ZAP receiver.*

RECEIVER PARTS LIST

C1,C3—0.0047-µF disc ceramic capacitor
C2,C10—0.01-µF disc ceramic capacitor
C4,C5—0.001-µF, 5% tolerance Mylar or polystyrene capacitor
C6,C7,C8,C9,C12, C13—0.1-µF disc ceramic capacitor
C11—100-µF, 25-volt axial-lead aluminum electrolytic
D1,D2—1N270 or equivalent germanium diode
D3 through D6—1N4001 rectifier
D7,D8—1N914 or 1N4148 silicon switching diode
IC1—CD4069 hex inverter
IC2—CD4013 dual D flip-flop
IC3—CD4071B quad 2-input OR gate (device must have B suffix)
IC4—CD4012 dual four-input NAND gate
IC5—CD4040 12-stage binary counter
IC6—LM78L05 5-volt, 100-mA regulator
K1,K2—Spdt relay with 12-volt dc, 1400-ohm coil (Guardian No. 1345-1C-12D or equivalent)
LED1—Yellow light-emitting diode
LED2—Red light-emitting diode
Q1—FPT-100 phototransistor (Fairchild)
Q2, Q3—2N2222 npn silicon switching transistor
The following, unless otherwise specified, are ¼-watt, 5% tolerance, carbon-composition fixed resistors.
R1, R20—10 MΩ
R2, R16—10-kΩ linear-taper, horizontal pc-mount trimmer potentiometer
R3,R26,R29—4.7 kΩ
R4, R6—10 kΩ
R5, R7, R23—220 kΩ
R8—15 kΩ
R9, R12—150 kΩ
R10, R11—39 kΩ, 1%-tolerance, ¼-watt, metal-film
R13, R14, R17, R22—100 kΩ
R15, R18, R24, R25, R32, R33, R35—1 MΩ
R19, R21, R34—470 kΩ
R27, R30—47 Ω
R28, R31—680 Ω
R36—3.3 MΩ
S1—Spst, normally open, momentary-contact pushbutton switch
S2—Dpdt miniature slide switch
T1—12-volt ac, 100-mA wall-mount plug-in transformer
Misc.—Printed circuit board, suitable metallic enclosure, LED mounting collars, grommets, infrared bandpass filter (see note below), heat-shrinkable tubing, hookup wire, solder, pc standoffs, suitable hardware, etc.

Note 1—Pushbutton switch S1 is a Panasonic No. EVQ-P1R component that is available from Digi-Key, Box 677, Highway 32 South, Thief River Falls, MN 56701.

Note 2—There are several possible items that can be used as an infrared bandpass filter. The author used a ¼-inch circular piece of Eastman Kodak Wratten No. 89B gelatin filter. Kodak advises that a piece of unexposed but processed Kodachrome slide film can also be used, as it blocks visible light almost completely but is transparent to infrared. Gelatin Wratten filters measuring 2 inches square are available from Eastman Kodak dealers for approximately $5.00 each.

work.) The phototransistor should be mounted on the front panel of the AD•ZAP receiver's enclosure. The device specified just fits a standard 0.200-inch (Jumbo) LED mounting collar.

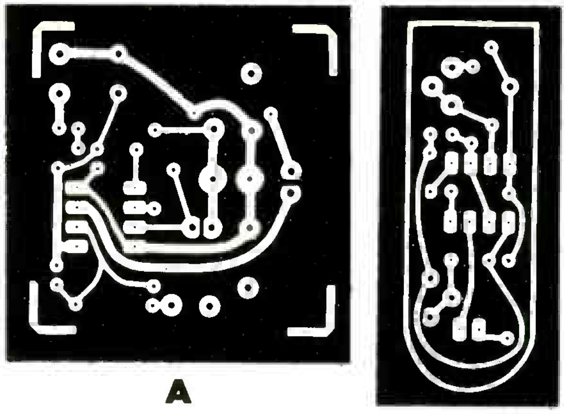
An infrared optical filter is mounted in front of the phototransistor's aperture. Use black silicone cement or some similar opaque material to ensure that no light can leak in behind the filter. The two indicator LEDs can also be mounted on the receiver enclosure's front panel. To facilitate interconnection of the receiver circuit and relay board, a multiconductor connector should be mounted on the enclosure.

For convenience, the author mounted his relay board inside the television receiver with which the AD•ZAP system was to be used. If you plan to use your system with more than one TV set, a separate relay board can be used in each. You can substitute the relays specified so long as their coils are rated at 12 volts dc and have resistances of 400 ohms or more. If a dpdt relay is employed for *K1*, the second set of contacts can be used to stop the transport of a video tape recorder during commercial messages.

The transmitter can be housed in a standard plastic enclosure or, for dramatic fun, a plastic six-shooter such as that used by the author. The "gun," manufactured by Coleco for use in a game, contains a trigger-actuated switch and a lens system. The pc board pattern of Fig. 3B was designed for use with this gun. Careful attention to dimensions will ensure proper alignment of the LED with the lenses, giving a narrow, correctly aimed beam.

To fit a nine-volt battery into the handle of the pistol, the internal plastic posts between the holes for the two handle screws must be cut away. This can be done with a heated knife or with a hobby power tool and its saw blade. Also, the terminals on the rear of the trigger-actuated switch must be cut off. The necessary electrical connections between the switch and the rest of the transmitter circuit should be made by soldering suitable lengths of hookup wire directly to the switch's leaf springs. Use a vise to hold the switch and then tin the leaf springs and the ends of the lengths of hookup wire. Place the tinned end of each wire next to the appropriate leaf spring and remelt the solder to form the connection. Work quickly to avoid losing the temper of the springs. Finally, make a 1/8-inch hole in the plastic body over the position occupied by trimmer potentiometer *R2* so that the circuit's frequency of oscillation can be conveniently adjusted.

If you prefer a more conventional transmitter enclosure, you will need a lens to focus the infrared beam. Focusing the invisible beam is difficult. Alter-



A

B

Fig. 3. Full-size etching and drilling guides for the box-style (A) and gun-style (B) transmitter pc boards.

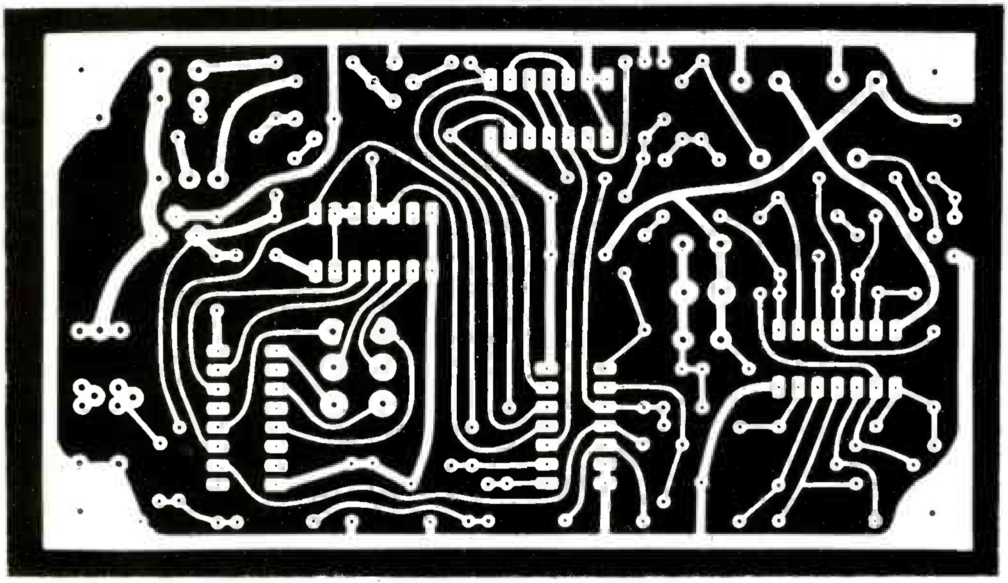


Fig. 4. Full-size etching and drilling guide for the receiver pc board.

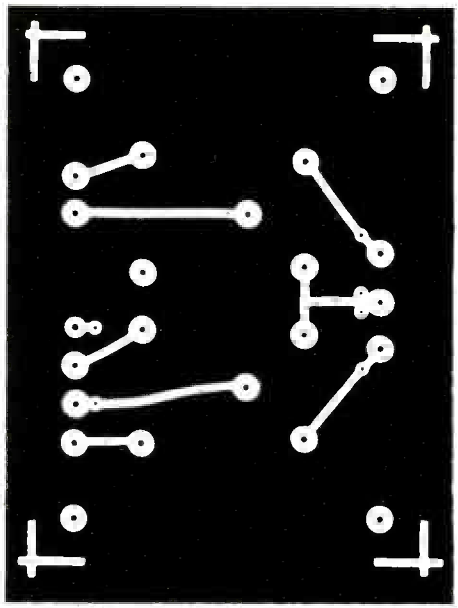
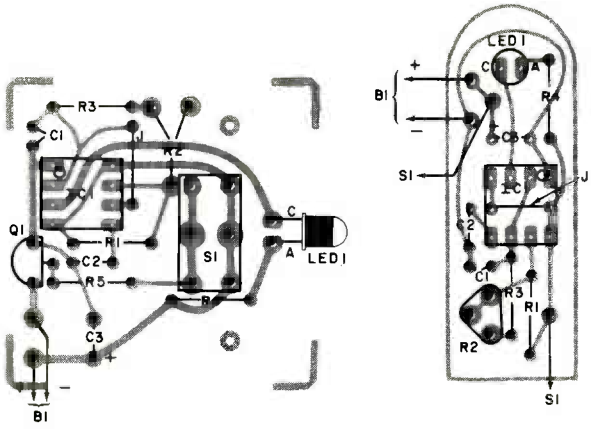


Fig. 5. Etching and drilling guide for relay pc board.



A B

Fig. 6. Parts placement guides for the box-style (A) and gun-style (B) infrared transmitters.

try another FPT-100 phototransistor.

When the voltage across *R3* is correct, cover the filter aperture with a totally opaque shield and adjust *R2* so that 0.25 volt appears across *R3*. Then remove the opaque shield.

Next, turn *R16* fully counterclockwise and check the voltage at *TP2*. This should be 0 volt. Slowly turn *R16* clockwise. At some point, *TP2* should suddenly go to +5 volts. When this happens, back *R16* off and stop just past the point at which *TP2* returns to 0 volt. Depress switch *S1* momentarily and verify that *TP1* goes to +5 volts with *S1* closed and returns to 0 volt when it is

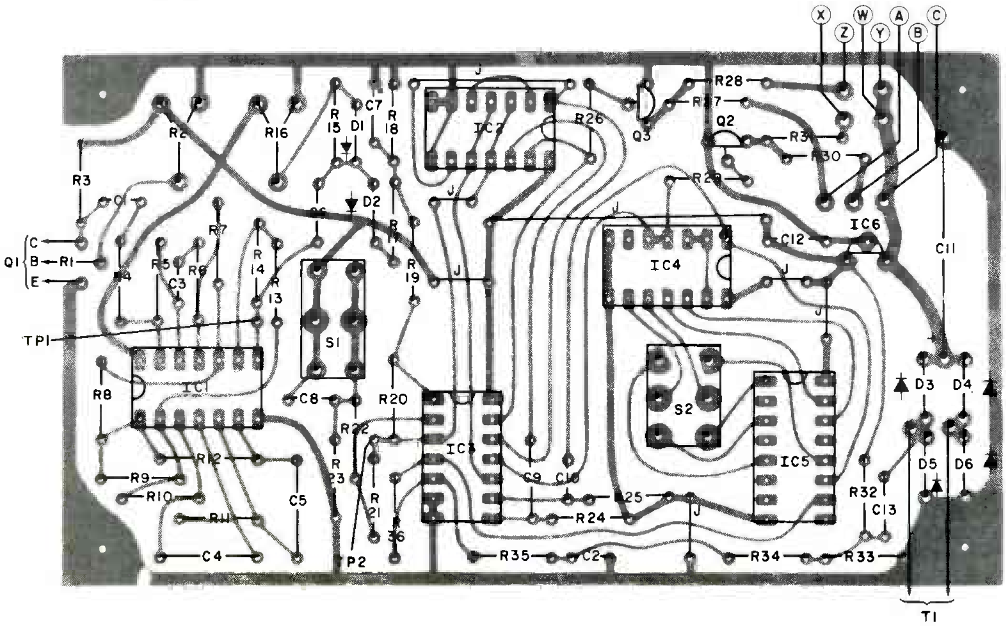


Fig. 7. Parts placement guide for the AD*ZAP infrared receiver printed circuit board.

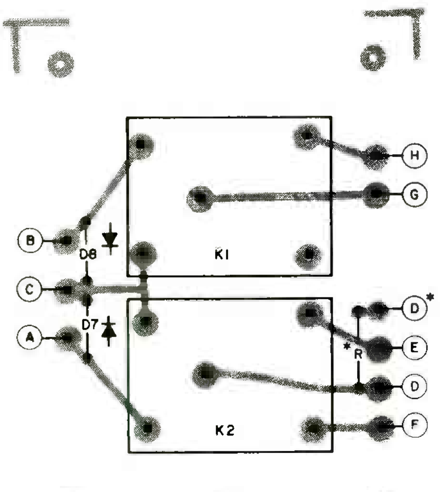


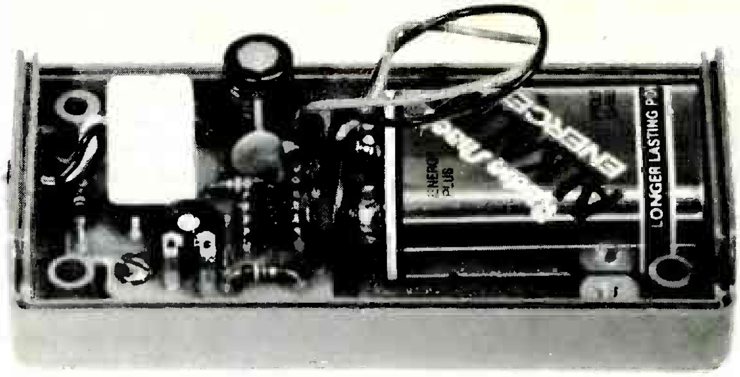
Fig. 8. Component placement guide for the relay pc board.

natively, you can use a Texas Instruments TIL31 or General Electric LED55C infrared-emitting diode. These include internal reflectors and glass lenses and mount in standard 0.200-inch LED mounting collars. They also tolerate larger forward currents, allowing reduction of the value of *R4* in the transmitter to 15 ohms. Pass transistor *Q1* and base resistor *R5* in the circuit of Fig. 1A allow switch *S1* to be a light-action, low-current keyboard switch.

Adjustment. After the receiver and transmitter have been assembled, plug *T1* into a wall socket. With the top of the receiver enclosure removed, monitor the voltage across resistor *R3* with a high-impedance multimeter. Place an unshaded, lighted 60-watt light bulb two feet away from the filter that shields phototransistor *Q1*, and set the wiper of trimmer potentiometer *R2* fully counterclockwise. The voltage across *R3* should be 2.5 ±0.5 V. If necessary, change the value of *R3* to obtain this reading. Should this prove impossible, opened; if *TP2* fails to return to 0 volt when *S1* is released, turn *R16* a bit further counterclockwise.

Finally, to set the frequency of the transmitter's astable multivibrator to match the receiver's filter passband, connect an ac voltmeter or oscilloscope between *TP1* and ground. Have a friend monitor the voltage reading while you stand several feet away and "fire" the transmitter at the receiver's infrared filter. Hold the transmitter switch *S1* so that a continuous infrared output is generated. (With a pistol transmitter, pull the hammer back all the way and hold it.) Adjust transmitter trimmer potentiometer *R2* for a maximum voltage reading on the test instrument.

Place the top on the receiver enclosure and secure it in place. Connect the relay board to the rest of the receiver circuit and, if necessary, button up the transmitter enclosure. Making certain that the receiver is getting operating power, aim the transmitter at the receiver's infrared filter. When transmitter switch *S1* is closed momentarily, relay



Photograph of the author's prototype box-style transmitter.

INSTALLATION WHEN SCREEN CAN'T BE DARKENED

Here are possible ways of darkening the screen even if it doesn't go fully to black when the BRIGHTNESS control is at minimum. First, you will need a schematic of the television receiver. (If one was not supplied with the receiver or is not available from the manufacturer, try the Sama Fotofact series of publications.) Next, you will have to determine how the brightness of the CRT is controlled, and how the range of the BRIGHTNESS potentiometer is affected by the "one-button" color preset, if any.

Several methods of brightness control are common; the simplest is found in many vintage color receivers and in many contemporary monochrome models. (Figure 9 is typical.) The video signal is capacitively coupled to the cathode of the picture tube, and the BRIGHTNESS potentiometer controls the dc bias voltage that sets the average beam current. The lower the bias voltage, the higher the beam current and the brighter the picture. Resistor *R34* limits the beam current to a maximum value.

Brightness-control circuits of this type almost always are able to send the CRT well past cutoff (screen completely dark). If you have a color receiver that employs a similar circuit (the partial schematic illustrated is of a General Electric HB color chassis), note that the red, green and blue SCREEN controls interact with the BRIGHTNESS control. While a video signal is being received, try adjusting the SCREEN controls for cutoff with the BRIGHTNESS control at its minimum setting. Then if the CRT image is too dim when the BRIGHTNESS control is advanced to its maximum setting (this will rarely be the case), make the value of *R34* half as large. Check to see that the high voltage is at its specified value before making a substitution for *R34*.

The more usual approach to brightness control in today's solid-state receivers is to vary the dc bias at the input of one of the video amplifiers. Video is either dc or ac-coupled (or a combination of the two) into the stage, and is sometimes clamped to the bias voltage during the blanking interval. The BRIGHTNESS potentiometer can be wired into the circuit either as a voltage divider (as a three-terminal device) or as a variable resistor (a two-terminal device). In the latter case, the potentiometer is only part of a voltage-dividing network. The Sharp Model XR-2194 typifies the first method, the Sony 9000U the second.

In the Sony, the bias voltage of the Y DRIVE amplifier is mixed with the video signal. The video signal is positive, that is, white is more positive than black. Blanking the screen can therefore be accomplished by bringing the base of the Y DRIVE stage to ground, either directly or by opening the path between the voltage divider that sets the bias and the low-voltage supply from which the bias is derived. In the Sharp receiver, the "one-button" color-preset switch selects between the BRIGHTNESS control and a screwdriver adjustable trimmer potentiometer that is preset at the factory. Both the front-panel BRIGHTNESS control and the trimmer have range-limiting series resistors that prevent them from cutting off the CRT totally. Blanking can be achieved by having the relay disconnect the ends of the front-panel and trimmer potentiometers that are tied together from the source of the low voltage which supplies them.

In some sets, the "one-button" color preset leaves the front-panel BRIGHTNESS control in the circuit, but restricts its effective range. One receiver that uses such a circuit is Toshiba's Model C345, chassis TAC-9310. The base of the fourth video amplifier is biased through a fixed resistor by a voltage divider composed of a fixed resistor and the BRIGHTNESS control, one end of which receives positive voltage via a SUB-BRIGHTNESS control. This latter control limits CRT brightness.

When the receiver's "one-button" color preset is engaged, a fixed resistor is placed in parallel with the front-panel BRIGHTNESS control. This restricts the effective range of the control to its upper half. To have AD*ZAP totally darken the screen, relay *K2* can be wired either to ground the wiper of the SUB-BRIGHTNESS control or connect a fixed resistance of approximately 5000 ohms between the base of the fourth video amplifier and ground. The use of such a resistor rather than a direct short to ground prevents the total loss of the demodulated video signal, which would also disable the sync circuits. This way, when *K2* is deenergized, the picture returns instantly—in sync and with no rolling or tearing. The relay pc board includes provisions for such a resistor (*R*) at point D*.

PARTS AND KIT AVAILABILITY

The following are available from Videomega, 2715 N.E. 14th Avenue, Portland, OR 97212. Prices do not include shipping and handling charges ($2 per order). Kits of all components for one transmitter, receiver, and relay board, enclosures, and a nine-volt battery for the transmitters: complete kit for AD*ZAP system employing gun-style transmitter (limited quantities available). No. KZ-S, for $69.00; complete kit for AD*ZAP system employing box-style transmitter, No. KZ-T, for $69.00; complete kit for AD*ZAP system capable of controlling VTR pause circuit, employing gun-style transmitter, and including VTR control cable (limited quantities available) No., KZ-SV, for $79.00; complete kit for AD*ZAP system capable of controlling VTR pause circuit, employing box-style transmitter, and including VTR control cable, No. KZ-TV, for $79.00. Individual kits for additional receivers, transmitters, and relay boards are also available. Write for prices.

Drilled, solder-plated and silk-screened (component-placement legend) printed-circuit boards are also available separately: Set of boards for receiver, relay circuit, and gun-style transmitter, No. AZ-S, for $16.00; set of boards for receiver, relay circuit, and box-style transmitter, No. AZ-T, for $16,00; set of boards for receiver, relay and VTR pause-control circuits, and gun-style transmitter, No. AZ-SV for $16.00; set of boards for receiver, relay and VTR pause-control circuits, and box-style transmitter No. AZ-TV, for $16.00; receiver board only, No. AZ-A for $7.50.

K1 should pull in and *LED1* glow. When transmitter switch *S1* is closed a second time, *K2* and *LED2* should do likewise. At the end of the interval determined by the setting of receiver switch *S2*, both relays should drop out and both LEDs darken. If *S1* is closed a third time before the receiver times out, this too should de-energize the relays and LEDs. Closure of receiver switch *S1* should initiate the timing sequence or, if it has already begun, interrupt it.

Modifying the TV Receiver. If control of only the audio output of the television is desired the AD*ZAP system can be used with any TV set and installation procedure is simple. However, achieving control of both sound and picture may be somewhat more difficult, depending on the TV set used. Two simple tests will tell you how much of a problem it will be to obtain picture control. If the CRT screen goes completely black when the BRIGHTNESS control is at minimum, installation will be easy. Alternatively, if the receiver has a "one-button" color preset, and the screen goes completely dark when the preset is engaged and the BRIGHTNESS control is at minimum, installation is again not complicated. However, if the screen cannot be wholly "blackened," installation will be more

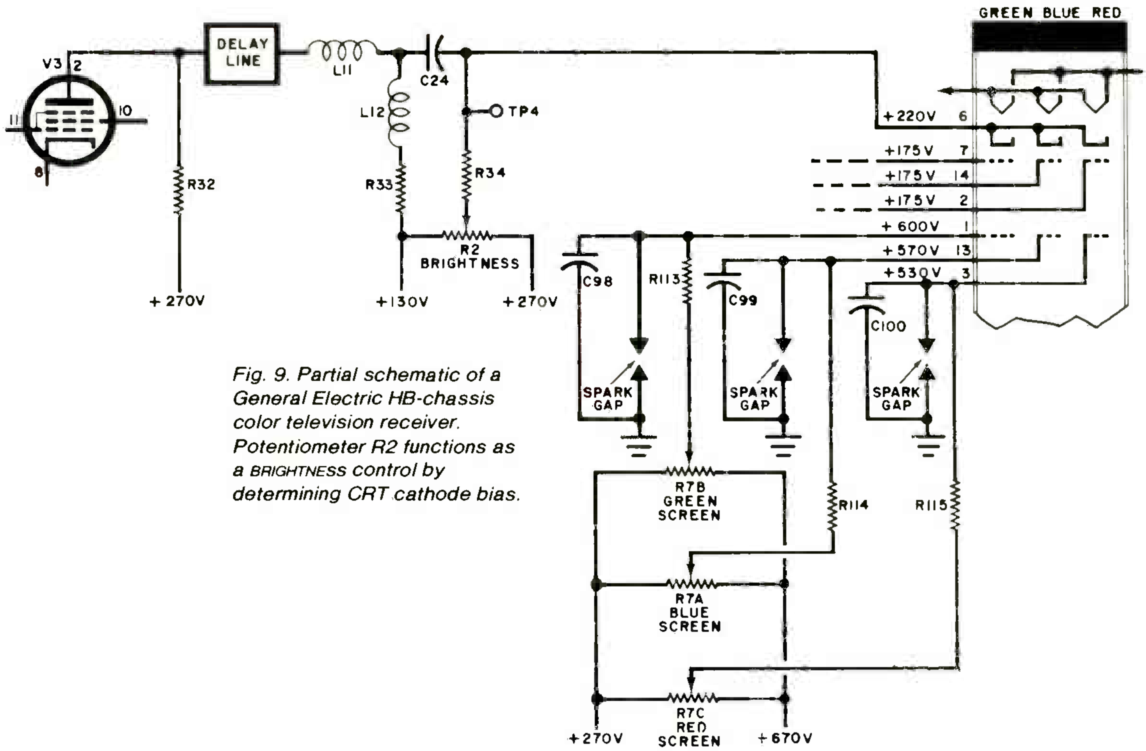
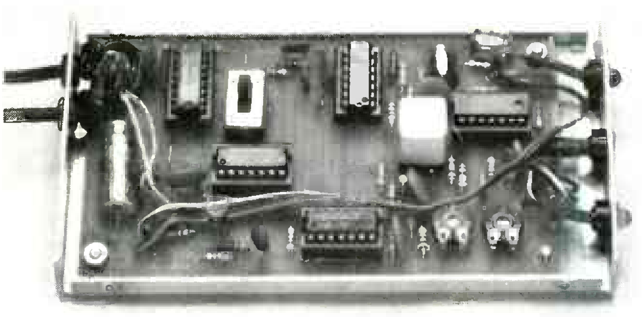


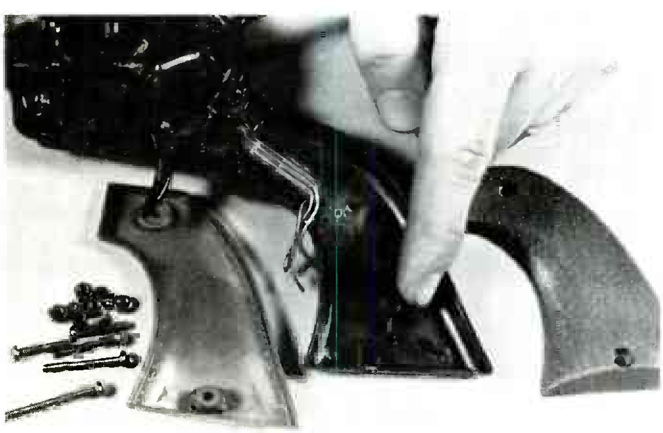
Fig. 9. Partial schematic of a General Electric HB-chassis color television receiver. Potentiometer R2 functions as a BRIGHTNESS control by determining CRT cathode bias.

troublesome, as detailed in a boxed section on the opposite page.

Here's the procedure that should be followed if test results are positive. Begin by removing the rear panel of the TV receiver (which should also remove ac power through the interlock) to gain access to the BRIGHTNESS control. Detach the wire connected to the center lug of the BRIGHTNESS control and connect it to point D on the relay printed circuit board. The free ends of the wires from points E and F on the relay board should be soldered to the center and left lugs, respectively, as seen from the *rear* of the BRIGHTNESS control. To control the audio, disconnect one of the two output leads from the loudspeaker and connect it to point H on the relay circuit board. If necessary, extend the length of this lead by splicing on a piece of hookup wire. Solder the splice and insulate it using PVC electrical tape or heat-shrinkable tubing. Then attach one end of suitable length of hookup wire to the free speaker lug, and the other end to point G on the relay circuit board. The relay board can be mounted inside the television cabinet using either screws and standoffs or two or three layers of double-sided adhesive foam tape.



*Photograph shows construction details of the prototype AD*ZAP infrared receiver.*



Photograph of the Coleco surplus plastic pistol modified by the author for use as a transmitter.

Using AD*ZAP. Although the receiver module includes an infrared filter, high levels of ambient light can affect phototransistor *Q1*. Therefore, avoid illuminating the sensor with bright sunlight, and keep incandescent lamps several feet away. The on-axis range of the six-shooter transmitter is more than 35 feet. That of the box-style transmitter is more than 20 feet. Because of its more diffuse radiation, the box-style transmitter need not be critically aimed.

Receiver switch *S1* should be set to provide the desired delay interval. The growing use of 30-second commercial messages on television prompted the inclusion of the switch. A few hour's attentive viewing of TV programs *and* commercials will enable you to judge which delay interval is more useful. To be certain not to miss any desired program material, you may want to avoid darkening the picture, at least at first. ◇

BUILD THE POOR MAN'S STROBE

Inexpensive circuitry allows timed, sequential flashes for multiple photographic exposures of moving subjects

BY IMRE GORGENYI*

STROBOSCOPIC photography, which exposes a single frame with light from a sequence of timed flashes, is an interesting way to capture a moving subject on film. The result is a series of still images that catch the subject in successive positions along its path, clearly suggesting motion. Stroboscopic photographs of a gymnast working out appear on the cover of this issue.

Unfortunately for shutterbugs, commercial equipment for stroboscopic photography is high in price. There are, however, circuits designed around readily available, inexpensive components that are easily built and will enable amateur photographers to experiment with the technique.

*Motorola Semiconductor Group

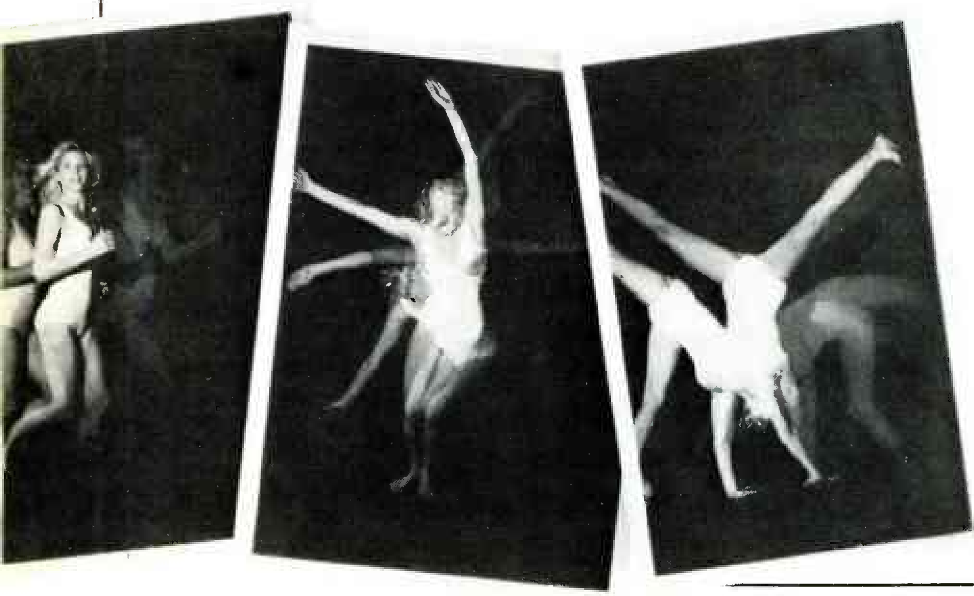
The Basic Poor Man's Strobe. The circuit (Fig. 1) triggers a flash unit at a predetermined time after the receipt of a light pulse from another flash unit actuated by the camera's flash-sync output. A portion of the light from the camera-triggered flash falls on the window of phototransistor *Q1*, which briefly conducts. The resulting negative voltage pulse at the collector of *Q1* triggers the timing circuit comprising *C1*, *R2* through *R6*, and *Q2*.

At the end of the timing interval, whose duration is adjustable by means of potentiometer *R3*, *Q3* and its associated passive components generate a positive voltage pulse and couple it to the gate of *SCR1*. The SCR breaks into conduction and triggers the flash unit whose sync contacts are connected to jack *J1*. Simultaneously, the timing circuit resets itself by means of *R6* to prepare for the next triggering light pulse. Power for the circuit is provided by a 9-volt alkaline battery via switch *S1*. Quiescent current drain is approximately 1 mA, so long battery life can be expected.

The delay between the arrival of the triggering light pulse and the actuation of the secondary flash can be varied from approximately 0.1 to 1 second. For shorter delays, the value of *C1* can be reduced to 0.1 μF. If this is done and *R3* is set for minimum resistance, the delay is so short that the attached flash unit can be used as a simple slave. Light from the slave will reinforce that from the camera-triggered unit and will yield brighter or more diffuse lighting of the subject. Of course, a number of basic Poor Man's Strobes can be built and each one adjusted for a different delay time to produce multiple images on a single emulsion.

Other Circuits. The slave-trigger circuit in Fig. 2 has practically no delay at all. It is therefore suitable for situations in which the slight delay introduced by the timing circuit of the PMS would cause an undesirable second image or smearing. This circuit has two unusual characteristics—it is not triggered by steady-state ambient light, and it derives its modest operating power from the flash to which it is connected.

Although ambient light would tend to cause phototransistor *Q1* to conduct, inductor *L1* prevents this from happening. Upon receipt of a light pulse, however, a voltage is set up across the inductor and the base-emitter junction of the phototransistor, and the device briefly conducts. This in turn forward-biases the base-emitter junction of switching transistor *Q2*, and a positive voltage appears across *R12*. The SCR breaks into conduction and triggers the flash unit whose sync contacts are connected to jack *J1*. A manual trigger switch (*S1*) is wired in parallel with *SCR1*. Power for *Q1* and *Q2* is derived from the flash unit by means of voltage divider *R3R4* and storage capacitor *C1*, which is wired in parallel with the *R3* leg of the voltage divider. The circuit's power requirements are so modest that almost any flash unit can easily satisfy them.



The circuit shown in Fig. 3 is a sequential flash trigger that can ac-

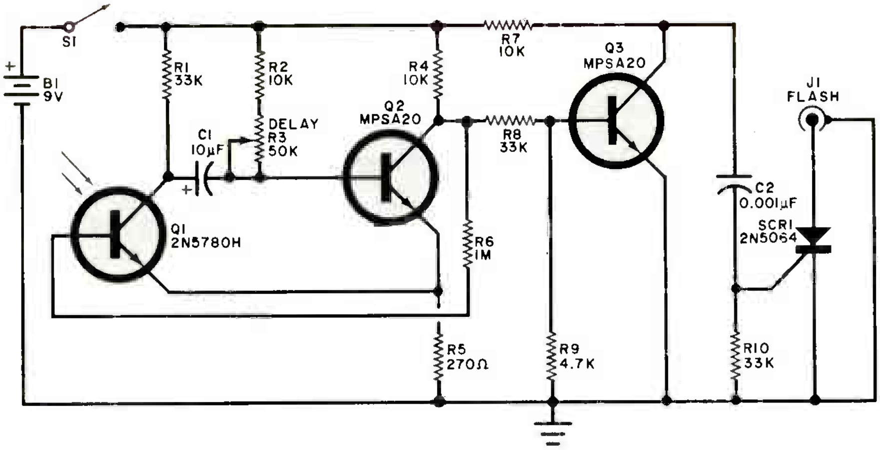
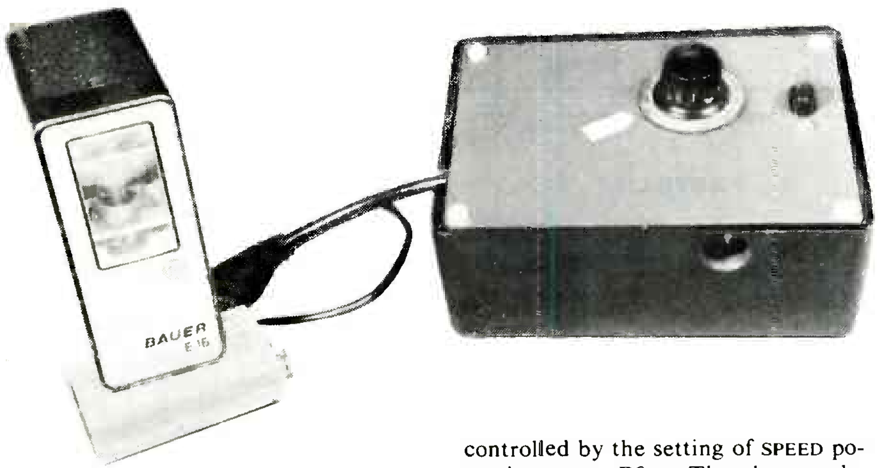


Fig. 1. Schematic diagram (above) of the basic Poor Man's Strobe. Below, a photograph of the author's prototype. The large control knob determines delay between trigger pulse and actuation of flash.

PARTS LIST

B1—9-volt alkaline battery
C1—10-µF, 16-V tantalum capacitor
C2—0.001-µF, 50-V disc ceramic capacitor
J1—Suitable jack (chosen to match the plug of the flash unit's sync extension cord)
Q1—2N5780H npn silicon phototransistor
Q2,Q3—MPSA20 npn silicon transistor
R1,R8,R10—33-kΩ, ¼-W, 10% resistor
R2,R4,R7—10-kΩ, ¼-W, 10% resistor
R3—50-kΩ, linear-taper potentiometer
S1—Spst switch
SCR1—2N5064 or similar silicon controlled rectifier (minimum voltage rating, 200 volts)
Misc.—Perforated board, battery holder, battery clips, sync extension cord, control knob, suitable enclosure, hookup wire, solder, hardware, etc.



tuate as many as five flash units. These units will be triggered at equal intervals after the camera's sync contacts close. The circuit functions as follows: when the sync contacts close, transistor *Q3* cuts off and capacitor *C2* begins to receive charging current from the constant-current source comprising *Q4*, *Q5*, and their associated passive components. The ramp voltage that appears across the capacitor is coupled to position 1 of switch *S2* by Darlington emitter follower *Q6*. If *S2* is in position 1, the ramp voltage is applied to the gates of *SCR2*, *SCR3*, *SCR4*, and *SCR5* through a series of voltage dividers. The gate of *SCR1* receives a separate voltage pulse via a different circuit path almost immediately after the camera's sync contacts close.

As the ramp voltage at the pole of *S2* increases in amplitude, *SCR2*, *SCR3*, *SCR4*, and *SCR5* successively break into conduction and trigger the flash units to whose sync contacts they are connected. The rate at which the SCRs fire is determined by the slope of the ramp, which is ultimately controlled by the setting of SPEED potentiometer *R9*. The lower the resistance of *R9*, the greater the output of the constant-current source. Thus, more current will flow through *LED1*, and the LED will glow more brightly to indicate that the slope of the ramp will be steep and the flash sequence rapid. The total duration of the flash sequence can be adjusted from approximately 50 milliseconds to 3 seconds.

The monostable multivibrator comprising *Q1*, *Q2* and associated passive components performs two functions. First, it triggers *SCR1* when the camera's sync contacts close. Then, after three seconds, it resets the rest of the circuit to prepare for the next flash sequence. When switch *S2* is in position 2, the initial pulse across *R1* is simultaneously applied to the gates of *SCR1* through *SCR5*, triggering all the flash units simultaneously. Power

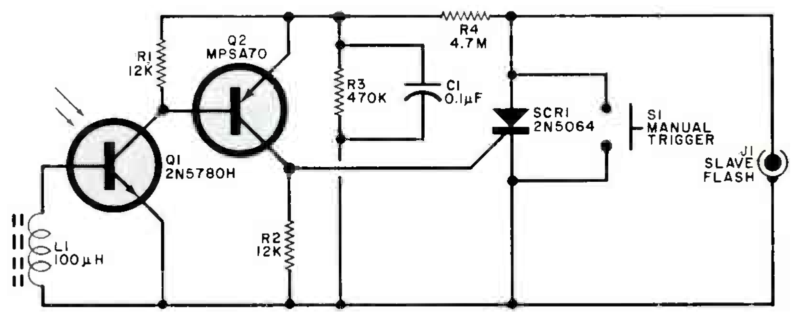


Fig. 2. Circuit for a slave-flash trigger that is not affected by steady-state ambient light.

PARTS LIST

C1—0.1-µF, 250-V Mylar capacitor
J1—Suitable jack (chosen to match the plug of the slave flash unit's sync extension cord)
L1—100-µH choke
Q1—2N5780H npn silicon phototransistor
Q2—MPSA70 pnp silicon transistor
R1,R2—12-kΩ, ¼-W, 10% resistor
R3—470-kΩ, ¼-W, 10% resistor
R4—4.7-MΩ, ¼-W, 10% resistor
S1—Normally open, momentary-contact pushbutton switch
SCR1—2N5064 or similar silicon controlled rectifier (minimum 200-volt rating)
Misc.—Perforated board, sync extension cord, suitable enclosure, hookup wire, solder, hardware, etc.

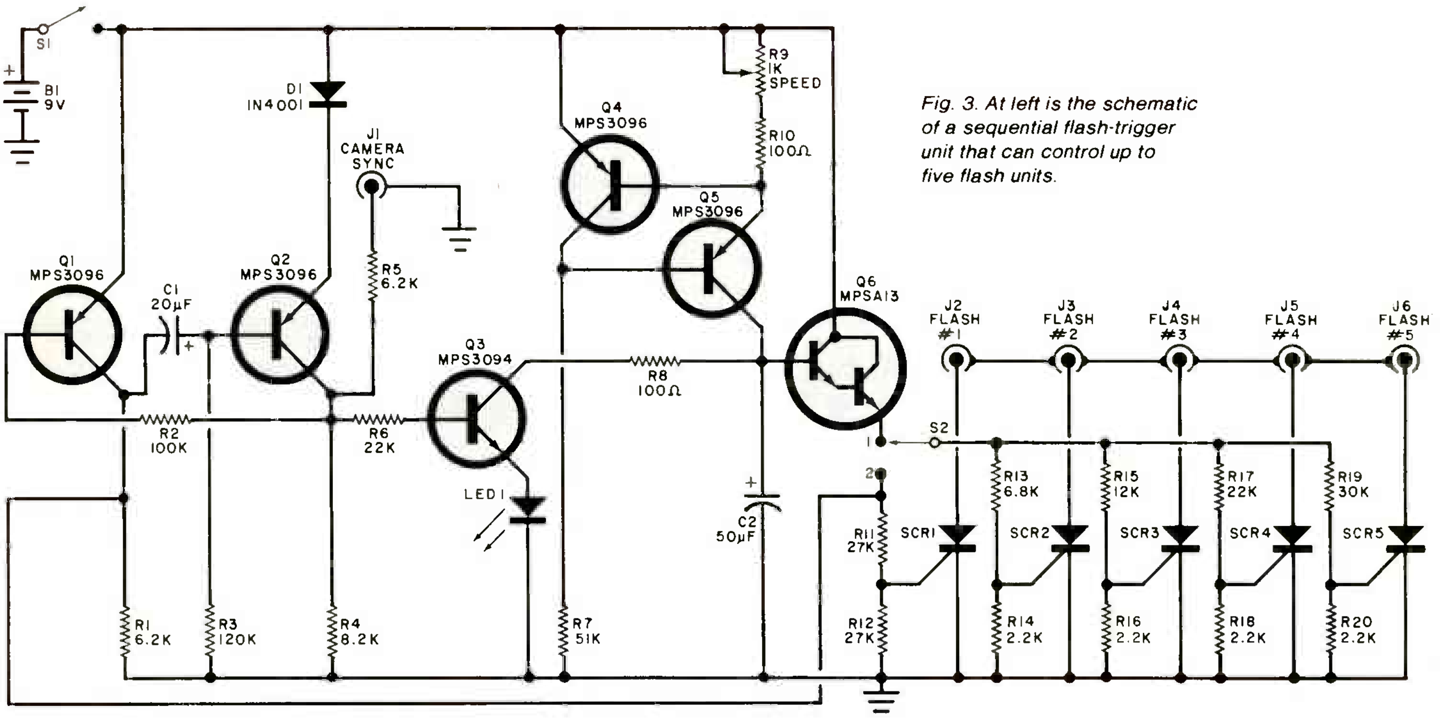


Fig. 3. At left is the schematic of a sequential flash-trigger unit that can control up to five flash units.

PARTS LIST

B1—9-volt akaline battery
C1—20-µF, 25-V aluminum electrolytic
C2—50-µF, 25-V aluminum electrolytic
D1—1N4001 rectifier
J1—Suitable jack (to match the plug of the camera's sync extension cord)
J2 through J6—Suitable jacks to match the plugs of the sync extension cords for Flash #1 through Flash #5)
LED1—Light-emitting diode
Q1,Q2,Q4,Q5—MPS3096 pnp silicon switching transistor
Q3—MPS3094 npn silicon transistor
Q6—MPSA13 npn silicon transistor

The following, unless otherwise specified, are ¼-W, 10% tolerance, carbon-composition fixed resistors
R1,R5—6.2 kΩ
R2—100 kΩ
R3—120 kΩ
R4—8.2 kΩ
R6,R17—22 kΩ
R7—51 kΩ
R8,R10—100 Ω, ½-watt
R9—1-kΩ, linear-taper potentiometer
R11,R12—27 kΩ
R13—6.8 kΩ
R14,R16,R18,R20—2.2 kΩ
R15—12 kΩ
R19—30 kΩ
S1—Spst switch
S2—Spdt switch
SCR1 through SCR5—2N5064 or similar silicon controlled rectifier (minimum voltage rating, 200 volts)
Misc.—Perforated board, sync extension cords, suitable enclosure, battery holder, battery clips, control knob, hookup wire, LED mounting collar, solder, hardware, etc.

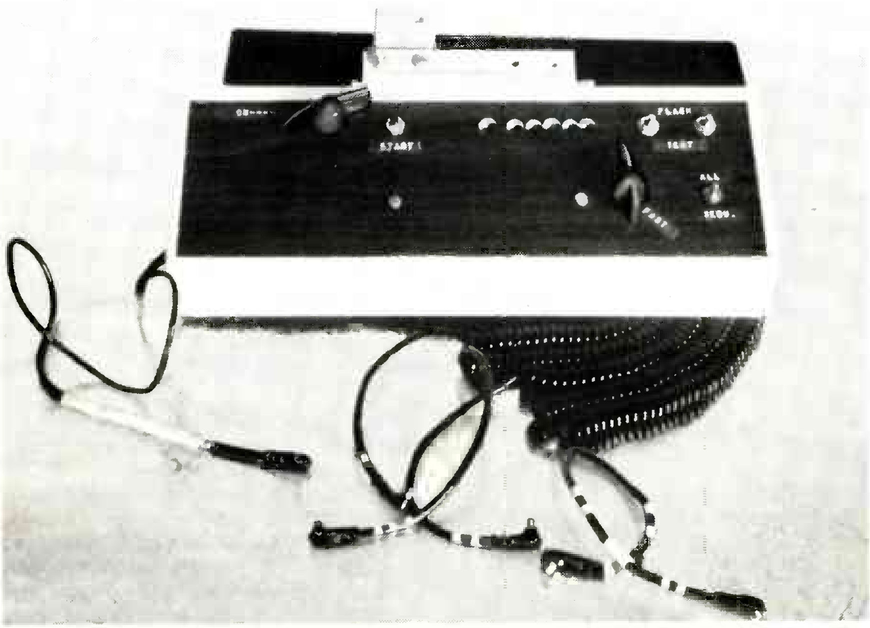


Photo of the prototype sequential flash-trigger unit.

for the circuit is supplied by 9-volt alkaline battery *B1* via switch *S1*.

Another sequential flash trigger circuit is shown schematically in Fig. 4. Here, the trigger pulse from the camera's sync contacts enables unijunction transistor *Q1* to generate clock pulses that drive CMOS decade counter/decoder *IC1*. The rate at which clock pulses are generated is determined by the position of rotary switch *S3*, which selects one of five RC timing networks (*R22C3* through *R26C7*). The gate of *SCR1* is driven by the output pulses of the UJT, but the gates of the other SCRs are driven by various of the counter's decoded output lines. Switch *S1* allows the user to determine whether the gate of *SCR5* will be driven by the Q_4 or Q_6 output line of the counter—that is, whether the flash unit connected to

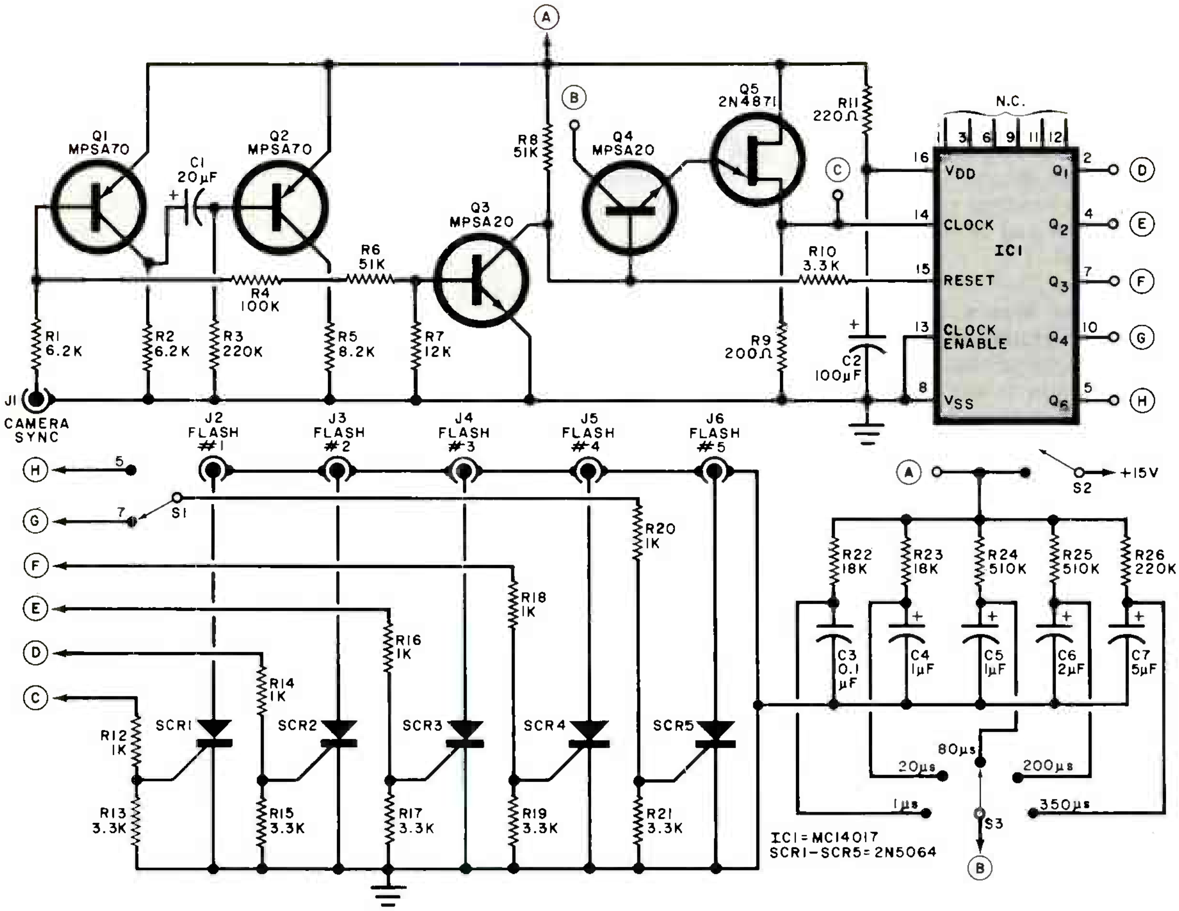


Fig. 4. Another sequential flash-trigger unit. This circuit employs a UJT clock and a CMOS decade counter/decoder.

PARTS LIST

C1—20-μF, 25-V aluminum electrolytic
C2—100-μF, 25-V aluminum electrolytic
C3—0.1-μF, 50-V Mylar capacitor
C4,C5—1-μF, 25-V tantalum capacitor
C6—2-μF, 25-V tantalum capacitor
C7—5-μF, 25-V tantalum capacitor
IC1—MC14017 decade counter/decoder
J1—Suitable jack (to match the plug of the camera's sync extension cord)
J2 through J6—Suitable jacks (to match the plugs of the sync extension cords for Flash #1 through Flash #5)
Q1,Q2—MPSA70 pnp silicon transistor
Q3,Q4—MPSA20 npn silicon transistor
Q5—2N4871 unijunction transistor
The following, unless otherwise specified, are ¼-W, 10% tolerance, carbon-composition fixed resistors.
R1,R2—6.2 kΩ
R3,R26—220 kΩ
R4—100 kΩ
R5—8.2 kΩ
R6,R8—51 kΩ
R7—12 kΩ
R9—200 Ω
R10,R13,R15,R17,R19,R21—3.3 kΩ
R11—220 Ω
R12,R14,R16,R18,R20—1 kΩ
R22,R23—18 kΩ
R24,R25—510 kΩ
R26—220 kΩ
S1—Spdt switch
S2—Spst switch
S3—Single pole, 5-position nonshorting rotary switch
SCR1 through SCR5—2N5064 or similar silicon controlled rectifier (minimum 200-volt rating)
Misc.—+15-volt power supply or battery, perforated board, sync extension cords, suitable enclosure, IC socket, control knob, hookup wire, solder, hardware, etc.

jack *J6* will fire at the fifth or seventh clock pulse. As in the circuit of Fig.3, a monostable multivibrator built around *Q1* and *Q2* resets the circuit to prepare for the next flash sequence. Power for the circuit is provided by a +15-volt supply (not shown) via switch *S2*.

Construction. The prototype Poor Man's Strobes were assembled using perforated board and point-to-point wiring. However, printed-circuit construction can also be used. Type 2N5064 silicon controlled rectifiers are specified for each of the circuits that have been described. These devices have TO-92 plastic packages and are rated at 200 volts peak blocking voltage, 200 μA gate trigger current, and 6 amperes peak forward surge current. They are compatible with most flash units on the market. However, if you intend to use a flash unit that impresses more than 150 volts or so across its sync terminals, an SCR with a greater peak blocking voltage rating will have to be used.

Circuit layout is not critical, and the projects can be housed in any convenient enclosures. The various input and output jacks should be selected to match the plugs of the sync extension cords that your photographic gear employs. Photographs of the prototypes whose circuits are shown in Figs. 1 and 3 appear with the respective diagrams. In the circuits of Figs. 1, 3 and 4, the use of alkaline cells will extend battery life. Be sure to observe standard CMOS handling procedures for *IC1* of Fig. 4 and to use an IC socket to mount it.

Using the Poor Man's Strobes. As with any photographic hardware, a good deal of experimentation is required to learn how to use the Poor Man's Strobes for the best results.

Start with two flash units in an unlit room with dark walls or wall coverings. If you are using the circuit shown in Fig. 1, connect one flash to the camera's sync contacts and the other to jack *J1*. If you are using one of the circuits shown in Figs. 3 and 4, connect one flash unit to *J2* and the other to *J3*. Run a sync extension cord from the camera to input jack *J1*. Place your camera in its "B" (bulb) exposure mode and either set the object to be photographed in motion or direct your model to move around the room. Trip the shutter and hold it open. One flash will fire immediately, and the other will be triggered after a delay. Release the shutter after the second flash has fired.

This first trial should be a "dry run" with no film in the camera. Your eyes will register the strobed images. Repeat the experiment several times, varying the delay between the triggering of the two flash units and the rate at which the object or model is moving. If you have built several of the basic Poor Man's Strobes or one of the sequential trigger circuits shown in Figs. 3 and 4, add more flash units to see how multiple-flash stroboscopic photographs will look.

Next, determine a sequence of connecting the flash units to the output jacks and applying power that does not result in inadvertent triggering of the units. The proper procedure might be as follows: apply power to the Poor Man's Strobe; connect the flash units to it; and finally apply power to the flash units.

Once you have acquired a feel for the Poor Man's Strobe, you can take real pictures. Here again experimentation is needed. Vary the positions of the flash units, use different levels of light output, and for color work place different color filters on each flash unit. With a bit of experience, you'll be able to turn out interesting and unusual photographs that are as much fun to display as they are to take. ◇

COMMERCIAL KILLER FOR A CLOCK RADIO

Low-cost system cuts off the audio on cue from the listener and restores it after one minute

BY HERBERT L. BRESNICK

DID you ever wish you could eliminate radio commercials and TV commercial sound? My clock radio, tuned to the local news station, is set for 6:00 a.m. This means 5 minutes of news interspersed with 5 minutes of commercials, and I find few things worse than listening to soap or laxative jingles at that hour! Fortunately, most commercials are exactly one minute long—which makes them not too hard to silence.

Basically, the system cuts off the audio on cue from the listener and uses a one-minute delay circuit to restore it—presumably after the commercial is over. Figure 1 shows the schematic diagram of the system, which uses about \$3.00 worth of parts, depending upon the size and condition of your parts junkbox. Here's how it works: As soon as the commercial starts, push switch *S1* momentarily. This triggers *IC1*, a 555 IC timer chip, wired as a monostable. Triggering forces pin 3 of the IC high, operating relay *K1*, which pulls in, opening its normally closed contacts. These contacts, in series with the loudspeaker, squelch the audio. After one minute (as set by *C1* and *R1*), pin 3 goes low releasing the relay and restoring the audio—just in time for resumption of the broadcast.

The circuit is easily wired, point-to-point on a 2" x 2" piece of perf board. Supply voltage (9 to 12 volts) is tapped from the radio or TV at any convenient point, and one speaker lead is placed in series with the relay contacts. It is recommended that a resistor be placed across the two leads that normally feed the speaker, as most power circuits do not like to be left unloaded. A 10- or 20-ohm resistor will do fine. Wrap the board with tape to protect the wiring and position it in a convenient space inside the receiver. The trigger wires can be brought out through the rear of the set, and connected to a pushbutton switch that can be placed at any convenient location.

Adding the "commercial killer" to my radio, has restored my sanity, and I'm able to face the morning shower, my wife, and the world with a smile. It may do as well for you. ◇

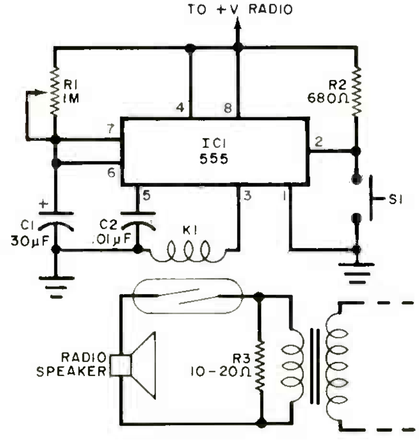


Fig. 1. Duration of silencer period is set by R1 and C1.

PARTS LIST

C1—30-μF, 15-V capacitor
C2—0.01-μF, disc capacitor
IC1—555 timer
K1—9-to-12-V, reed relay
R1—1-M Ω trimpot
R2—680 Ω, ½-W resistor
R3—10-to-20 Ω, ½-W resistor
S1—Momentary-contact pushbutton switch
Misc.—Perf board, wire, solder, etc.

CANCEL RUMBLE WITH THIS BASS-SUMMING AMPLIFIER

Versatile project can also be used as an electronic crossover for a subwoofer power amp.

BY JOHN H. DAVIS

THE presence of deep bass in the output of an audio system adds a satisfying "floor" to reproduced program material. However, designing a system to reproduce low frequencies well heightens the probability that rumble will make itself disconcertingly apparent. Presented here is the Bass Summing Amplifier, a project that can attenuate rumble without adversely affecting the low-frequency content or the high-frequency separation of a phonograph disc. It can also be used as an electronic crossover that sums the extreme bass to feed a subwoofer power amplifier. The Amplifier is easily and inexpensively constructed and requires no critical components or adjustments.

Rumble is low-frequency noise that is generated by phonograph recording and playback equipment. High-pass filtering can attenuate subsonic noise to a large extent, but it can't suppress audible rumble without also removing some desired bass content.

Most of the rumble entering a phono cartridge does so as vertical modulation that results in out-of-phase electrical signals at the phono cartridge's outputs. If these low-frequency out-of-phase signals are combined, they will cancel each other. Since recordings contain little or no out-of-phase, low-frequency information, low-frequency summation does not appreciably degrade the program material. What little bass separation exists and is recorded is not audibly significant to human beings. Psychoacoustic studies indicate that bass localization is mostly a function of attack transients and overtones.

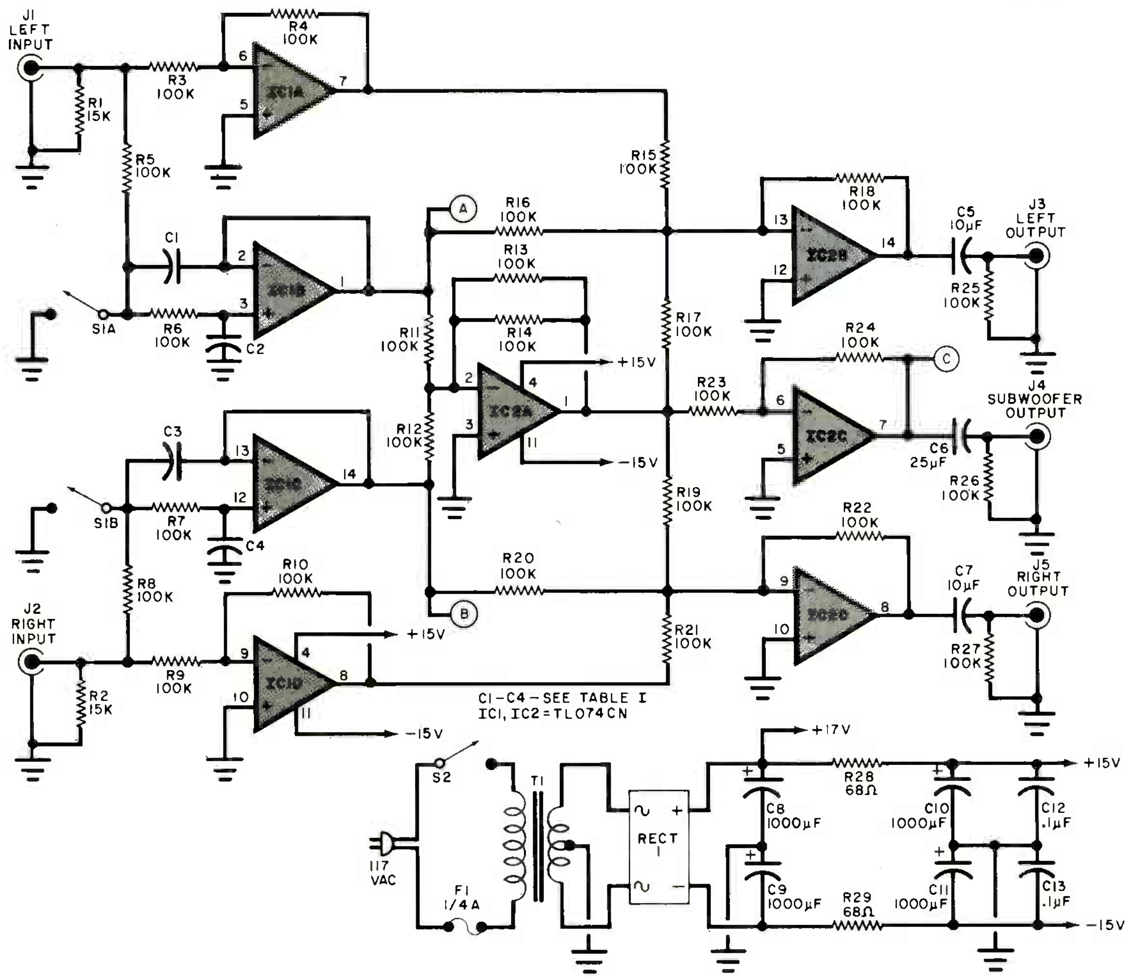
To verify that bass summing will attenuate rumble, play a silent groove on a vinyl disc and increase the volume until the rumble can readily be heard. Then switch your amplifier or preamplifier to its monaural mode. If your left and right channels are balanced and in proper phase, you will hear a drop in the rumble level.

About the Circuit. A schematic of the Bass Summing Amplifier appears in Fig. 1. Line-level stereo inputs are applied to jacks *J1* and *J2*. Unity-gain inverters *IC1A* and *IC1D* shift the phase of the input signals by 180°. However, the unity-gain, low-pass filters comprising *IC1B*, *IC1C* and their associated passive devices do not appreciably alter the phase of those components of the input signals below their cutoff frequencies. If the outputs of *IC1A* and *IC1B* and those of *IC1C* and *IC1D* are combined, the low frequencies will cancel, leaving inverted midrange-and-treble stereo signals.

If the bass outputs of *IC1B* and *IC1C* are combined, a composite, summed bass signal results. This summed bass contains all of the in-phase information but no difference information. If this composite bass is recombined with the middle-and-high-frequency stereo signals, the resulting stereo outputs are almost indistinguishable from the original—except for the lack of rumble components. Because the operation of *IC1A* and *IC1D* involves phase inversion, *IC2B* and *IC2D* perform an additional compensating inversion.

The performance of the project in the rumble-suppressing mode is summarized by the graphs of Fig. 2. The heavy curve shows the extent to which low-frequency difference information is cancelled when the low-pass filters have cutoff frequencies of 220 Hz. The lighter-weight curve shows the extent to which channel separation is maintained as a function of frequency. Two dashed curves show the measured separation available from modestly priced and premium phono cartridges. These latter curves demonstrate that, above bass frequencies, the project does not adversely affect realizable separation.

A monaural signal that can be used to drive a subwoofer power amplifier is available at the output of *IC2C*. This filtered and summed bass signal is in phase with respect to the bass components of the stereo input signals. However, in this application, resistors *R17* and *R19* must be deleted so that the summed bass is not also present in the stereo outputs. Accordingly, the stereo system handles only the upper bass, midrange, and high frequencies. Figure 3 shows the low-pass-filter response that characterizes the output presented at *J4* for a cutoff frequency of 110 Hz. The stereo out-



PARTS LIST

Components denoted by an asterisk can be deleted if the optional, dynamic separation indicator is not to be built.
C1,C2,C3,C4—Metallized polyester, metallized Mylar, monolithic ceramic or polystyrene capacitor, 10% or closer tolerance (see Table I for capacitance)
C5,C7—10-µF, 50-V, axial-lead, nonpolarized electrolytic
C6—25-µF, 50-V, axial-lead, nonpolarized electrolytic
C8,C9,C20*—1000-µF, 25-V, radial-lead electrolytic
C10,C11—1000-µF, 25-V, radial-lead electrolytic
C12,C13—0.1-µF, 50-V disc ceramic capacitor
C14*,C15*—0.033-µF, 100-V Mylar capacitor
C16*,C17*—0.33-µF, 35-V tantalum capacitor
C18*,C19*—0.68-µF, 35-V tantalum capacitor
C21*—0.15-µF, 100-V Mylar capacitor
C22*—0.001-µF, 100-V Mylar capacitor
D1*,D2*,D3*—1N300 silicon switching diode
D4*—1N4001 rectifier
F1—1/4-ampere fast-blow fuse
IC1,IC2,IC3*—TL074CN quad BiFET operational amplifier
IC4*—LM324N quad operational amplifier
J1 through J5—RCA phono jack
LED1*—Red light-emitting diode
LED2*,LED3*—Green light-emitting diode
The following, unless otherwise specified, are 1/4-watt, 5% tolerance, carbon-film fixed resistors.
R1,R2—15 kΩ
R3 through R27, R30* through R35*, R41*, R42*—100 kΩ (see text for recommended preselection procedure)
R28,R29—68 Ω, 1/2-watt
R36*,R37*,R44*—22 Ω, 1/2-watt
R38*—330 kΩ
R39*—120 kΩ
R40*—82 kΩ
R43*—27 kΩ
R45*,R46*,R47*—68C Ω
RECT1—1-A, 100-PIV modular bridge rectifier
S1—Dpdt switch
S2—Spst switch
T1—24-V, 300-mA, center-tapped step-down transformer
Misc.—Printed-circuit bcard, standoffs, suitable enclosure, fuseholder, line cord, shielded cable, hookup wire, suitable hardware, strain relief, solder, etc.

***Note:** A partial kit of parts, No. BPKA, including etched and drilled printed-circuit board, matched C1 through C4 capacitors, and set of preselected R3 through R22 resistors, is available for $13.95 postpaid in U.S. (Georgia residents, please add state and local sales tax.) from Roland Electronics, P.O. Box 516, Greenville, GA 30222.*

puts presented at *J3* and *J5* have complementary (high-pass) responses.

For those who want reassurance that difference information cancelled along with the rumble is audibly insignificant, an unusual, dynamic separation indicator is presented as an option. It responds primarily to the frequencies affected by the bass-summing process, and is shown schematically in Fig. 4. The design of this indicator is based on the fact that separation is reflected as an increase in the level of difference information relative to the level of in-phase information. Differential amplifier *IC3A* processes the filtered right- and left-channel bass signals to obtain differ-

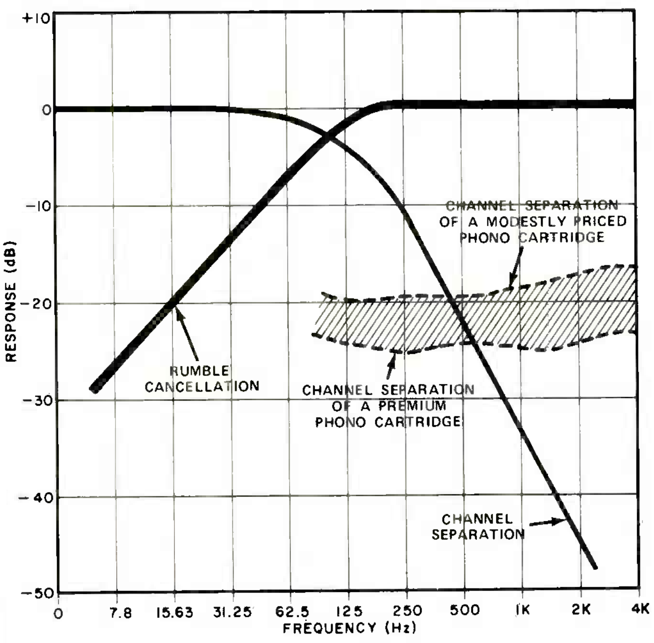


Fig. 2. *Performance curves for low-pass-filter cutoff frequency of 220 Hz. Heavy curve shows the extent to which difference information is suppressed as a function of frequency.*

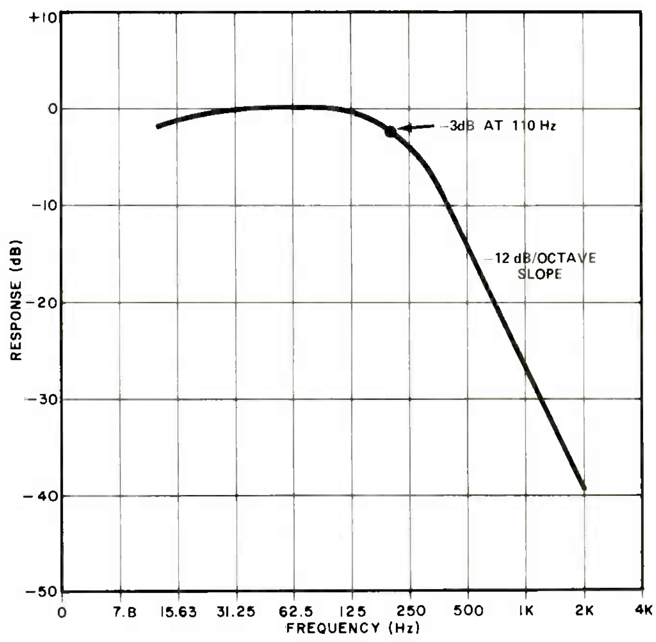


Fig. 3. *Low-pass-filter response that characterizes the subwoofer-output channel. Stereo-output channels have a complementary, high-pass characteristic.*

ence information. The output of *IC3A* is rectified by *IC3B* and *D1*, and charges *C18*.

Summed bass is available at the output of *IC2C* (point C in Fig. 1). It is brought up to an equivalent level by amplifier *IC3C*. The frequency response of this stage is shaped by capacitors *C21* and *C22* to attenuate the unwanted higher frequencies. The amplified, summed bass output of *IC3C* is rectified by *IC3D* and *D2*, and charges *C19*.

Comparators *IC4A*, *IC4B*, and *IC4C* compare the two resulting dc levels and light *LED3*, *LED2*, and *LED1* at progressively higher levels of separation. The network comprising *D3*, *D4*, *R43* and *R44* maintains a small bias voltage across *C19*. This prevents random triggering of the comparators by noise at low signal levels. Such triggering would otherwise be troublesome because signal comparison is based on ratios, not fixed voltage levels.

Options and Modifications. Before undertaking construction, you should determine exactly what function(s) you want this project to perform. If you want only to suppress rumble, you will probably want a filter cutoff frequency of 220 Hz (330 Hz if the rumble is severe). Table I shows which values of capacitors and resistors to use for these frequencies. Also listed are component values for a cutoff frequency of 110 Hz, which is a better choice if a subwoofer is used.

In a Bass Summing Amplifier to be used for rumble reduction only, there are a few components which *can* be eliminated (*C6*, *J4*, and *R26*). To drive a subwoofer power amplifier in addition, however, two resistors (*R17* and *R19*) *must* be deleted. Whether the project is used for both purposes or only for rumble suppression, you have the option of including the separation indicator. If you choose not to include it, some parts can be deleted. They are denoted by an asterisk in the Parts List.

Construction. There are no high-gain or other stages in which circuit layout is critical. However, the use of a printed-circuit board is recommended because of the rather high parts count. The full-size etching and drilling guide for a suitable pc board appears in Fig. 5. Its corresponding component placement guide appears in Fig. 6. The use of IC sockets or Molex Soldercons is recommended.

There are a few points to consider concerning component selection. To minimize distortion, the capacitors in the low-pass filters (*C1* through *C4*) should be metallized plastic-film or other high-quality components. For the same reason, *C5*, *C6*, and *C7* should be nonpolarized electrolytics. Purists will also want to connect 0.1-µF metallized plastic-film capacitors in parallel with *C5*, *C6*, and *C7*.

Carbon-film, 5%-tolerance resistors are acceptable for use in this project, but a simple preselection procedure requiring only an ohmmeter is recommended. The ohmmeter need not be particularly accurate, but should allow you to resolve slight differences in resistance around a center value of 100 kilohms. Exact values are not as important as close matches.

First, measure the values of some 100-kilohm resistors and set aside four that match very closely for *R15*

TABLE I
VALUES OF FILTER COMPONENTS FOR SELECTED CUTOFF (−3-dB) FREQUENCIES

Frequency	Recommended Application	R5, R6, R7, R8	C1, C3	C2, C4
110 Hz	Rumble suppression and subwoofer crossover	100 kΩ	0.02 µF	0.01 µF
220 Hz	Rumble suppression	100 kΩ	0.01 µF	0.005 µF
330 Hz	Suppression of severe rumble	68 kΩ	0.01 µF	0.005 µF

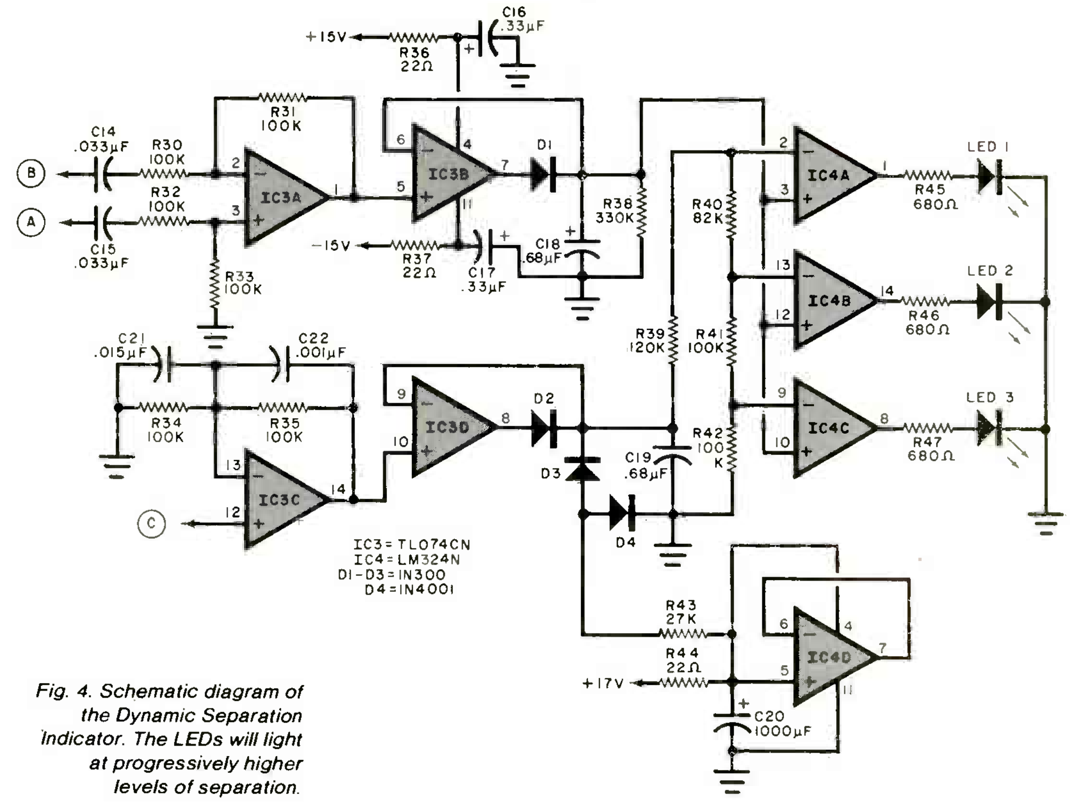


Fig. 4. Schematic diagram of the Dynamic Separation Indicator. The LEDs will light at progressively higher levels of separation.

through *R18*. Select another matching group of four as *R19* through *R22*. Select a third group of four as *R11* through *R14*. Finally, select two closely matched pairs, one pair for *R3* and *R4*, the other for *R9* and *R10*.

The project will perform reasonably well even if this process is not followed, but the more closely matched in value the members of a given group, and the closer the tolerances of *C1* through *C4*, the smoother the frequency response.

When mounting the components on the printed-circuit board, take note of device orientation and the presence of the two short jumpers at pins 5 and 10 of *IC1*. Also note that *R1* and *R2* are soldered across each of the input jacks—they are not mounted on the board. Similarly, *R25*, *R26*, and *R27* are soldered across the appropriate output jacks. The project should be housed in a metal enclosure with shielded cable connecting the pc board to the input and output jacks and switch *S1*.

Testing. Doublecheck the circuit assembly. Then apply power and verify that the positive and negative supply voltages are equal and less than 18 volts. A one-volt, 30-Hz signal applied to *J1*, the LEFT INPUT jack, should result in the appearance of half-volt signals at both *J3* and *J5*, the LEFT and RIGHT OUTPUT jacks. If the project has been built for subwoofer use, the half-volt signal should appear at *J4*, the SUBWOOFER OUTPUT jack, *only*. If a 30-Hz, one-volt signal is applied to *J1* and *J2* simultaneously, the outputs at *J3* and *J5* or the output at *J4* should increase to one volt.

If you have built the dynamic separation indicator, you can test its operation by applying a 30-Hz signal. When the input signal is applied to either *J1* or *J2* (but not both), all three LED's should glow. Ideally, they should all extinguish when both channels are driven by the same input signal. Check to see if this happens.

Next, change the frequency of the test signal to 3000 Hz but keep its amplitude at one volt. Apply this signal to *J1*. A one-volt signal should now appear only at *J3*. Then apply the signal to *J2* and verify that an output appears only at *J5*. At this frequency, none of the LEDs should glow, even if only one channel is driven. If *LED3* does glow, decrease the level of the input signal to see if it extinguishes. (These statements assume, of course, that *S1* is open.)

If you don't have access to test equipment, you can patch the project into your system at a line-level point in the signal chain. The Bass Summing Amplifier should be connected *after* any signal-processing components such as an equalizer, a dynamic-range expander, etc. Then find a quiet groove on a vinyl disc and play it. Listen for rumble, and open and close switch *S1*. A difference in the rumble level should be noticeable. During such a test, *LED3* might flicker, but the other two LEDs should flash only very rarely.

Use. For the Bass Summing Amplifier to function properly, your audio system needs to be well balanced at the point at which signals are routed to the inputs of the Bass Summing Amplifier. Use the monaurally recorded bands of a test record, or listen to a quiet groove of a standard disc

AUTHOR'S SPECIFICATIONS

Input Impedance: 10 KΩ
Recommended Load Impedance: 10 kΩ or greater
Input-signal Level: 0.3 to 3.0 volts rms; 1.0 volt recommended
Total Distortion: Less than 0.05%
S/N: Better than 70 dB (unweighted)
Frequency Response: 50 Hz to 16 kHz ± 1/4 dB at stereo outputs with *R17* and *R19* in project; filter resistors preselected according to procedure described in text; both channels driven, *S1* open.

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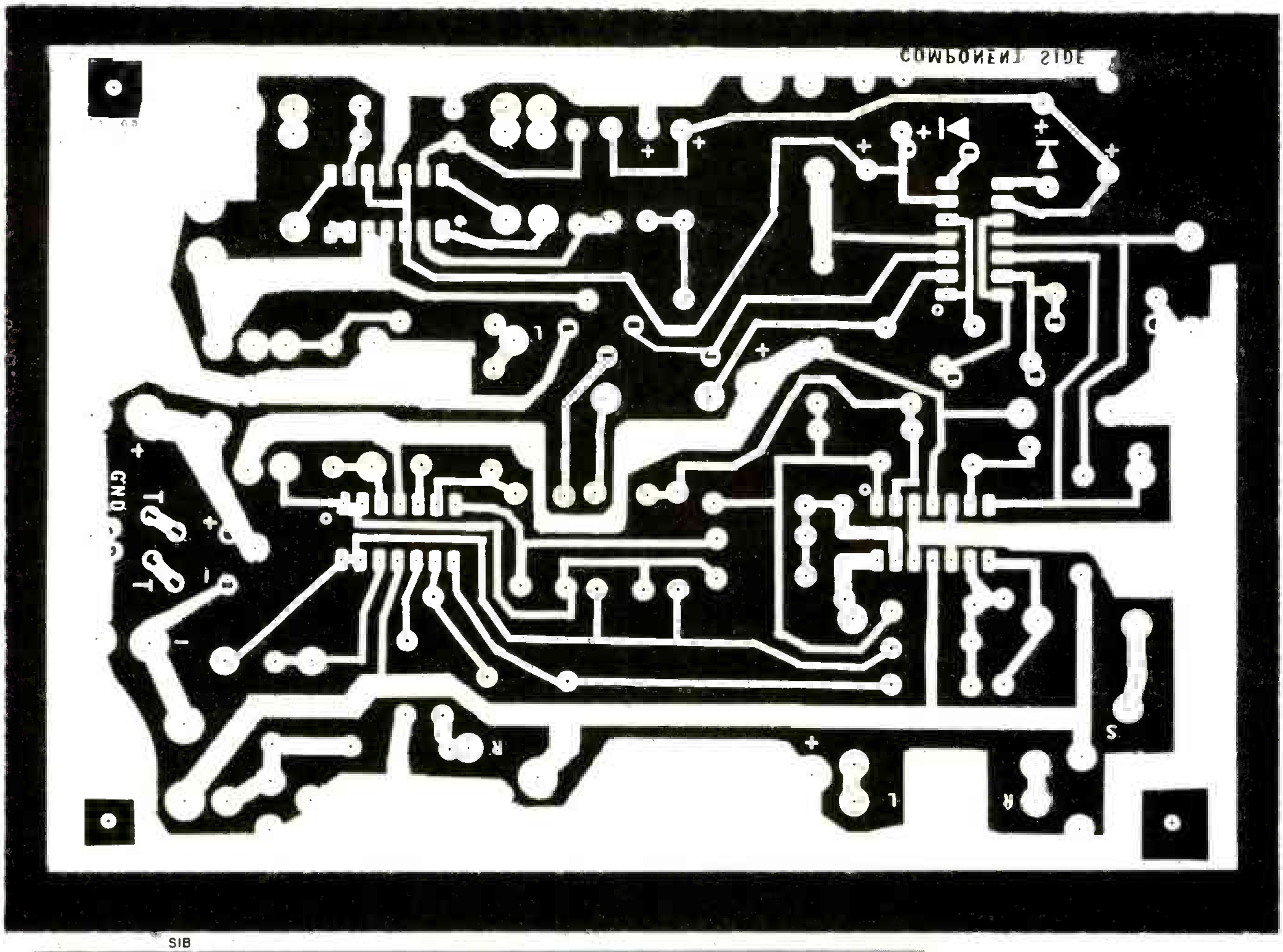


Fig. 5. Full-size etching and drilling guide (above) for the Bass Summing Amplifier and Dynamic Separation Indicator.

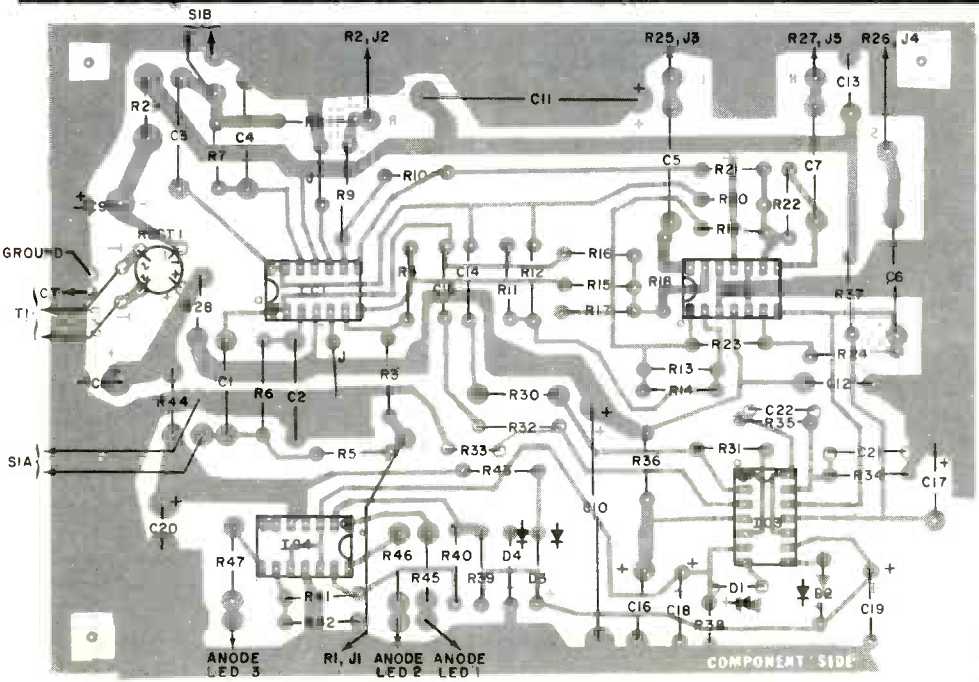


Fig. 6. Component placement guide to be used with the printed-circuit board.

while adjusting interchannel balance. Maximum cancellation occurs when the channels are exactly balanced. Even high-quality phono cartridges have some imbalance, and as much as 2 dB will degrade the rumble-cancelling capability of the project.

The net result of your efforts will be quieter and more satisfying bass. As a bonus, the bass summing amplifier can be used to reduce rumble on tapes that have been dubbed from noisy turntables or from FM broadcasts generated using outdated studio equipment. ◇

LOW-COST POWER SUPPLIES FROM **RECYCLED AC ADAPTERS**

BY RALPH TENNY

How to check out and use modules that clutter your junk box

AC ADAPTERS for operating portable equipment such as radios, tape decks, calculators, or shavers from the power line instead of the usual batteries represent an often unrecognized resource for the electronics experimenter. The chassis for a project can often be made smaller and cheaper if one of these devices is used to supply operating power. And if small children are involved in any way with the project, the isolation from the power line provided by the adapter can be a safety factor. In addition, one adapter can power several projects if they are not all in use at once. Best of all, you probably have several of these devices left over from old, discarded appliances.

Types of Units. Since adapters are designed to reduce the nominal 117 volts at the wall socket to a lower voltage, all of them contain a small low-power transformer. There are two basic outputs from these devices; ac only or some form of dc. To identify the output, read the label on the case. If the label cannot be read, an oscilloscope across the output with a light resistive load (1 to 5 kΩ) will quickly identify it. An ac-only device will display a line-frequency sine wave, while a dc-output device that incorporates filtering will show a dc level with a small amount of ripple. If there is just a rectifier with no filtering, a line-frequency half sine indicates half-wave rectification while a series of half sines at twice the line frequency indicates full-wave rectification.

Testing. The setup used for testing ac and dc output adapters is shown in Fig. 1. The only practical difference between the two types is that a rectifier is used with the ac device.

With the load resistor disconnected, the supply will deliver its maximum dc voltage (1.41 times the rms value of the transformer output voltage). Construct a graph with voltage on the vertical axis and current on the horizontal axis. The upper end of the voltage axis is marked with the maximum (unloaded) voltage from the test circuit; from that point to the bottom (where this line joins the current axis) divide the voltage axis evenly into volts and parts of volts.

Ohm's Law ($R=E/I$) is used to determine the value of load resistor used. If, for example, the dc output is 15 volts, a 15,000-ohm resistor will draw 1 mA, a 1500-ohm resistor 10 mA, and a 150-ohm resistor 100 mA. If we wanted to start the current plot at, say, slightly under 10 mA, then a potentiometer (5-watt) having a value of 2000 to 2500 ohms will be required. To avoid burning out the module when the pot is set toward its low end, connect a 150-ohm, 2-watt resistor in series with the potentiometer to limit current flow to 100 mA. This latter resistor can be reduced if the supply proves capable of delivering more than 100 mA.

Adjust the potentiometer until the current meter indicates 10 mA. Observing both meters, plot the voltage and current on the graph. Reduce the potentiometer resistance until 15 mA is flowing. Plot the voltage and current again. Repeat these steps until you have sufficient data to construct a curve like that in Fig. 2. During these tests, make sure that the transformer does not overheat (though it may feel warm to the touch), indicating excessive current drain.

An oscilloscope connected across the output of a dc supply may show considerable ripple, particularly if the supply uses a half-wave rectifier or is heavily loaded. To reduce this ripple, add more filter capacitance. As a general rule of thumb, doubling the capacitance will halve the ripple.

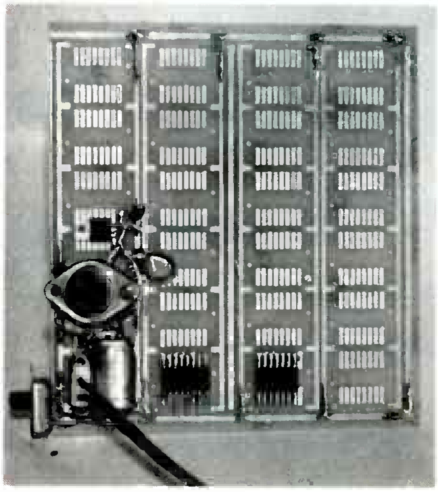
The graph you have drawn will give a close estimate of output voltage at any given load current. In addition, it allows you to determine regulation (the degree to which the voltage varies with load). This is expressed as the percentage of the open-circuit voltage measured with maximum output current. Thus, the curve shown in Fig. 2 indicates regulation of 48%. The higher the regulation, the better the supply.

Before an adapter is used to power a project, it should be tested under load for an hour or more. If the exterior case gets too hot to touch comfortably, a hazard may exist, and a higher capacity adapter should be used.

ac adapters

AC Circuits. Four typical rectifier circuits for use with ac-only adapters are shown in Fig. 3. A full-wave rectifier like that in Fig. 3A can be had as an encapsulated module or synthesized from discrete silicon diodes. A filter capacitor is added to smooth the output and produce useful dc. For low-current applications where cost is a big factor, a half-wave rectifier circuit can be used. This is shown in Fig. 3B. The voltage doubler (Fig. 3C) and tripler (Fig. 3D) will deliver two and three times, respectively, the open-circuit voltage of a half-wave supply but with only small currents. In addition, they have very poor voltage regulation and excessive ripple unless very large valued filter capacitors are used.

DC Circuits. These types of adapters usually have some internal filtering, but for good results require about 1000-μF of external filtering. To improve voltage stability under load, an external regulator module can be added. The most convenient type of regulator to use is a



Rectifier and regulator on prototype board.

Ac adapter used as a trickle charger for automotive battery.

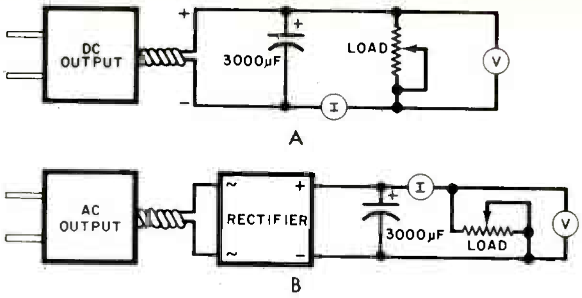


Fig. 1. The difference between the test circuit for an ac and dc adapter is the rectifier required by the ac version.

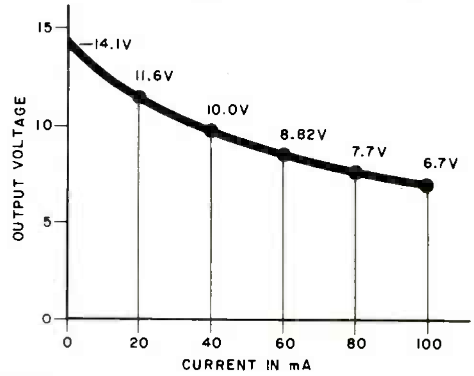


Fig. 2. A typical load regulation curve used to evaluate an ac adapter.

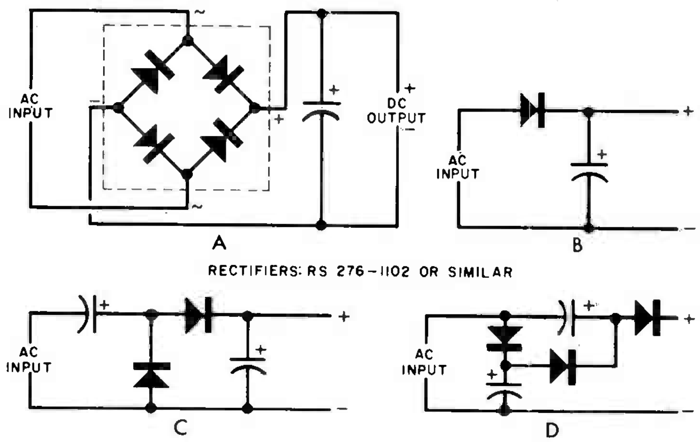


Fig. 3. Four circuits for an ac adapter. Full-wave rectifier (A), half-wave (B), half-wave voltage doubler (C), and voltage tripler (D).

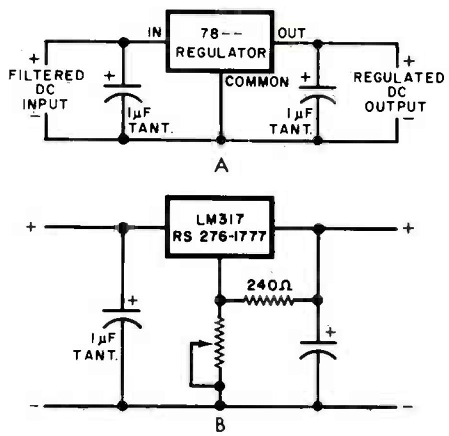


Fig. 4. Three-terminal regulator at (A) delivers a fixed voltage while the circuit shown in (B) is adjustable and regulated.

three-terminal device such as the 7805, 7809, or 7812. These accept up to 35 volts input and deliver 5, 9, and 12 volts respectively. A typical circuit is shown in Fig. 4A. This circuit is ideal for non-critical, low-power applications, and is inexpensive. Three-terminal regulators are very rugged, and have internal circuits to protect them from overheating and overload. Keep in mind that the input voltage to the regulator must be at least 2.5 volts higher than the desired output voltage with maximum current drawn from the supply.

The graph of Fig. 5 illustrates a dc source applied to a 9-volt regulator with the ripple voltage added. Note that as the output current increases, the output voltage comes closer to the desired regulated voltage. At some current, the regulator input voltage will intersect the lower edge of the ripple band. This then becomes the maximum allowable output current for this particular combination. This curve illustrates the need for load testing a finished supply.

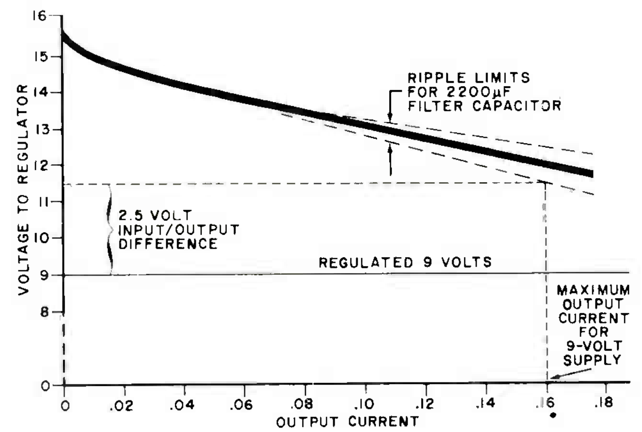


Fig. 5. Graphical operation of a 9-volt regulator showing how ripple affects delivered current.

By using a "third generation" three-terminal regulator such as that shown in Fig. 4B, a variable regulated voltage from about 1.2 volts to the input voltage minus 2.5 volts can be built.

Multi Voltages. Circuits requiring more than one dc voltage are shown in Fig. 6. For a dc adapter, the simplest approach is Fig. 6A. This circuit delivers 12 and 5 volts, both regulated. An ac adapter can use the circuit shown in Fig. 6B to deliver both a positive and negative voltage. If desired, a 7905 can be used in the *negative* line to deliver regulated −5 V, while a 7805 in the *positive* line delivers regulated +5 V. The circuit in Fig. 6C can deliver both positive and negative voltages if the output of the dc adapter is about two V higher than the sum of the two output voltages. The LM317 is set to the sum of the two voltages, while the 741 op amp forces the two transistors to sink current from both loads. This creates a common line that is treated as the circuit ground. This circuit can be used to create positive and negative voltages of equal or unequal magnitude, depending on the ratio of *R1* to *R2*. Both voltages will be as well regulated as the output from the regulator.

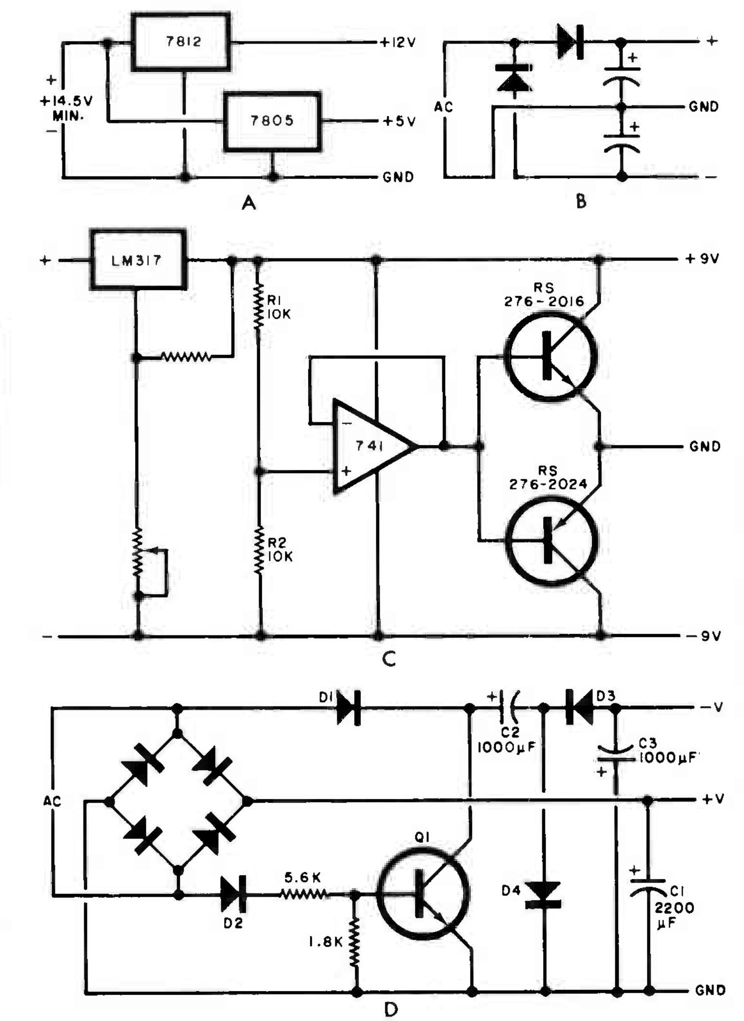


Fig. 6. Various methods of generating positive and negative voltages from a single power source.

A negative voltage may be generated from a positive supply by a circuit called a "charge pump" as shown in Fig. 6D. This circuit uses alternate cycles of the transformer voltage to charge *C2* via *D1*. The other half cycle, selected by *D2*, turns on *Q1*. When *Q1* is turned on, the charge on *C2* is dumped via *D3* into *C3*, creating a negative voltage. With the values shown, this circuit has about 30% regulation.

A perusal of the many books covering power supplies will show a number of other circuits that can be adapted for use with ac and dc output power line adapters. With this information, it is possible to salvage most of those previously useless ac and dc adapters. ◇

AN ALARM FOR TOXIC GASES

Detects oxygen-hungry gases such as carbon monoxide and methane. . . . sounds a warning before dangerous concentrations are reached

BY CASS LEWART

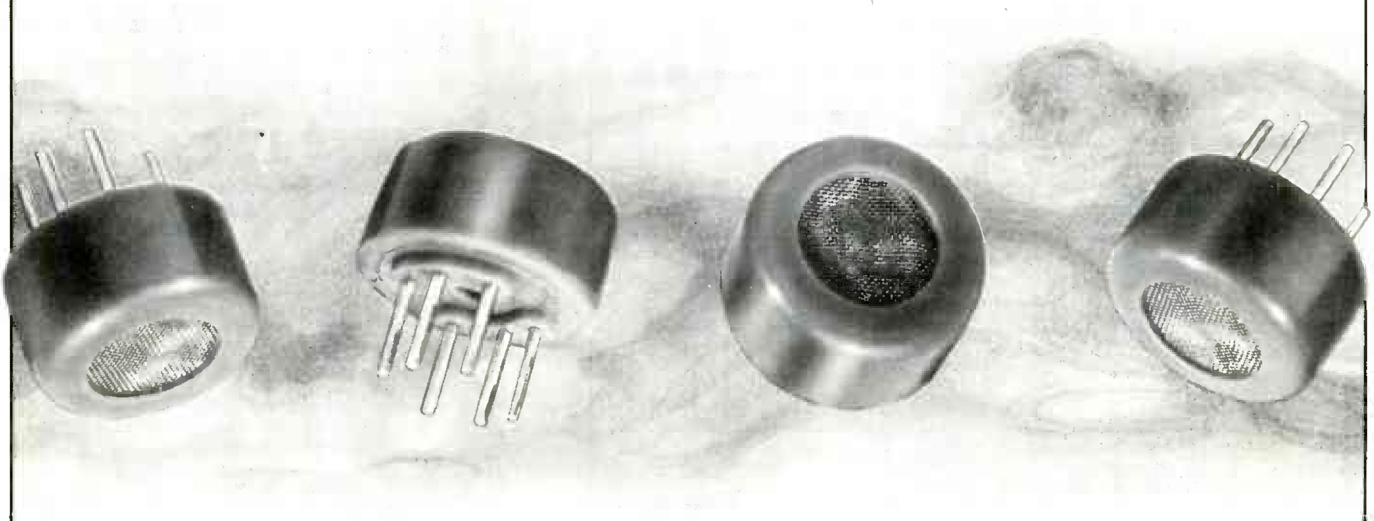
WHEN a lethal fire starts, flame and smoke are not the only killers. Colorless, odorless carbon monoxide gas (CO) has been known to kill or incapacitate people—often far from the fire itself. One factor that makes CO such a stealthy, insidious assassin is its ability to elude conventional smoke detectors. These devices are similarly insensitive to dangerous hydrocarbon gases like methane (CH_4), a toxic compound that is the chief component of natural gas.

The Gas Alarm described here has been designed to sound its warning *before* dangerous levels of poisonous gases accumulate. The Gas Alarm should be considered complementary to, and not a replacement for conventional smoke detectors, as it will *not* respond to ionized gases generated by fire unless the fire is smoldering in an enclosed area lacking oxygen. This project has the advantage of being self-powered, thus providing portable protection both at home and in hotels or motels when you travel.

The alarm is based on an inexpensive semiconductor sensor whose electrical resistance changes when its active surface is exposed to gases such as carbon monoxide, methane, butane, and alcohol vapors that have a strong affinity for oxygen. (These are known as *reducing gases*.) The sensor element is enclosed in a small capsule and protected by a stainless steel mesh, while a low-power heater activates the sensor element and purifies it after exposure to gas.

Circuit Operation. As shown in Fig. 1, transformer *T1*, fullwave rectifier *RECT1*, resistor *R2*, and filter capacitor *C1* make up the line-powered power supply for 5-volt regulator *IC1*. Resistor *R1*, in conjunction with rectifier *D1*, maintains the charge on the rechargeable cells in *B1*, while diode *D2* allows *B1* to power the circuit in stand-by mode when the line power is interrupted. Under these conditions, *D1* is reverse biased and battery power flows through forward-biased diode *D2* to power the circuit. The regulated output from *IC1* maintains a fixed heater voltage for gas sensor *TGS1* to provide uniform sensitivity. The combination of *R3* and *LED1* forms a power-on indicator.

When gas is present at *TGS1*, the



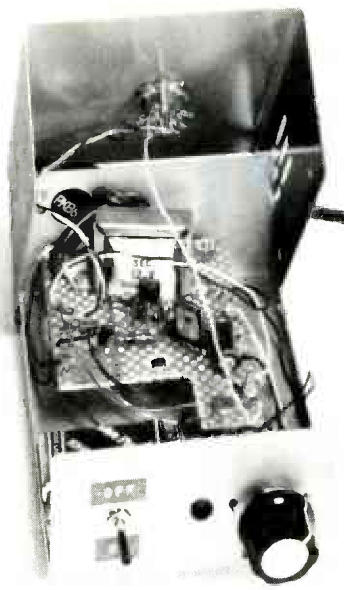


Photo of the author's prototype.

resistance of its sensor element drops, raising the voltage applied across calibration potentiometer *R4*. The rotor of *R4* is connected to the gate of

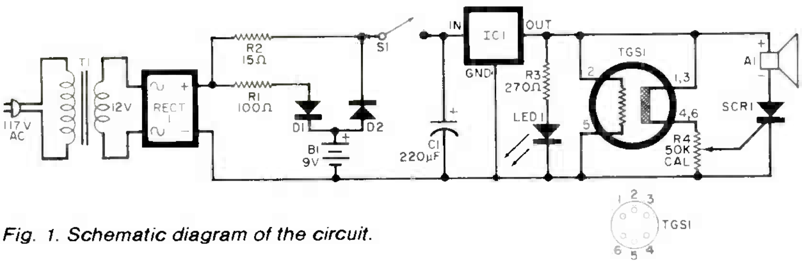


Fig. 1. Schematic diagram of the circuit.

PARTS LIST

A1—Piezoelectric buzzer (Radio Shack 273-060 or similar)
B1—Battery (six rechargeable 1.5-V cells)
C1—220-µF, 16-V electrolytic
D1, D2—200-V, 1-A silicon diode
IC1—5-V regulator (Radio Shack 276-1770 or similar)
LED1—Red LED (optional)
R1—100-Ω, ½-W resistor
R2—15-Ω 1-W resistor
R3—270-Ω, ½-W resistor (optional)
R4—50-k Ω linear potentiometer
RECT1—50-V, 1-A full-wave rectifier
S1—Spst switch
SCR1—200-V, 6-A SCR (Radio Shack 276-1067 or similar)
TGS1—Gas sensor (See note)
T1—12-V, 1-A transformer (Radio Shack 273-1505 or similar)
Misc.—6" x 4" x 2½" enclosure with cover, perf board or terminal strips, etc.
Note: The following is available from C&R Electronics, Box 217, Holmdel, NJ 07733: Pretested gas sensor, with socket, for $10.95 plus $1 postage and handling. NJ residents, add 6% tax. Allow 2 to 3 weeks for delivery.

SCR1, and when voltage at that point reaches approximately 0.3 V, *SCR1* turns on, supplying power to alarm *A1*. The piezoelectric alarm specified for *A1* interrupts current flow periodically, so *SCR1* does not latch permanently on. Switch *S1* allows for faster battery charging while the gas sensor is turned off.

Construction. The project will easily fit in a 6" x 4" x 2½" metal cabinet, and all components except the alarm and gas sensor can be mounted on perf board or multi-lug terminal strips using point-to-point wiring. Mount the socket for sensor on top of the cabinet for maximum exposure to surrounding air, and mount the alarm on the side or back of the cabinet for best audio output. The six rechargeable cells forming *B1* can be mounted in readily available battery holders.

Adjustment. (1) Plug the Gas Alarm into a 117-volt ac outlet; (2) rotate *CAL* control *R4* fully CCW for minimum resistance between the SCR gate and ground; (3) apply power and allow the sensor to stabilize for 1-2 minutes, then rotate the *CAL* control clockwise till the alarm sounds; (4) rotate *CAL* control CCW till the alarm stops. The alarm is now ready for operation. Test the system by rubbing a drop of alcohol between your fingers, near the sensor. When the alarm sounds, repeat steps two through four.

The rechargeable batteries are trickle charged when the alarm is plugged into an ac outlet, and will be fully charged after approximately 24 hours. To ensure that the batteries are working properly, unplug the alarm and, after allowing it to stabilize with the batteries, repeat the alcohol test described above. The fully charged AA-size batteries should operate the sensor for over an hour during a power failure. For longer standby operation use C- or D-size rechargeables. These will operate the alarm longer, but also require longer charging time. When the alarm is not in use, open *S1* to protect batteries from discharging through *IC1*. ◇

BY THOMAS R. FOX

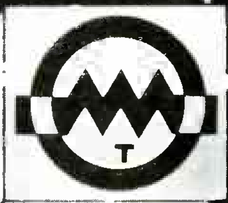
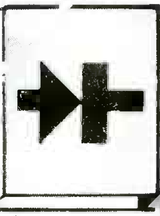
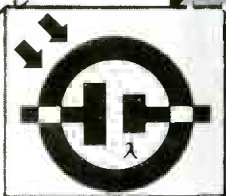
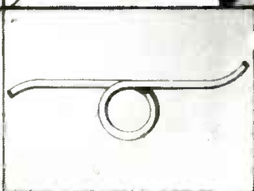
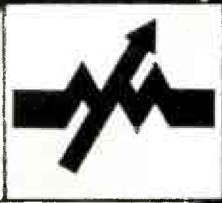
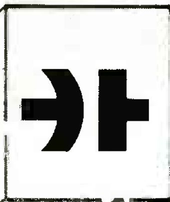
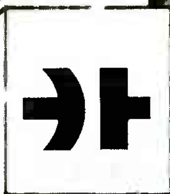
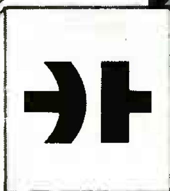
SOME LIKE IT HOT...

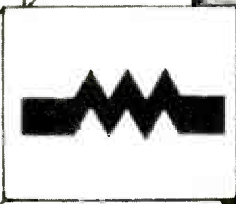
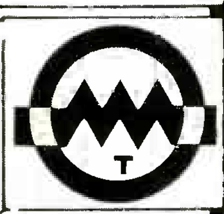
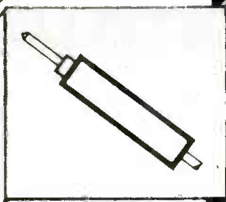
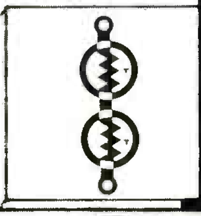
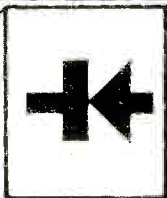
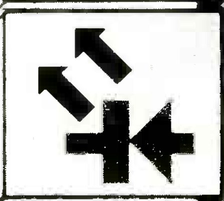
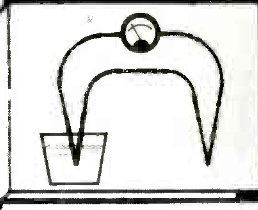
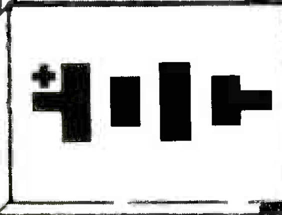
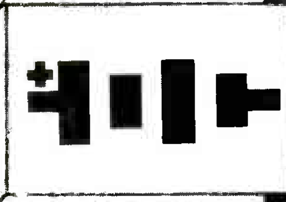
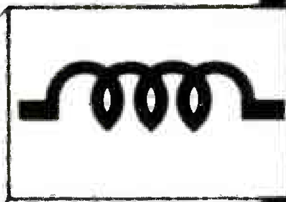
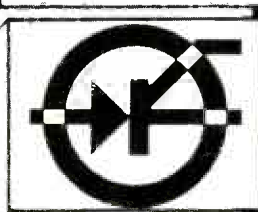
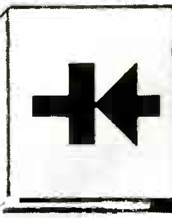
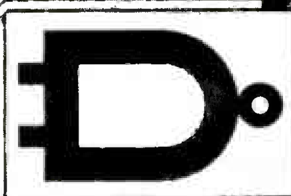
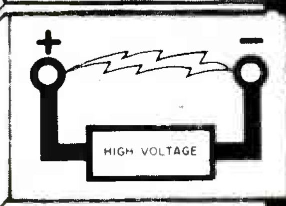
But which ones?
Test your knowledge of
how circuit components respond
to temperature.

SOME electronic components, especially semiconductors, are extremely sensitive to temperature changes. Even passive components (resistors and capacitors, for example), which are normally insensitive to temperature variations, can undergo parameter changes that are sometimes sufficient to influence circuit behavior.

Here is a quiz that will check your knowledge of how the parameters of some common electrical components (as well as a few rare ones) change with temperature. The quiz gives you the common name and electrical symbol or pictorial representation of the components and the parameters of interest under temperature change (resistance, voltage, etc.).

Your task is to answer the following questions about each component: (A) Does the parameter of interest increase or decrease as the component's temperature increases from 68°F (20°C) to 95°F (35°C)? (B) Is the component frequently used in temperature measuring, control, or compensation circuits? As an example, for component No. 1, the thermistor, the answers are: (A) Decrease; (B) Yes. Answers for the rest are on the third page of the quiz. If you get 35 correct answers out of the total 50, you have done very well indeed.

Component	Symbol	Parameter of interest
1 Thermistor		Resistance
2 Silicon diode		Forward voltage drop
3 Silicon photovoltaic cell (Solar cell)		Power output
4 Copper wire		Resistance
5 Platinum wire		Resistance
6 Electrolytic capacitor (A1)		Capacitance
7 Polystyrene capacitor		Capacitance
8 NPO-type capacitor		Capacitance

Component	Symbol	Parameter of interest
9 Class I ceramic capacitor		Capacitance
10 Carbon composition resistor		Resistance
11 Positive temp. coef. silicon resistor		Resistance
12 Insulated test lead		Insulation resistance
13 Thermistor (TC= −1000 ppm/°C) Sensitor TC= +1000 ppm/°C) (Pos. temp. coef.)		Resistance between points A and B (Assume perfect linearity)
14 NPN silicon transistor		DC Beta (current gain)
15 Germanium diode		Reverse leakage current
16 Red LED		Radiant power (light output)
17 Red LED		Wavelength of light (Red = long wave Violet = short wave)
18 Copper-iron thermocouple		Current when temp. of test junction rises
19 Lead-acid storage battery		Capacity
20 Typical primary battery (Zn/C, for example)		Storage life
21 Inductor		Inductance
22 Silicon controlled rectifier		Minimum trigger voltage
23 Passivated alloy silicon diode		Reference voltage
24 7400 TTL gate		Threshold voltage
25 CMOS gate		Transfer voltage
26 Spark gap		Minimum spark voltage

QUIZ ANSWERS

1. See introduction.

2. (A) Decrease; (B) Yes. **Note:** The silicon diode has a relatively linear forward voltage vs. temperature characteristic. It is also low-cost and readily available. However, it is comparatively insensitive.

3. (A) Decrease; (B) No. **Note:** Keeping the cell cool raises efficiency.

4. (A) Increase; (B) No. **Note:** Except possibly at high temperatures, copper's variation of resistance is seldom taken into account in designs.

5. (A) Increase; (B) Yes. **Note:** Platinum makes probably the best of the metallic type of temperature probe. Its advantages are: it can be highly refined; it resists contamination; it is electrically and chemically stable; its resistance characteristic is quite linear; and its drift and error with age are negligible.

6. (A) Increase; (B) No. **Note:** Seldom used in critical circuits.

7. (A) Slight decrease; (B) No. **Note:** The capacitance of polystyrene units varies little with temperature.

8. (A) Almost no change; (B) No. **Note:** NPO (Negative-Positive-Zero) is a temperature compensating dielectric that has an ultrastable temperature characteristic. Used in certain types of ceramic capacitors.

9. (A) Most decrease (B) Yes. **Note:** Some types of Class I ceramic capacitors, which are usually made of titanium dioxide, are frequently used in compensation circuits.

10. (A) Increase; (B) No. **Note:** This workhorse of the resistor world has quite a high temperature coefficient and thus isn't used frequently in critical circuits that must be temperature stable. Carbon-film, metal-film, or wire-wound resistors are better choices for application in critical circuits.

11. (A) Increase; (B) Yes. **Note:** Because of its fairly linear resistance/temperature characteristic (especially with a properly chosen fixed resistor in parallel) this component has possible use in simple digital thermometers.

12. (A) Decrease; (B) No. **Note:** Keep this in mind when testing high-voltage circuits.

13. (A) None; (B) No. **Note:** The thermistor resistance decreases by 0.1% for every degree Celsius increase in temperature (remember, 1000 ppm/°C = 0.1%) and the Sensitor resistance increases by an identical amount. Thus, the overall effect is zero.

14. (A) Increase; (B) Yes. **Note:** This effect has been used in inexpensive electronic thermometers. Also, it must be compensated for when designing a transistor circuit so that the transistor's operating point doesn't change significantly with temperature.

15. (A) Increase; (B) Yes. **Note:** A simple electronic thermometer can be constructed from a reverse-connected germanium diode, a battery, and a microammeter. The relatively high, temperature-dependent reverse leakage currents of germanium diodes make the silicon diode, whose leakage is far smaller, preferable in some applications.

16. (A) Decrease; (B) No. **Note:** Keep LEDs cool for increased brightness.

17. (A) Increase; (B) No.

18. (A) Decrease; (B) Yes. **Note:** Does this surprise you? Well, this is sort of a trick question. One normally thinks of a thermocouple's output as increasing with an increase in temperature. The fact is, a thermocouple's output increases with an increase in the *difference* in temperature between its standard junction and the test junction. Since the standard junction shown is at a constant 120°F, the thermocouple's output *decreases* until the test junction reaches 120°F, at which point the output is zero. For test junction temperatures above 120°F, the output increases with further increase in temperature. Since we are limited to a maximum temperature of 95°F, the output is said to *decrease* with increasing temperature.

19. (A) Increase; (B) No. **Note:** This answer is obvious to anyone who had no trouble starting his car on a relatively mild winter afternoon, but early the following morning, when it was bitter cold, had to jumper the battery to start the car. (Of course, thickening oil exacerbates the problem.)

20. (A) Decrease; (B) No. **Note:** This effect is more important than most people realize. One answer is to store batteries in as cool an area as possible. A standard battery will retain nearly all its original capacity for as long as two years if stored at 32°F. This same battery, if stored at 160°F (say in an attic), will have only about 15% of its original capacity after only 1 month of storage!

21. (A) Increase; (B) No.

22. (A) Decrease; (B) No. **Note:** A substantial increase in temperature can trigger a false alarm. (Although the author has never seen it done, he speculates that a simple fire alarm can be constructed using an SCR with its gate clamped to a constant voltage just below the minimum trigger point (at room temperature).

23. (A) Almost none; (B) No. **Note:** This diode provides a reference voltage whose stability compares with that of standard cells.

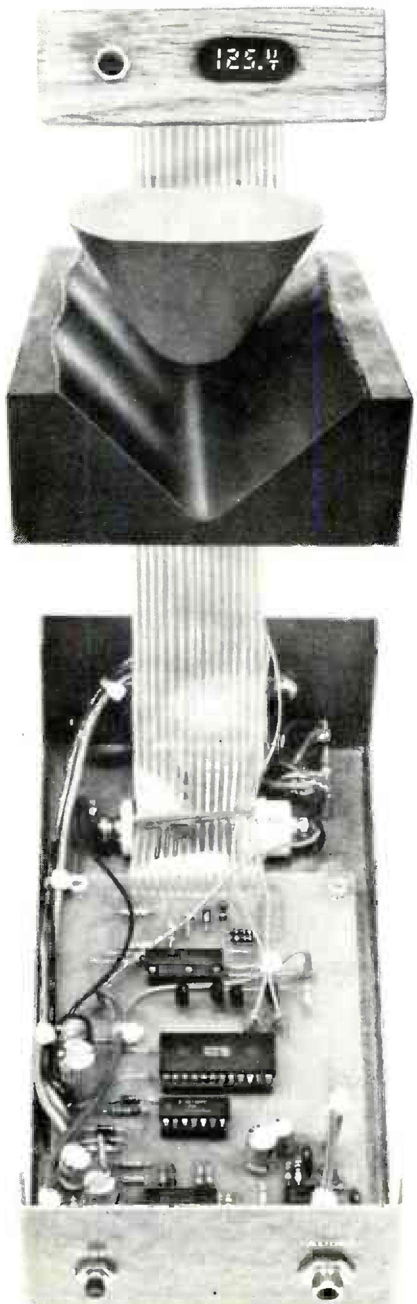
24. (A) Decrease; (B) No. **Note:** Here is one reason why commercial-quality TTLs should be used only between 0°C and 70°C.

25. (A) Slight decrease; (B) No. **Note:** CMOS devices are less sensitive to temperature than TTLs. Plastic-cased CMOS are guaranteed to operate satisfactorily from −40°F to 185°F (−40°C to 85°C).

26. (A) Decrease; (B) No. **Note:** Spark gaps are frequently used to measure extremely high voltages. While this method may seem crude, it is accurate.◇

"I said, I think maybe the ghosts seem sharper now!"

HOW MANY HOURS ARE ON YOUR PHONO STYLUS?



BY DENNIS BOHN

ALMOST every hi-fi phono stylus is made from the hardest substance known to man—diamond. Even a diamond stylus, however, will become appreciably worn after a given number of hours of use. Keeping track of the number of playing hours a stylus has accumulated—and thus indirectly the degree to which it has become worn—is important for two reasons. Using a worn phono stylus dramatically reduces playback fidelity and can cause catastrophic, permanent physical damage to the grooves of a vinyl recording.

Presented here is a simple, inexpensive project that logs the number of hours a stylus has been used. This information is displayed at the push of a button on a four-digit, seven-segment LED readout to the nearest tenth of an hour. The low construction cost of this project—$50 or less—makes it an ideal solution to the problem of monitoring stylus use. With it, you will eliminate both the risk of using the same stylus too long and the needless expense of replacing it too soon.

About the Project. One principal design goal was to produce a circuit that would provide as accurate a count of actual stylus *playing time* as possible. This immediately ruled out the use of any scheme involving the sensing of the amount of time that the turntable was simply on. What was required was a method of determining the amount of time that the cartridge would actually be generating an audio output for subsequent processing by the phono preamp. This is the approach that was taken in the project described here.

The project is shown schematically in Fig. 1. Because there is no easy access to the output of the phono-preamp stage (apart from the fact that most equipment warrantees would be voided by any such tampering), the stylus timer begins with its own RIAA phono preamplifier. The audio output of one of the cartridge's channels is tapped at the stereo system's phono-preamp input by means of a Y connector/adapter and a short patch cord. Sensing the input signal of only one audio channel was deemed sufficient for the accuracy required. It is highly unlikely that long periods of time will exist in which there is a total absence of signal in one channel of a typical stereo disc.

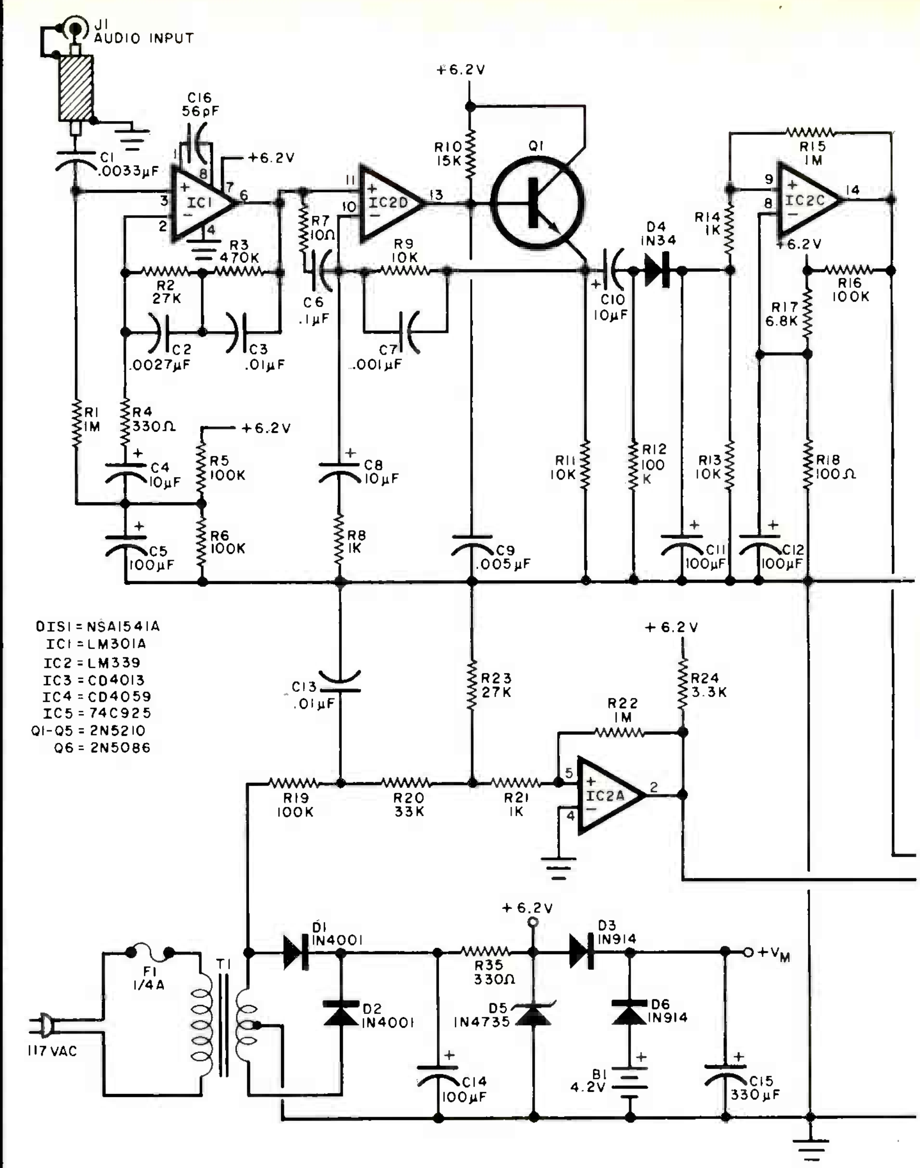
The output of the phono cartridge is applied to AUDIO INPUT jack *J1*. One megohm of resistance (*R1*) and 20 pF or less of parasitic shunt capacitance comprise the input impedance of the project. This means that there is no additional, significant loading of the cartridge. Therefore, the stylus timer's input network does not appreciably alter the loading and hence sonic performance of the phono cartridge.

Operational amplifier *IC1* boosts the level of the input signal and, with the help of *R2*, *R3*, *C2* and *C3*, provides RIAA playback equalization. Because the op amp is powered by a single-ended supply, dc level-shifting of the input signal (performed by *C5*, *R5* and *R6*) and capacitive input coupling (furnished by *C1*) are required. Output signals from *IC1* are directly coupled to the noninverting input of *IC2D*, which is one-fourth of an LM339 quad comparator. This stage is operated in linear fashion as an op amp with transistor *Q1* inside the overall feedback loop. Resistors *R10* and *R11* determine the bias of *Q1*. Resistor *R7* and capacitors *C6*, *C7* and *C9* furnish frequency compensation to ensure stability.

The 20 dB of gain provided by *IC2D* and the 40 dB of gain supplied by *IC1* (at 1 kHz) boost the input signal to the level required by the half-wave rectifying and averaging network *D4*, *C11*, and *R13*. The amplified input signal is converted into a positive dc voltage appearing across capacitor *C11*, which charges rapidly and discharges slowly through *R13*.

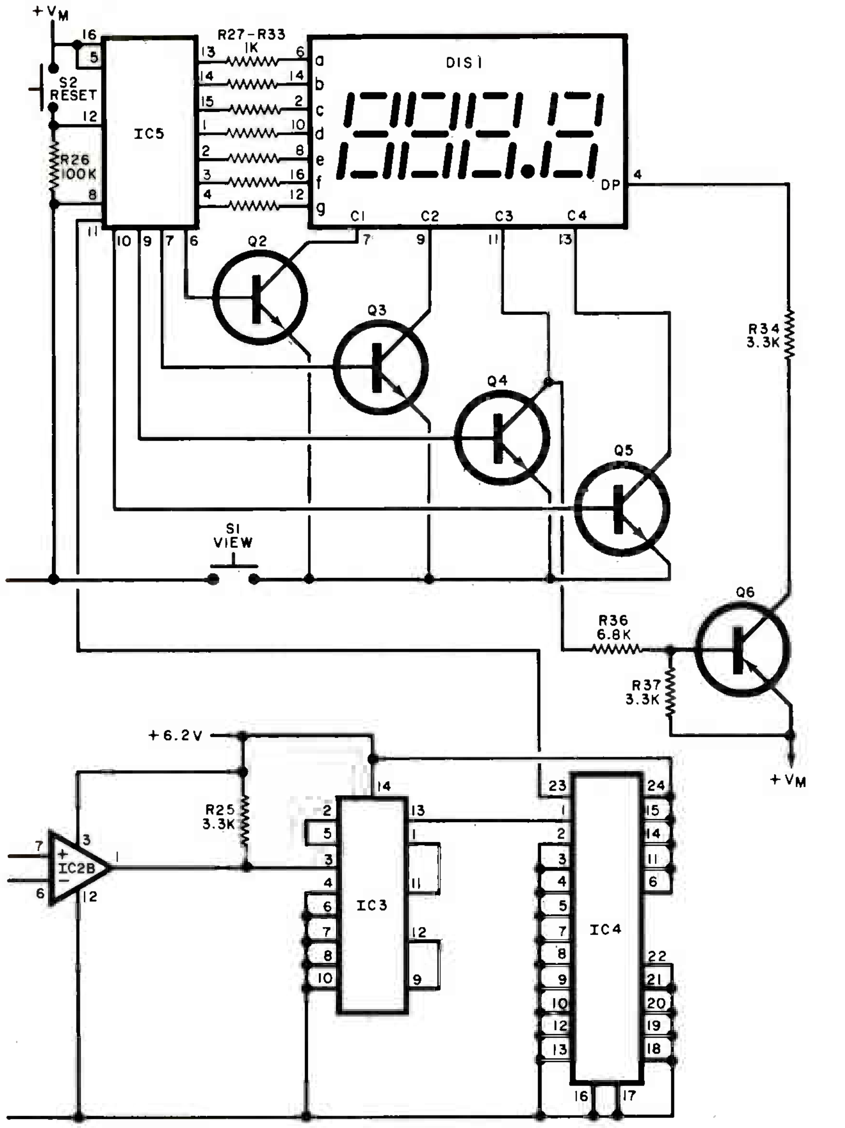
Comparator *IC2C* accepts the dc voltage appearing across *C11* and compares it with the reference of approximately 100 mV generated by *R17*, *R18* and *C12*. Resistors *R14* and *R15* provide hysteresis to stabilize the comparator. The output of this comparator is applied to the noninverting input of comparator *IC2B*, while the inverting input receives a shaped timebase signal derived from the ac power line. Transformer *T1* supplies a low-voltage 60-Hz sine wave to low-pass filter *R19C13*, whose output is attenuated by voltage divider *R20R23*. The attenuated sine wave, converted into a square wave with a dc offset by *IC2A*, is applied to the inverting input of comparator *IC2B*.

This comparator passes timebase pulses when audio from the cartridge drives the output of *IC2C* high. Timebase pulses then reach the CLOCK input of the first section of dual D flip-flop *IC3*. The mismatch between pull-up re-



PARTS LIST

B1—4.2-V mercury battery (Mallory No. TR-133 or equivalent)
C1—0.0033-µF Mylar capacitor
C2—0.0027-µF Mylar capacitor
C3—0.01-µF Mylar capacitor
C4,C8,C10—10-µF, 6.3-V tantalum capacitor
C5,C11,C12—100-µF, 10-V, radial-lead electrolytic capacitor
C6—0.1-µF disc capacitor
C7—0.001-µF Mylar capacitor
C9—0.005-µF disc capacitor
C13—0.01-µF disc capacitor
C14—100-µF, 35-V, radial-lead electrolytic capacitor
C15—330-µF, 6.3-V tantalum capacitor (see text)
C16—56-pF disc capacitor
D1,D2—1N4001 rectifier diode
D3,D6—1N914 signal diode
D4—1N34 germanium signal diode
D5—1N4736 6.2-V zener diode
DIS1—Four-digit, common-cathode LED display (NSA 1541 or equivalent)
IC1—LM301A operational amplifier
IC2—LM339 quad comparator
IC3—CD4013 dual D flip-flop
IC4—CD4059 programmable divide-by-n counter
IC5—MM74C925 four-decade counter with multiplexed four-digit, seven segment output drivers
J1—Insulated phono jack
Q1 through Q5—2N5210 or equivalent npn silicon transistor
Q6—2N5086 or equivalent pnp silicon transistor
The following, unless otherwise specified, are ¼-watt, 10%, fixed carbon-composition resistors:
R1,R15,R22—1 megohm
R2,R23—27,000 ohms
R3—470,000 ohms
R4—330 ohms
R5,R6,R12,R16,R19,R26—100,000 ohms
R7—10 ohms
R8,R14,R21,R27 through R33—1000 ohms
R9,R11,R13—10,000 ohms
R10—15,000 ohms
R17,R36—6800 ohms
R18—100 ohms
R20 33,000 ohms
R24,R25,R37—3300 ohms



R35—330-ohm, ½-watt resistor

S1,S2—Normally-open, momentary-contact pushbutton switch

T1—24-volt center-tapped, 40-mA step-down transformer

Misc.—Printed circuit board; IC sockets or Molex Soldercons; battery holder; fuse holder; suitable enclosure; Y phono-connector/adapter; shielded cable; phono plugs; hookup wire; line cord and strain relief; suitable hardware; solder; etc.

Note: The following are available from TOLECO Systems, Box 401, Kingston, WA 98346: kit of parts consisting of all required integrated circuits, common-cathode LED display, and etched, drilled, and plated glass-epoxy printed circuit board, No. ST-1, for $34.95 plus $2.00 postage and handling in the U.S. and Canada, $4.00 all other countries; etched, drilled, and plated glass-epoxy printed circuit board, No. ST-2, for $10.00 postpaid in U.S. Washington residents, add 8% sales tax. No COD or foreign-currency orders. As designed, the project is suitable for use only in those areas where power-line frequency is 60 Hz.

Fig. 1. The audio input is obtained from one channel of the cartridge output to the phono preamp. It is then amplified and rectified and compared to a reference to create timed pulses and drive the digital display.

sistors *R16* and *R24* holds the output of *IC2B* low in the absence of a signal from the cartridge.

The timebase signal from *IC2B* passes to dual D flip-flop *IC3*, which functions as a divide-by-4 counter. A 15-Hz pulse train appears at the Q output of the second flip-flop in *IC3* (pin 13) when *IC2B* allows the clock signal to pass. This pulse train is applied to the input of *IC4*, which is programmed to divide the input frequency by 5400. The resulting output pulse train has a period of 6 minutes or 0.1 hour and appears at pin 23 of *IC4* to clock four-decade counter *IC5*.

This chip contains not only counting stages but also seven-segment decoders and multiplexed display drivers. The outputs of *IC5* drive not only the seven segment lines of *DIS1* but transistors *Q2* through *Q6* as well. The latter drive the digit and decimal-point cathode lines of the display. Their emitters are connected together and to one side of pushbutton VIEW switch *S1*, the other side of which is grounded. No current flows through the LED display until the VIEW switch is closed. The elapsed stylus playing time is indicated in hundreds, tens, units, and tenths of an hour up to 999.9 hours. When 999.9 hours have been tallied, counter *IC5* resets to 000.0. The user can manually clear the counter by closing RESET pushbutton switch *S2*. Resistor *R26* is the pull-down component for switch *S2*.

A simple single-ended, full-wave supply satisfies the project's power requirements. There is no power on/off switch; line power should be applied continuously so that the information stored in *IC5* is not lost. One simple way to do this is to plug its line cord into the audio preamplifier's or receiver's unswitched power socket. Mercury battery *B1* and steering diodes *D3* and *D6* ensure that the count stored in *IC5* is not lost during power failures and during times when it is necessary to unplug the timer from the power line. Current drain of *IC5* is low, making battery life at least as long as that of the stylus. It is good practice to replace the battery each time the stylus is replaced. Capacitor *C15* is optional and supplies power when both ac and battery power are lost.

Construction. The high impedances and gains of the early stages of the signal-processing chain make the use of a carefully designed printed-circuit board almost a necessity. An etching and drilling guide and component layout are shown in Fig. 2. To keep construction cost low, a single-sided pc board using several jumper wires was used. As long as the jumpers are as short as possible and are installed neatly, they need not be insulated.

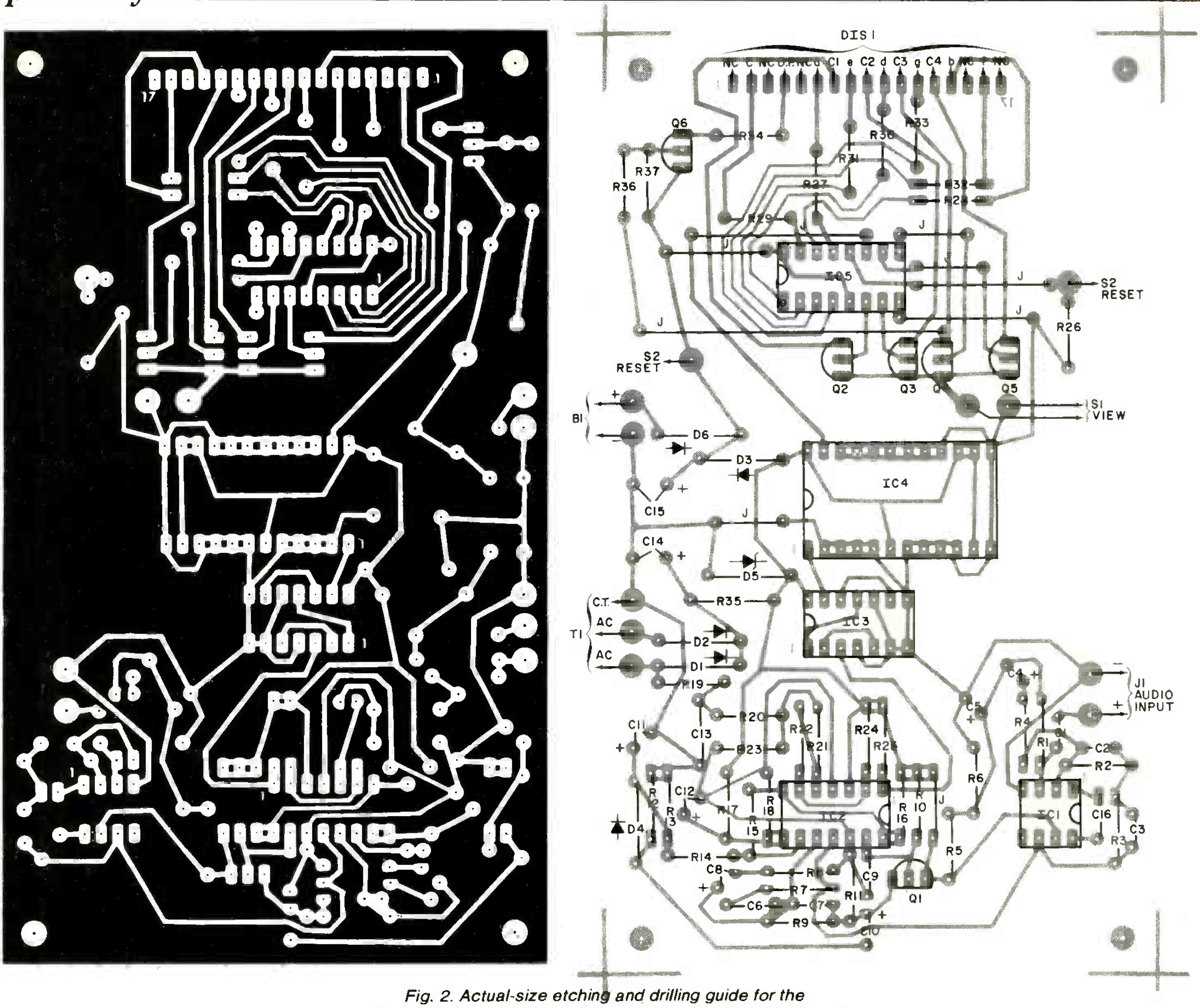


Fig. 2. Actual-size etching and drilling guide for the printed circuit board is above left, component layout at right.

After the jumpers are in place, install the resistors, and then the diodes—in the correct polarity. Molex Soldercons or IC sockets should be mounted on the board after the diodes, and then the capacitors should be installed. (The polarities of electrolytic capacitors must be observed.) Finally, the transistors should be installed. Using a small-tipped, low-wattage soldering iron and small-diameter (No. 22 AWG or similar), 60/40 rosin-core solder, make all necessary connections.

When all pc components have been mounted on the board, use suitable lengths of shielded cable and hook-up wire to connect the appropriate foil pads to those components that are not mounted on the board. Connect the shield of the cable running between input jack *J1* and the input foil pads at both ends. However, use an insulated phono jack to prevent a ground loop from arising. A suitable length of multiconductor ribbon cable can be used between the pc board and the display.

The author's prototype is housed in an aluminum utility box that encloses everything except the LED display and the VIEW switch. These were mounted on a small piece of oak and interconnected with the boxed section by a length of multiconductor ribbon cable. This arrangement permitted the placement of the utility box behind the audio preamplifier and the attachment of the oak display board to the rear of the turntable. The RESET switch was mounted *inside* the enclosure to prevent accidental switch closure and loss of count.

The display used by the author is a four-digit calculator-type readout selected for small size and low current demand. However, almost any type of LED display can be used, so long as it is of common-cathode design and is compatible with multiplexing. Discrete-digit LED readouts can be used in this application if all pins corresponding to the same display segment (a, b, c, etc.) are connected together to the appropriate outputs of *IC5*. Any available display color is acceptable. However, the use of a LED readout other than the one specified might require a change in value of current-limiting resistors *R27* through *R33*. Increasing the resistances will result in diminished display current and brightness. Decreasing them will cause more current to flow and more light to be radiated by the display segments. The output drivers of *IC5* can source a maximum of 30 mA, so the lower limit of resistance for *R27* through *R33* is approximately 100 ohms.

Transformer *T1* as specified is a 24-volt center-tapped component with a rated secondary current of 40 mA. The author's prototype has an actual current demand of approximately 32 mA in either the STANDBY (*S1* open) or VIEW (*S1* closed) mode. In the latter, the flow of display current causes a decrease in current flow through zener diode *D5*. This is why the overall current demand remains constant whether the readout is glowing or not. If a display requiring more current is used, *T1* will have to be a component that can deliver more secondary current.

In any event, to minimize hum pickup and possible false time counts, the transformer should be positioned as far away from the input stage as possible. Its leads should be routed along the opposite side of the pc board from the input cable or, even better, at the opposite side of the board and at right angles to the input cable.

Installation and Use. For initial checkout, plug the line cord into an ac power socket and depress the VIEW pushbutton switch. The display should read 000.0. If it indicates some other number, momentarily close the RESET switch and verify that the display returns to 000.0 when the VIEW switch is closed again.

Next, position the project near your turntable and preamplifier in such a way that the LED display can easily be seen. Make sure that the audio system is turned off. Then disconnect one of the signal cables running from the turntable to the PHONO input jacks of the system's preamplifier. Either the right- or left-channel output of the turntable can be used. Connect a suitable Y adapter to the unoccupied preamplifier PHONO input jack and plug the floating output cable from the turntable into one of the adapter's two phono jacks. Finally, connect one end of a patch cord to the remaining Y-adapter phono jack, and the other end of the patch cord to the project's audio input jack (*J1*).

Turn the stereo system on and play a record for slightly more than six minutes, verifying that the display reads 000.1 hour when the VIEW switch is closed. If it does, return the tonearm to its rest position and unplug the project's line cord from the power socket. Wait a few minutes and reconnect the project to the ac power source. Depress the VIEW pushbutton switch once more. A readout of 000.1 hour on the LED display confirms that the battery-powered memory-backup circuit is working.

Finally, apply ac power to the stylus timer and to the audio system. Place the preamplifier's mode selector switch in the PHONO position, leaving the tonearm in its rest position. At the end of an hour, press the VIEW pushbutton switch. If the display still reads an elapsed time of 000.1 hour, the project is not falsely counting the 60-Hz power-line frequency. If a false count is indicated, reroute any ac line cords passing near the project's audio input jack. Also, check the audio cable-s shield and the connections between the shield and phono jacks. Grounding the metal enclosure to the audio system's ground at only one point will also help keep 60-Hz ac out of the high-gain stages of the timer. Repeat the test procedure to ensure that the false-count problem has been solved.

Knowing the playing time of the stylus to the nearest hour or even ten hours is sufficient for replacement purposes. Contact the manufacturer of your cartridge for the recommended stylus replacement interval. If this information is not available, check spherical styli after about 200 hours, elliptical styli after 500 hours, and Shibata and similar styli after 900 hours. Use a stylus microscope for making visual inspections. If in double about replacement, consult a dealer.

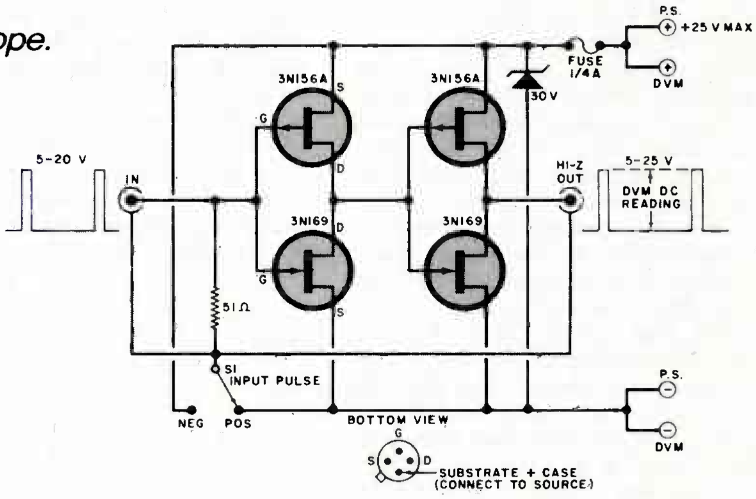
Pulse Amplitude Reference

Easy-to-build circuit amplifies input pulses when calibrating an oscilloscope.

BY IMRE GORGENYI

WHEN working with very narrow, low-amplitude, low-energy pulses, it is advantageous to calibrate the scope you are using at actual working conditions with probes and attenuators in place. This is not always easy since pulse amplitude calibrators usually have low-level outputs—often under one volt.

The simple, all-FET circuit shown here provides pulse amplitudes to 25 volts, if desired, from pulse inputs of 5 to 20 volts. Since the two FET pairs are driven to their open-saturated condition, output pulses have the same amplitude as the power supply voltage. Absolute amplitude of the output can be monitored by a DVM at all times.



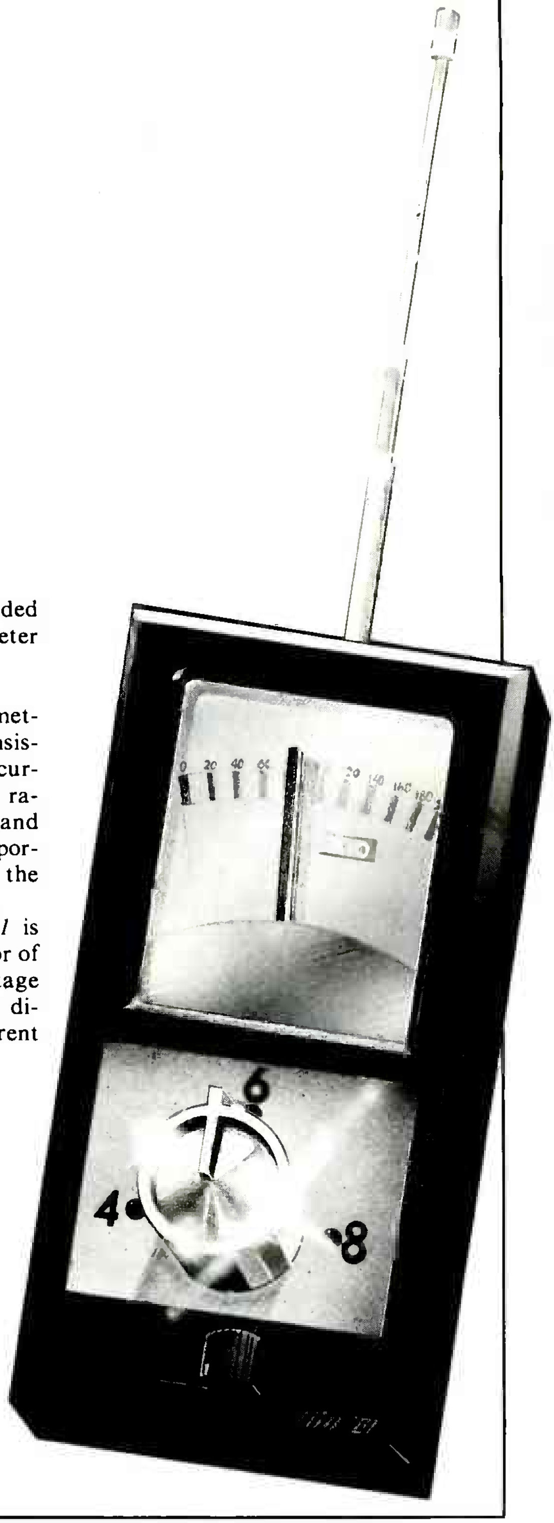
The circuit can be assembled on a perforated board.

The circuit can handle narrow pulses and slow repetition rates. It can be assembled on a small piece of perforated board using BNC connectors for the input and output and can be connected directly in the 50-ohm line between the pulse generator and scope. The circuit, including power supply and digital voltmeter connectors, is "floating." Circuit protection is formed by the fuse and zener diode. ◇

A WIRELESS **IDLE TACHOMETER** FOR AUTO TUNE-UPS

Eliminate risk of damage to electronic ignition systems

BY JOHN E. DAVIS



PERFORMING your own automobile tune-ups can be a source of personal satisfaction as well as a way to save money, but if you own a late-model car with electronic ignition, you'll find that the process is not what it used to be. Many modern ignition systems are magnetically triggered and have no points to adjust, thus relegating dwell meters to museums. However, the anti-pollution devices on modern engines have made idle speed considerably more critical than it once was, so an idle tachometer is still required. Since some of these systems can be severely damaged by momentarily grounding the tachometer tie-in point, the problem is where and how to connect the tach without damaging the ignition module.

The best way would be to avoid electrical interconnection with the ignition system entirely, and you can achieve this by building the Wireless Idle Tachometer described here. The tachometer is designed to operate with any four-, six- or eight-cylinder, four-cycle engine having spark ignition. It can be used with two-cycle engines, but the meter indications will be twice the actual engine speed.

Idle tachometers generally indicate from 0 to 1000 rpm. However, partly for ease of calibration it was decided to extend the range of the tachometer described here to 2000 rpm.

Circuit Operation. The tachometer circuit (Fig. 1) uses a two-transistor monostable as a frequency-to-current converter. The input signal is radiated from the ignition system and picked up on a small telescoping (portable radio-type) antenna nearby; the output is displayed on a meter.

Under quiescent conditions, *Q1* is off and *Q2* is on. Since the collector of *Q2* is low, there is not enough voltage to forward-bias series-connected diodes *D3* and *D4* and produce a current flow through *R10, R11,* and *M1*.

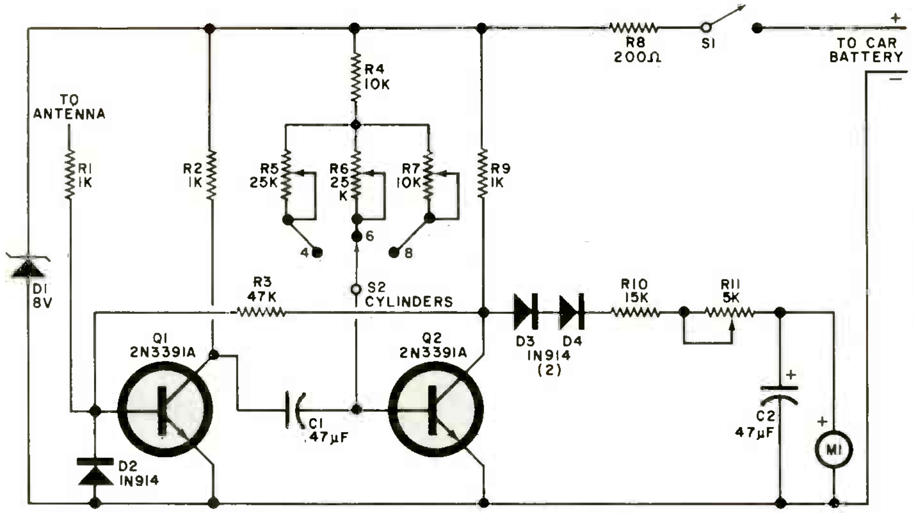


Fig. 1. The tachometer uses a two-transistor monostable circuit as a frequency-to-current converter.

PARTS LIST

C1—0.47-µF capacitor
C2—47-µF electrolytic
D1—8-V, 1-W zener diode
D2,D3,D4—Silicon diode (1N914 or similar)
M1—200-µA meter
Q1,Q2—2N3391A transistor
R1,R2,R9—1-kΩ, ½-W resistor
R3—47-kΩ, ½-W resistor
R4—10-kΩ, ½-W resistor
R5,R6—25-kΩ, mini-pc potentiometer (Radio Shack #271-336 or similar)
R7—10-kΩ mini-pc potentiometer (Radio Shack #271-335 or similar)
R8—200-Ω, 2-W resistor
R10—15-kΩ, ½-W resistor
R11—5-kΩ linear-taper potentiometer
S1—Spst toggle switch
S2—Three-position rotary switch
Misc.—Telescoping portable radio antenna, suitable plastic enclosure, two-conductor power cable, battery connector, etc.

When the antenna picks up a positive-going ignition signal, *Q1* turns on and forces *Q2* to turn off for an interval determined by the time-constant of *C1* and the resistance selected by switch *S2*. The choice of time constant sets the tach for 4-, 6-, or 8-cylinder engines.

When turned off, the collector of *Q2* rises to deliver a constant-voltage, constant-duration pulse to the meter network. Meter *M1* will indicate the current flow. When each positive-going ignition pulse finishes, *Q1* returns to its cutoff state, and *Q2* reverts to its conducting state. This stops generation of the meter pulses. As the ignition system rapidly cycles on and off, the two-transistor circuit will follow, and the meter needle will flutter. This is prevented by *C2* which smooths the current pulses.

Potentiometer *R11* provides means to compensate for errors due to ambient temperature variations. For example, if the ambient temperature is 20°F different from the temperature at which the tachometer was calibrated, an error of about 25 rpm will be found. If you are not overly concerned about temperature variations, use a fixed 2,200 ohms for *R11*.

Resistor *R8*, in conjunction with zener diode *D1*, maintains a constant 8 volts for the circuit. Switch *S1* is the on/off switch. Diode *D2* protects *Q1* from negative spikes, while *R3* provides the necessary feedback.

Construction and Calibration. Circuit layout is not critical and the builder may use point-to-point wiring on perf board or the printed circuit board shown in Fig. 2.

Meter *M1*, switches *S1* and *S2*, and control *R11* are mounted on the top panel of the case. Capacitor *C2* is mounted directly on the meter terminals. The two-conductor power cable exits the case where convenient.

continued on page 104

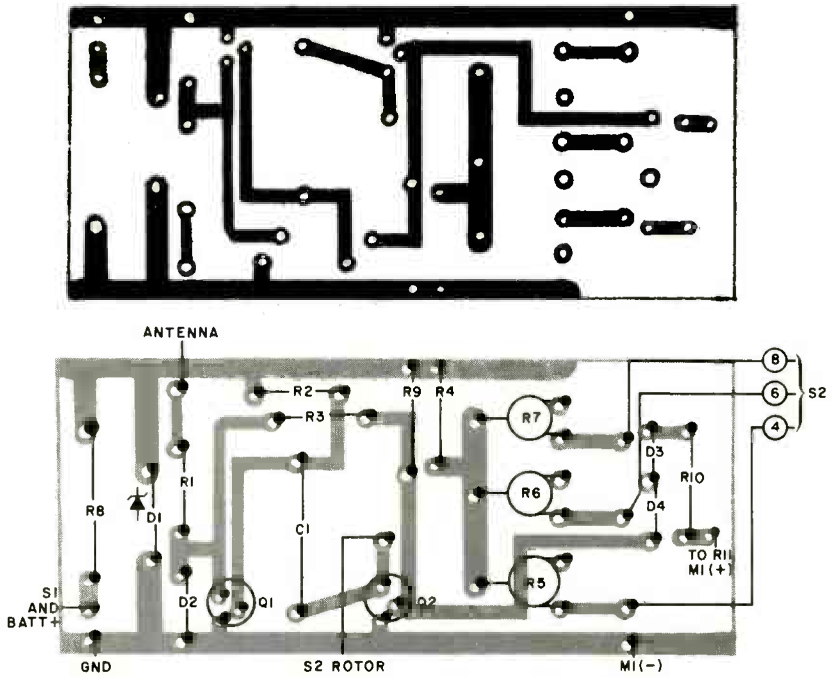


Fig. 2. Etching and drilling guide (top) and component layout diagram for a printed-circuit board for the tachometer.

BY ALLEN H. WOLACH

SIMPLE MEMORY ADDITION FOR TRAINING COMPUTERS

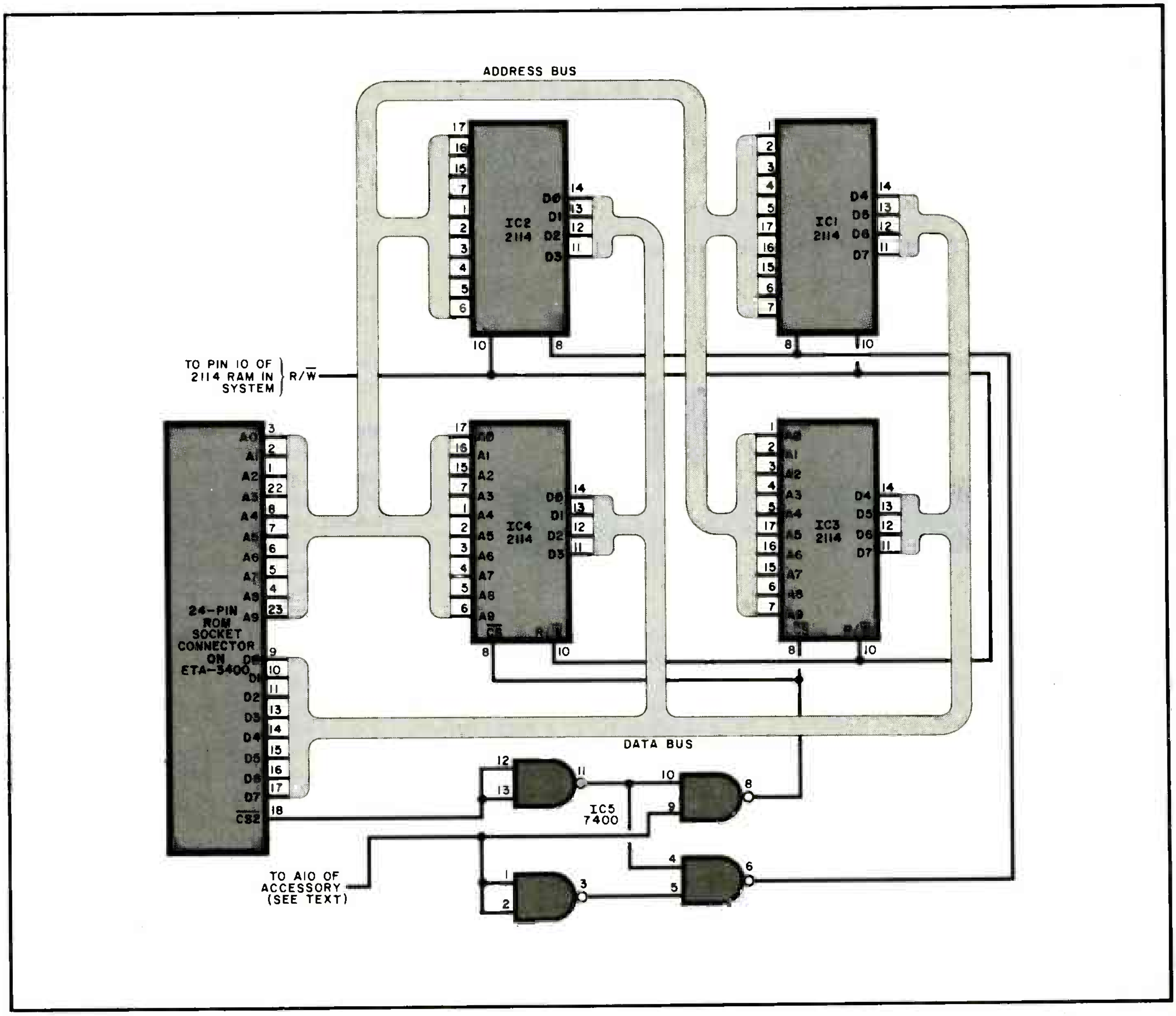
Substitute RAM for ROM

MOST one-board computers, particularly those intended for microprocessor training, contain an operating system and/or a limited high-level language in ROM and some small amount of user RAM. This RAM is usually sufficient to use the system for training purposes; but, after one becomes proficient, the need often arises for more user-memory space. Some systems provide for outboard memory but many do not. Although designed for the Heathkit ET-3400/ETA-3400 Computer Trainer/Trainer Accessory, the memory-expander approach described here can be adapted to other systems.

In this particular system, the Trainer Accessory contains Tiny BASIC in a 2K ROM. If this ROM is replaced with RAM, an additional 2048 bytes of user memory becomes available. If desired, the Tiny BASIC can be recorded on cassette and re-entered at any time using conventional cassette techniques.

Since the ROM is already placed in the system memory map, the address locations for the new RAM are safe. In actuality, the RAM connects to the system via the old ROM socket, thus no extensive wiring is required.

The 2114 static RAMs used in this project are 1K-x-4-bit types that have 1024 addresses with each addressing a



4-bit word. Thus, four 2114 RAMs create a 2048-x-8-bit memory.

In the ETA-3400, Tiny BASIC ROM pins 1 through 8, 22, and 23 are analogous to pins 1 through 7, 15, 16, and 17 of a 2114 RAM. On the ROM, pins 9, 10, 11, and 13 through 17 are the eight data I/O pins, while pins 11 through 14 are the four data I/O pins on the 2114. Pins 21 (CS3) and 20 ($\overline{\text{CS1}}$) on the ROM are chip-select that are placed high (pin 21) and ground (pin 20) in the Heath System. These pins can be ignored since the 2114 RAM uses pin 8 (chip select) that is analogous to pin 18 ($\overline{\text{CS2}}$) on the ROM.

When the ROM is addressed, a circuit within the ETA-3400 decodes address lines A10 through A15 and places a low at $\overline{\text{CS2}}$ (pin 18) when the appropriate high addresses, A10 through A15, occur for any memory locations within the ROM. Since the $\overline{\text{CS2}}$ pin goes low for all 2K locations contained in the ROM, this line must be further decoded so that it goes low separately for the first and last half of the 2K locations. When the decoded input for the first half of the 2K locations goes low, the first half of the replacement 2K RAM is addressed; and, when the decoded input for the second half of the 2K locations goes low, the second half of the replacement RAM is similarly addressed.

The modification can be wired on a "solderless socket" having room for four 18-pin 2114s and one 14-pin 7400 TTL chip. Mount the ICs on the board with one unused row of connections between the ICs. Sockets are optional.

The 24-pin ROM socket connector is formed from a 24-pin DIP header. If such a header is difficult to locate, two 16-pin DIP headers can be suitably cut and cemented together in such a way as to form one 24-pin device.

The upper row of connectors on the solderless socket is connected to pin 24 on the 24-pin header to supply +5 volts to the RAM system. The bottom row of connectors on the solderless socket is connected to pin 12 on the 24-pin header to supply −5 volts (ground). The 2114 RAMs, *IC1* through *IC4*, have their pins 9 connected to the ground line and their pins 18 connected to the +5-volt line. Pin 7 of *IC5* is connected to ground and pin 14 to +5 volts.

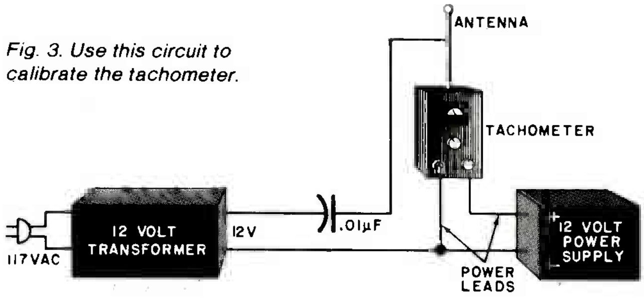
The five ICs are wired in accordance with Fig. 1 and connected to the 24-pin header as shown. Use lead lengths long enough to reach the ROM socket in the ETA-3400. The address and data busses shown in Fig. 1 are for the RAM addition and are *not* the system busses. For example, pins 17 of *IC2* and *IC4* are connected to A0 (address line 0) as do pins 1 of *IC1* and *IC3*.

The $\overline{\text{CS2}}$ modification is implemented by *IC5* as shown in Fig. 1. In the Heath system, the line goes low for memory locations 1C00h through 23FFh. Address line 10 in the accessory is high for the first half of these locations (1C00h through 1FFFh) and low for the remaining locations between 2000h and 23FFh. Thus, in the *IC5* stage of Fig. 1, the output from pin 8 is negative for locations 1C00h through 1FFFh while the output from pin 6 is negative for locations 2000h through 23FFh.

Only two connections must be made to the computer accessory. First, pins 1, 2, and 9 of *IC5* are connected (soldered) to A10 on the 40-pin connector of the accessory (pin 18 on the Heath 40-pin connector). Second, the R/$\overline{\text{W}}$ pin for the 2114 is pin 10. Interconnect pin 10 of each 2114 then connect them together via a length of wire to pin 10 of any one of the eight 2114 RAMs in the memory accessory. ◇

wireless tachometer (Continued from page 102)

Fig. 3. Use this circuit to calibrate the tachometer.



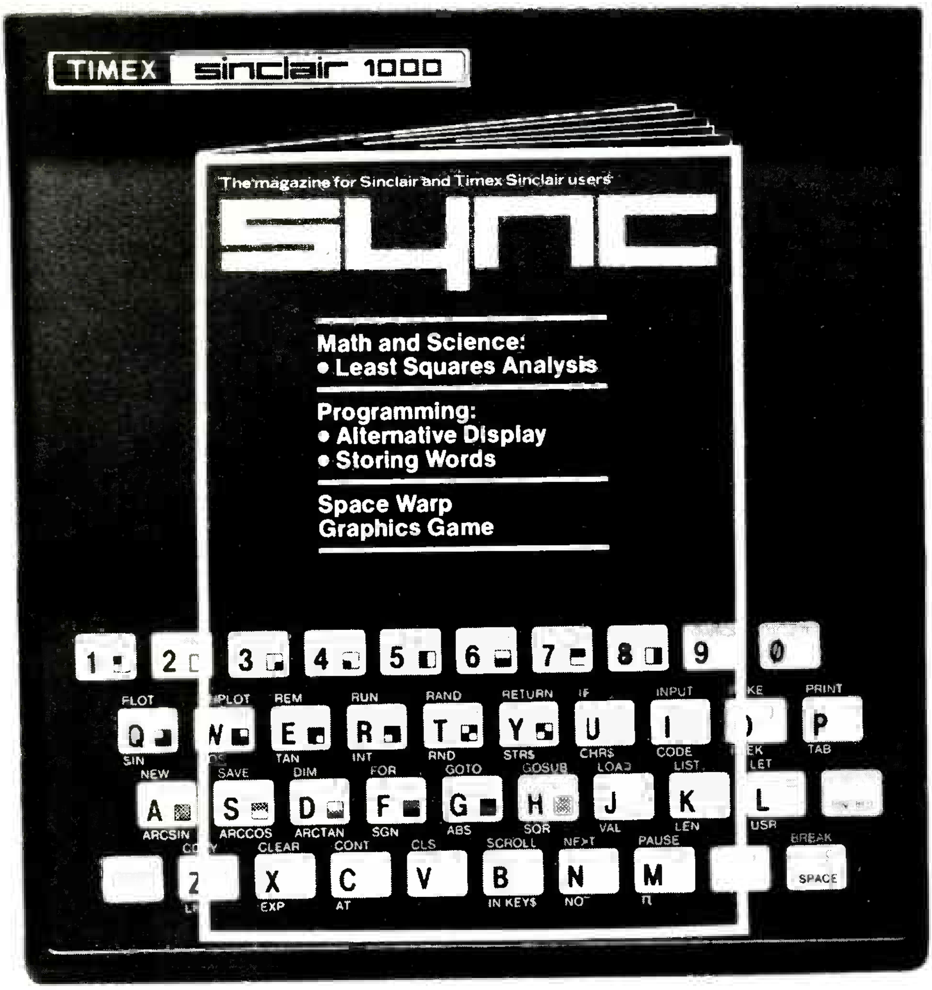
The antenna can be mounted in any part of the case where space allows, with a hole drilled so that the antenna can be extended. If you use a plastic case, it isn't necessary to insulate the antenna. If a metal case is used, insulation will be required whenever the antenna connects to, or passes through, the cabinet.

Calibration requires a 12-volt dc power supply (or a car battery), a 12-volt transformer, and a capacitor (approximately 0.01 µF). These components are arranged as illustrated in Fig. 3.

Turn the tachometer on and allow a few minutes for temperature stabilization. Position *R11* to the center of its rotation. This point should be marked on the case for future reference. Set cylinder-select switch *S2* to "4" and adjust *R5* for a meter indication of 180 (1800 rpm). Place the switch to "6" and adjust *R6* for an *M1* indication of 120 (1200 rpm), then set the switch to "8" and adjust *R7* for 90 (900 rpm).

If *R11* is left in the circuit and the user wishes to recalibrate the unit for accurate readings at an elevated or reduced ambient temperature, the procedure is as follows. At that ambient temperature chosen, hook up the circuit shown in Fig. 3, and adjust *R11* for the correct reading on any of the three settings of *S2*. The other two scales will also be correct, since *R11* adjusts all three scales simultaneously. Potentiometers *R5*, *R6*, and *R7* *should not be readjusted* for temperature compensation.

Use. With the vehicle engine running, hook the tachometer power leads to the car battery, turn it on, wait approximately one minute, then extend the telescoping antenna. Set cylinder-selector switch *S2* to the proper setting and hold the antenna about one or two feet over the engine. You should get a stable indication of engine rpm. If the display is erratic and the needle jumps around, there is insufficient coupling between the ignition system and the antenna. This is most likely to occur when the car's ignition wires are concealed by the air cleaner or some other metallic element. If this is the case, move the antenna closer to the ignition coil or distributor. If you get no meter display, the power leads of the tachometer may be reversed. This will keep the unit from operating, but won't damage it. Once you get stable readings, you can tune your car accurately and be confident that you won't "blow" costly ignition parts. ◇



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A LOW-COST **ELECTRONIC RINGER** FOR TELEPHONE LINES

Solid-state circuit can replace the electromechanical ringer in a telephone

BY BRADLEY ALBING

RECENT FCC rules changes allow users to connect electronic devices of non-Bell manufacture to telephone-company lines. One such device is the low-cost Electronic Ringer. Like a standard electromechanical ringer, it generates bursts of sound when triggered by ring pulses. However, it is not physically bulky and doesn't load down the telephone line. The sound it generates can be modified in several respects to suit the user's taste and to help him differentiate activity on one telephone line from that on another. The Electronic Ringer can also be used to actuate external devices in response to an incoming call. Several optional circuits for this application will be described.

About the Circuit. The schematic diagram of the Electronic Ringer appears in Fig. 1. At the onset of an incoming telephone call, an ac signal is applied between the green (*tip* or *T*) and red (*ring* or *R*) wires of the telephone line. This signal, which has an amplitude of approximately 90 volts root mean square and a frequency of between 20 and 40 Hz, is capacitively coupled to optoisolator *IC1*. The input network comprising *R1, R2, C1, D1, D2* and *IC1* minimizes the line loading and imbalance that simpler ring-detection circuits can cause. Diodes *D1* and *D2* are included to suppress "dial tapping"—the tendency of rotary-dial pulses to actuate the ringer circuit.

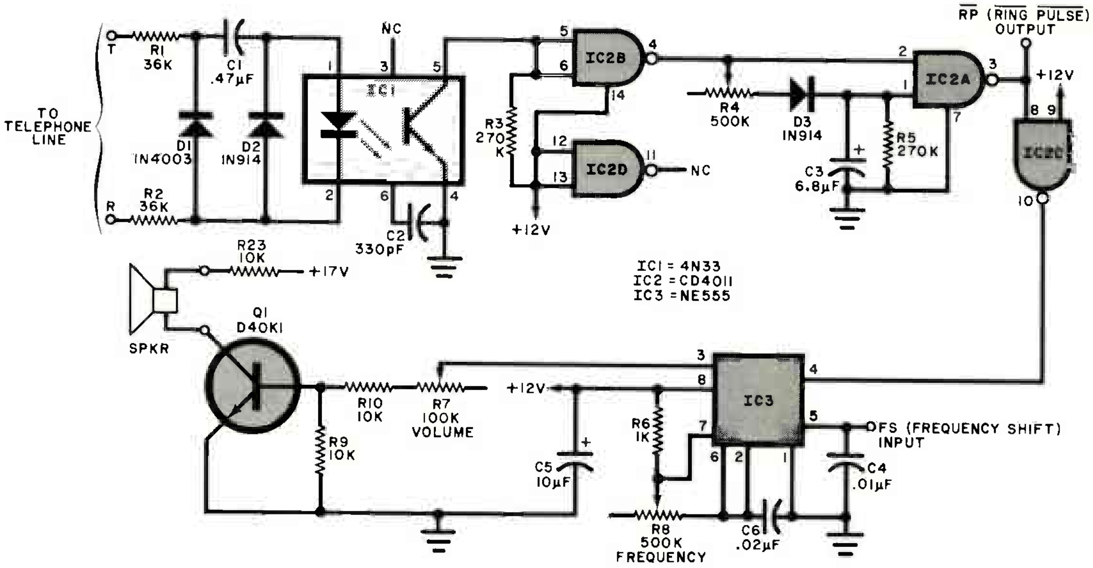


Fig. 1. Schematic diagram of the Electronic Ringer. Optoisolator IC1 couples ring pulses from the telephone line to the detector circuit.

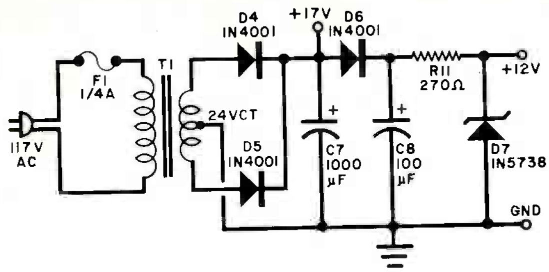


Fig. 2. Schematic diagram of the project's power supply which provides required operating voltages.

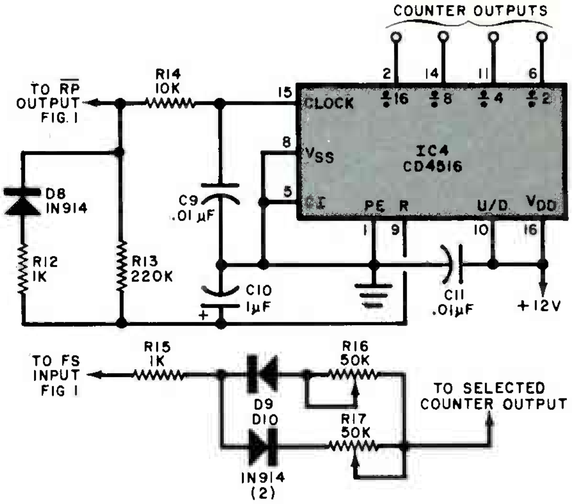


Fig. 3. An optional circuit that can convert the project into a two-tone ringer.

Output pulses from *IC1* are applied to *IC2B*, which squares and passes them to one input of NAND gate *IC2A* and to the delay network consisting of *R4*, *D3*, *C3* and *R5*. This network furnishes additional protection against dial tapping. Capacitor *C3* is initially discharged, so pulses of sufficient quantity or energy or both must be integrated by *C3* to cause the output of *IC2A* to change state. The pulses generated by a rotary-dial telephone are neither sufficiently numerous nor energetic. Potentiometer *R4* determines the charging time constant (delay time), and resistor *R5* discharges *C3* shortly after the end of the input pulse train.

The output of *IC2A*, designated the RP (RING PULSE) OUTPUT, is inverted by *IC2C* and applied to the RESET input of 555 timer *IC3* (pin 4). The timer is connected as a gated astable multivibrator. Its RESET input is normally at logic 0, which prevents the timer from oscillating. When ring

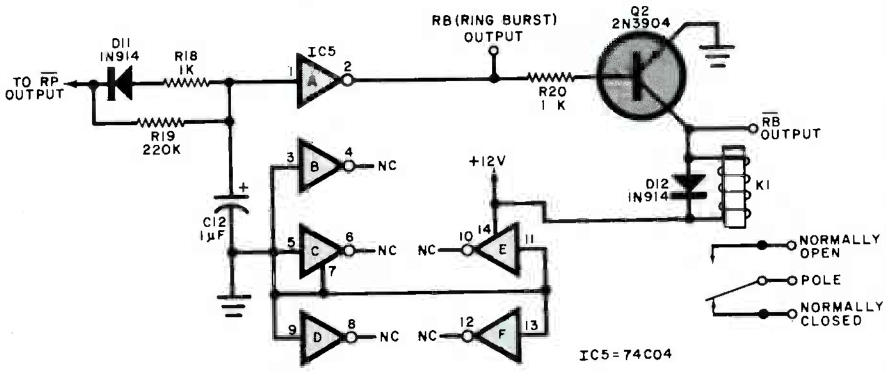


Fig. 4. Schematic diagram of an optional circuit that can actuate external electronic equipment by means of relay K1.

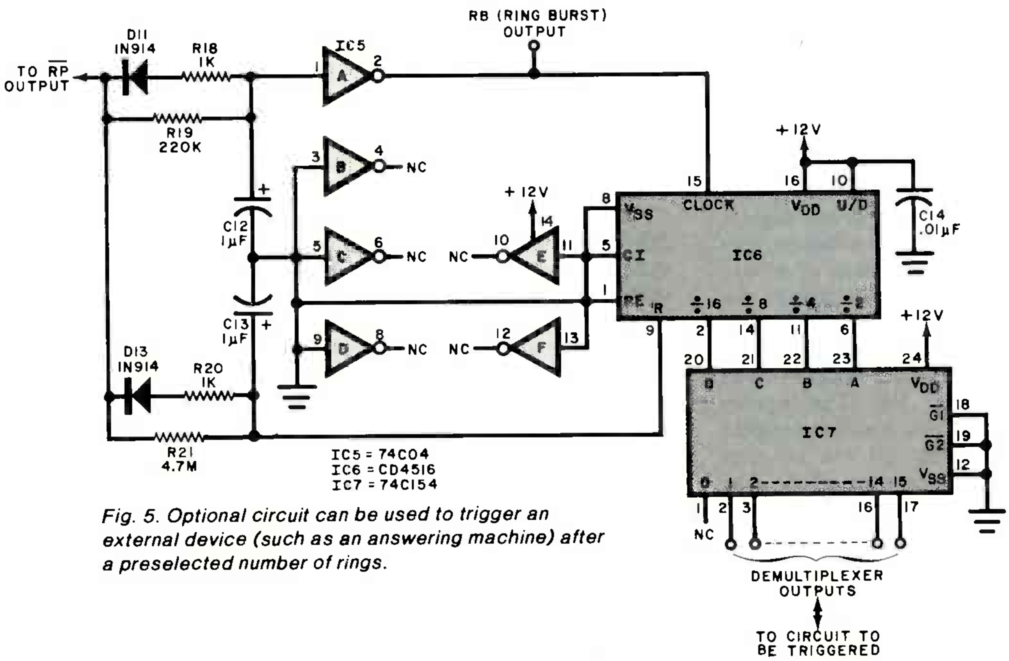


Fig. 5. Optional circuit can be used to trigger an external device (such as an answering machine) after a preselected number of rings.

Components denoted by an asterisk comprise the optional circuits shown in Figs. 3, 4 and 5.

C1—0.47-μF, 200-V Mylar capacitor
C2—330-πF, 25-V disc ceramic capacitor
C4, C9*, C11*, c14*—0.01-μF, 25-V disc ceramic capacitor
C3—6.8-μF, 16-V tantalum capacitor
C5—10-μF, 16-V tantalum capacitor
C6—0.02-μF, 25-V disc ceramic capacitor
C7—1000-μF, 36-V aluminum electrolytic
C8—100-μF, 35-V aluminum electrolytic
C10*,C12*,C13*—1-μF, 16-V tantalum
D1—1N4003 rectifier
D2,D3,D8*,D9*,D10*,D11*,D12*,D13*—1N914 silicon switching diode
D4, D5, D6—1N400 rectifier
D7—1N5738 12-V, ½-W zerner diode
F1—¼-A, fast-blow, type 3A fuse
IC1—4N33 optoisolator
IC2—CD4011 quad two-input NAND gate
IC3—NE555 timer
IC4*, IC6*—CD 4516 four-stage, up/down programmable binary counter

PARTS LIST

IC5*—74C04 hex inverting buffer
IC7*—74C154 4-line-to-16-line decoder/demultiplexer
K1*—12-V dc spdt relay
Q1—D40K1 or equivalent npn silicon power transistor
Q2—2N3904 or equivalent npn silicon switching transistor
The following, unless otherwise specified, are ¼-watt, 10% tolerance, carbon-composition fixed resistors
R1,R2—36,000 ohms
R3—100,000 ohms
R4,R8—500,000 ohms
R5—270,000 ohms
R6,R12*,R15*,R18*,R20*,R22*—1000 ohms
R7—1000,000-ohm linear-taper pc-mount trimmer potentiometer
R9,R10,R14*—10,000 ohms
R11—270 ohms
R13*,R19*—220,000 ohms
R16*,R17*—50,000-ohm linear-taper, pc-mount trimmer potentiometer
R21—4.7-megohms
T1—24-V, 500-mA center-tapped step-down transformer
Misc—Printed circuit or perforated board, IC sockets or Molex Soldercons, fuse-holder, line cord, strain relief, suitable enclosure, standoffs, terminal, strips, suitable connectors, two-conductor cable, hookup wire, solder, etc.

Note—The following is available from BFA Electronics, Box 212, Northfield, OH 44067‘ Kit of parts for the basic Electronic Ringer project (Figs. 1 and 2) excluding the dynamic speaker, No. ER—Kit, priced at $25.00 plus $2.00 postage and handling for U.S.A. Also available separately is an etched and drilled printed-circuit board (Fig. 6), for $6.00 plus $1.00 postage and handling for U.S.A. orders. Ohio residents, add state sales tax.

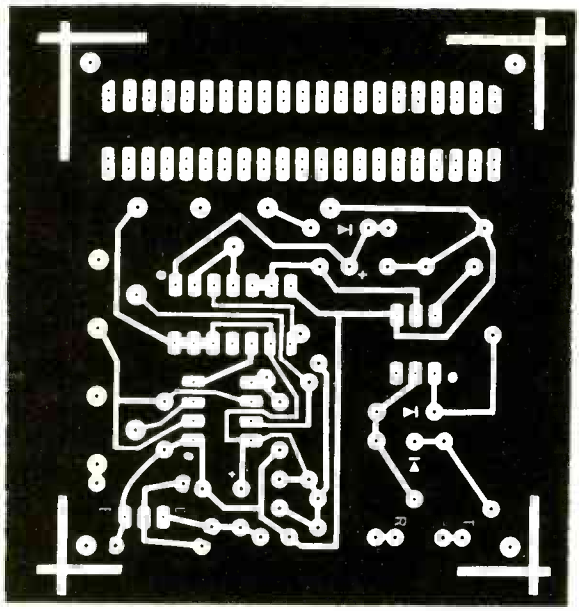


Fig. 6. Etching and drilling guide for pc board.

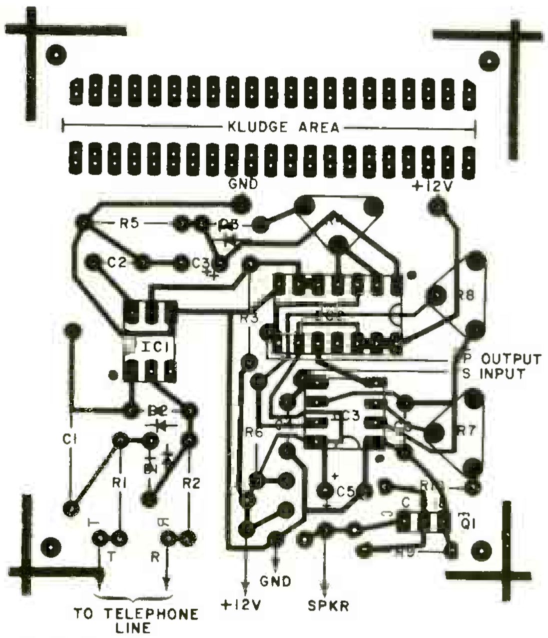


Fig. 7. Component-placement guide for pc board.

pulses are received, the RESET input is switched between logic 0 and logic 1 by *IC2C*, and the multivibrator produces bursts of oscillation at a rate determined by the frequency of the pulse train. The output of the timer is a square wave whose frequency (nominally 500 Hz to 2 kHz) is determined by potentiometer *R8*. The square wave appears at pin 3 and is coupled to driver transistor *Q1* via VOLUME control *R7* and resistor *R10*. The transistor alternately saturates and cuts off at an audio rate and causes a square-wave current to flow through the voice coil of the dynamic speaker.

Power for the Electronic Ringer is provided by the supply shown in Fig. 2. Line-voltage ac is stepped down by *T1* and full-wave rectified by *D4* and *D5*. Capacitor *C7* filters the output of the rectifier into an unregulated +17 volts dc. This voltage is applied to one side of the voice coil of *SPKR* and to the voltage-regulating network *D6*, *C8*, *R11* and *D7*. This network provides +12 volts dc, regulated, to the rest of the circuit. Note that the supply lacks a switch; in use, the project should be powered continuously.

Circuit Options. The pitch of the Electronic Ringer's tone signal can be varied by means of potentiometer *R8*, and its volume by means of *R7*. Further modification of the tone is possible by use of the circuit shown in Fig. 3. The $\overline{\text{RP}}$ OUTPUT from *IC2A* clocks four-bit binary counter *IC4*, which generates output pulse trains at one-half, one-fourth, one-eighth and one-sixteenth of the input signal frequency. One of these outputs can be fed back to the FS INPUT of timer *IC3* by means of the network *R16*, *R17*, *D9*, *D10* and *R15* to shift the frequency of the timer's square-wave output. The high- and low-frequency tones can be adjusted independently by means of *R16* and *R17*. At the end of each burst of ring pulses, counter *IC4* is reset by the network *D8*, *R12*, *R13* and *C10*.

The $\overline{\text{RP}}$ OUTPUT can be used to drive

telephone ringer

other circuits, such as those shown in Figs. 4 and 5. External devices can be actuated by means of the circuit shown in Fig. 4. The network *D11*, *R18*, *R19* and *C12* integrates the $\overline{\text{RP}}$ OUTPUT into a dc level that is inverted by *IC5A*. This inverting buffer provides base drive to *Q2* when its output is at logic 1. When the transistor receives base drive, it conducts and sinks current for the coil of relay *K1*. The contacts of this relay can control an external electronic circuit or electromechanical device.

In the more complex circuit of Fig. 5, the $\overline{\text{RP}}$ OUTPUT is processed by an input network similar to that of Fig. 4. The output of inverting buffer *IC5A*, however, drives four-bit binary counter *IC6*, whose four output lines are connected to the address inputs of demultiplexer *IC7*. Fifteen of the demultiplexer's output lines are employed in this project. Each in turn changes states when the appropriate number of pulses clocks counter *IC6*. A selected demultiplexer output can be connected to a driver/relay circuit or similar interface. If this is done, an external circuit or device will be actuated after the appropriate number of rings.

Construction. The Electronic Ringer can be assembled on either a printed-circuit or perforated board. Full-size etching-and drilling, and component-placement guides for a suitable pc board appear in Figs. 6 and 7, respectively. The board contains a kludge area at one end within which circuit options can be installed. If the existing ringer of a standard 500-series desk telephone is removed, this pc board can be installed inside the telephone enclosure. Alternatively, a custom enclosure can be used.

The project's power supply should be isolated from the telephone to prevent stray pickup of 60-Hz ac radiated by the power line and the step-down transformer. A two-conductor cable can be used to connect the *T* and *R* input terminals of the project to the green and red wires, respectively, of the telephone line. If desired, telephone-type connectors can be used to facilitate interconnection of the project and the line.

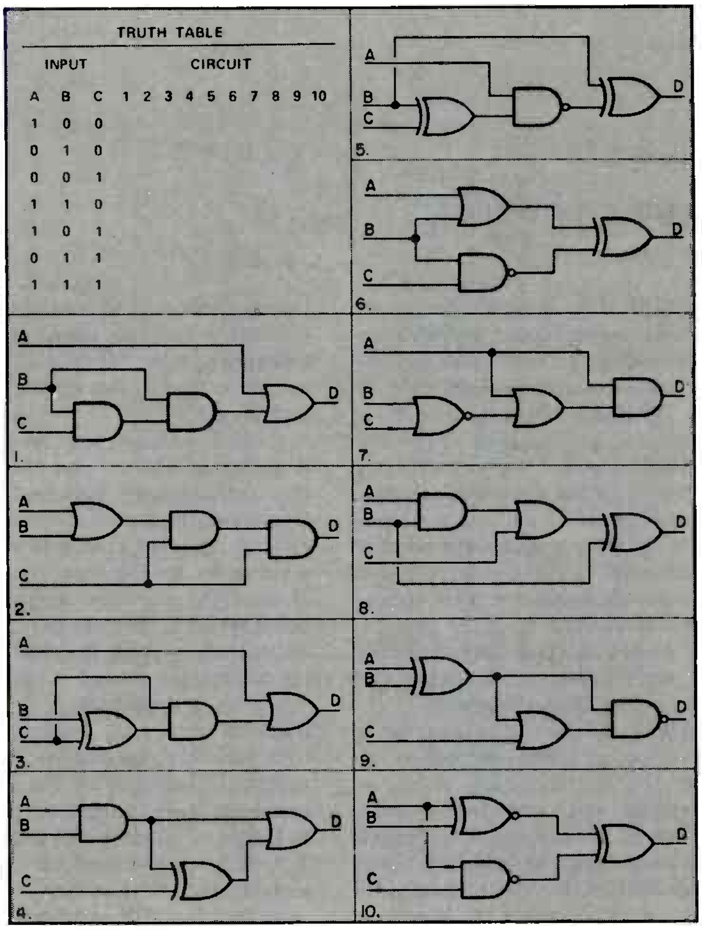
If the project won't respond to incoming calls or if dial tapping occurs, reverse the *T* and *R* connections. Also, reverse the polarity of the connections between power transformer *T1* and the ac line cord. ◇

TRUTH TABLE QUIZ

BY ROBERT P. BALIN

A TRUTH Table indicates how a gate or combination of gates, responds when level 0 and level 1 signals are applied to its inputs. The table present the kind of concise picture of a circuit's characteristics that we need to apply it to solving logic problems.

To test your ability for making a truth table, determine if the output at D on each of the circuits (1-10) below is a 1 or a 0 for each of the seven arrangements shown in the table at top left. The answers are in the truth table at bottom of page.



TRUTH TABLE

INPUT			CIRCUIT									
A	B	C	1	2	3	4	5	6	7	8	9	10
1	0	0										
0	1	0										
0	0	1										
1	1	0										
1	0	1										
0	1	1										
1	1	1										

ANSWERS:

INPUT			CIRCUIT									
A	B	C	1	2	3	4	5	6	7	8	9	10
1	0	0	1	0	1	0	1	0	1	0	0	1
0	1	0	0	0	0	0	0	0	0	1	0	1
0	0	1	0	0	1	1	1	1	0	1	1	0
1	1	0	1	0	1	1	1	0	1	0	1	0
1	0	1	1	1	1	1	0	0	1	1	0	0
0	1	1	1	1	0	1	0	1	0	0	0	1
1	1	1	1	1	1	1	0	1	1	0	1	1

A "SMART" GREENHOUSE LIGHT CONTROLLER

Grow temperamental plants with artificial light when the sunlight goes away

BY MARK L. McWILLIAMS

WITH their controllable growing conditions, greenhouses and hot frames can make possible the cultivation of plants too delicate to survive the rigors of the natural environment in many parts of the north Temperate Zone. Well-established technologies for the control of temperature and humidity exist, but photoperiod (the time for which the plant is exposed to light) and the intensity of light in its duration are also important, if not critical, to plant growth. Lamps whose spectral output is consistent with plant needs exist; the problem is how to control them.

To allow the lamps to run for a fixed period of time regardless of whether the sun is hidden or not is unacceptable. For one thing, some plants would be subject to excessive illumination, and, for another, heat build-up could stress the temperature-control system. Turning the lamps on when the sun is hidden and off when it reappears would be an improvement, but this too is subject to difficulties. One is that temporary occultations of the sun, as by passing clouds, birds, or aircraft, would cause an excessive number of on-off cycles and adversely affect lamp life.

An acceptable controller would give positive control of the duration of the photoperiod, turn on the lamps if the sun were to disappear for any significant length of time, and ignore short-term solar "dropouts." The system described in this article has these attributes.

Overall operation of the controller is shown in Fig. 1. The photoresistor monitors the sun's light and produces a voltage drop across its associated series resistor that is compared against a value set by the sensitivity control. If the light intensity, hence the voltage applied to the comparator noninverting input, is too low, the comparator will trigger timer 1. This timer will delay for a preset interval (up to 10 minutes or so) to determine if the light intensity remains low. Thus, momentary blockages of the sun won't cause the lamps to turn on. If allowed to time out, timer 1 will trigger timer 2, which will turn on the lamps for some minimum time (for example, 30 minutes), but will also keep the lights on as long as the sun remains hidden.

If it has finished timing-out, when the sunlight returns, timer 2 will trigger timer 3. This timer will keep the lamps on for some period (15-20 minutes) to make sure that the sun is back to stay. If it is, the lamps will turn off when timer 3 times out. If not, the comparator will trigger timer 1, and the whole cycle starts again. (If timer 1's delay is sufficiently less than that of timer 3, the lamps will stay on after the timer 3 period times out if the sun is hidden again.)

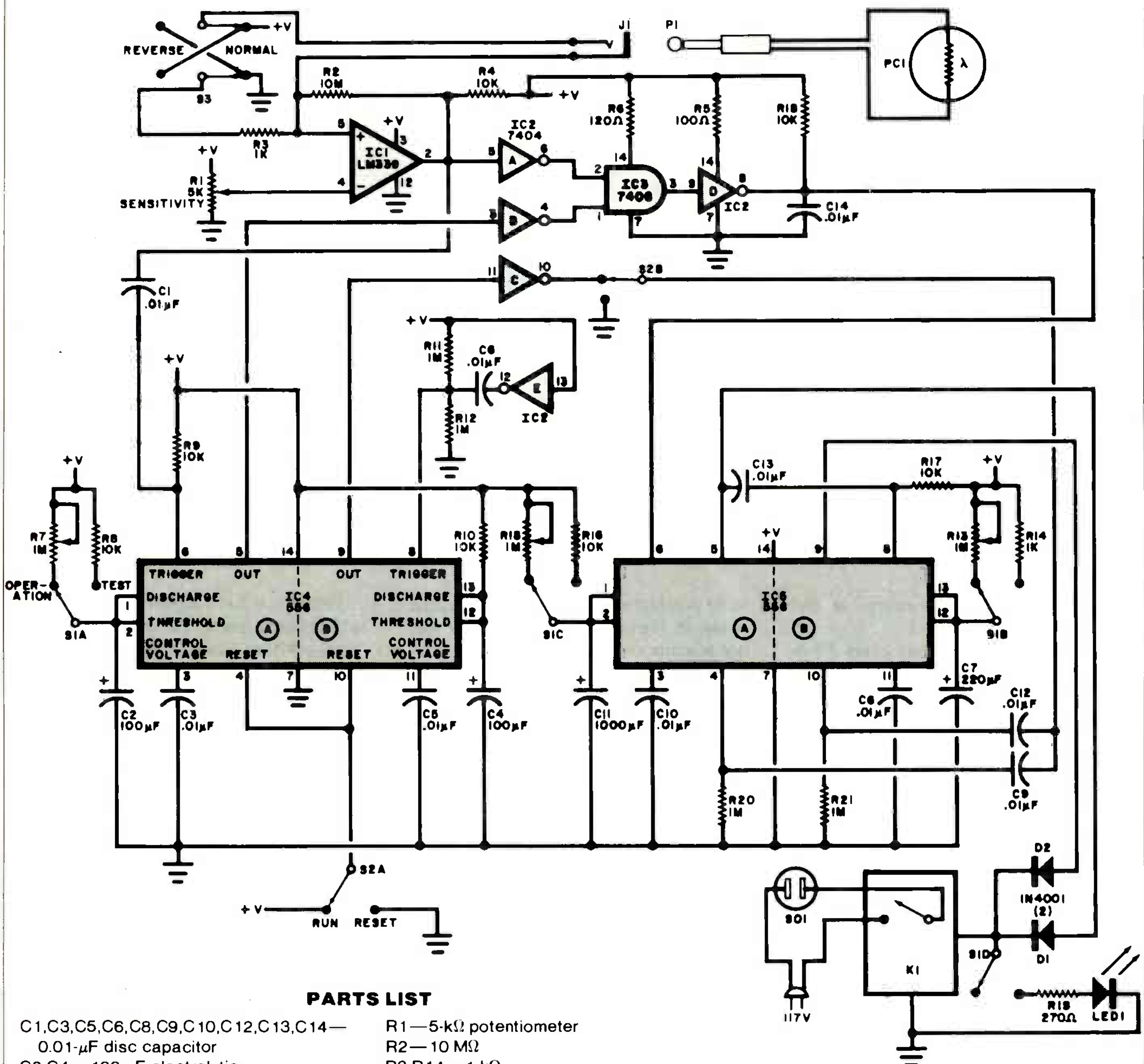
Circuit Operation. The complete circuit is shown in Fig. 2. Photoresistor *PC1's* resistance can range from a few hundred to 100,000 ohms or more depending on how much light falls on it. However, only 20 to 50 ohms difference was found when a bright sunny day was compared to an overcast day. To detect such a very small difference, comparator *IC1* is used. With *S3* in its normal position, the voltage drop across *R3* is compared against that set by sensitivity control *R1*. When the light is relatively dim, the *IC1* output at pin 2 goes low, thus triggering timer 1 (*IC4A*) via *C1*. The *IC1* output is inverted by *IC2A* and applied to one input of AND gate *IC3*. Resistor *R2* acts as feedback to improve the *IC1* switching action.

Timer 1 (*IC4A*) is one-half of a 556 operating in its one-shot mode. When it times out, its output at pin 5 is inverted by *IC2B* and fed to the other input of AND gate *IC3*. When both inputs to *IC3* are high, the gate triggers timer 2 (*IC5A*), via inverter *IC2D*. Thus, two conditions are necessary to trigger timer 2—low ambient light and the timing-out of timer 1.

Timer 2 (*IC5A*) will turn on for a

minimum period determined by *R15-C11*. However, this timer will stay on indefinitely as long as the light impinging on *PC1* is low, since the *IC1* output will remain low, and as long as it is low, timer 1 (*IC4A*) will not be released from its timing cycle. Capacitor *C14* will keep timer 2 on even after it has timed out for as long as timer 2 is in its "on" state, it will energize relay *K1* via *D1* which, in turn, supplies ac power to lamp socket *S01*.

After timer 2 turns off, it triggers *IC5B* timer 3 via *C13*. This timer remains on for a period determined by



PARTS LIST

C1,C3,C5,C6,C8,C9,C10,C12,C13,C14—0.01-µF disc capacitor
C2,C4—100-µF electrolytic
C7—220-µF electrolytic
C11—1000-µF electrolytic
D1,D2—1N4001 diode
IC1—LM339 quad comparator
IC2—7404 hex inverter
IC3—7408 AND gate
IC4,IC5—556 dual timer
J1—2-conductor jack
K1—Solid-state relay (Radio Shack 275-236)
LED1—20-mA light-emitting diode
PC1—CdS photoresistor (Radio Shack 276-116)
Following are ½-W, 10% resistors unless otherwise specified
R1—5-kΩ potentiometer
R2—10 MΩ
R3,R14—1 kΩ
R4,R8,R9,R10,R16,R17,R18—10 kΩ
R5—100 Ω
R6—120 Ω
R7,R13,R15—1-MΩ mini-potentiometer (Radio Shack 271-229)
R11,R12,R20,R21—1 MΩ
R19—270 Ω
S1—4-pole, 2-position rotary switch (Radio Shack 275-1384)
S2,S3—Dpdt miniature toggle switch (Radio Shack 275-620)
Misc.—Sockets for ac, IC mounting sockets, case (Radio Shack 270-627), pc board, wire, solder, 6-volt battery eliminator, etc.

Fig. 2. Schematic diagram of the complete timer circuit. Points marked +V can be connected to a 6-volt battery eliminator or a separate 6-volt supply can be built and mounted in the enclosure.

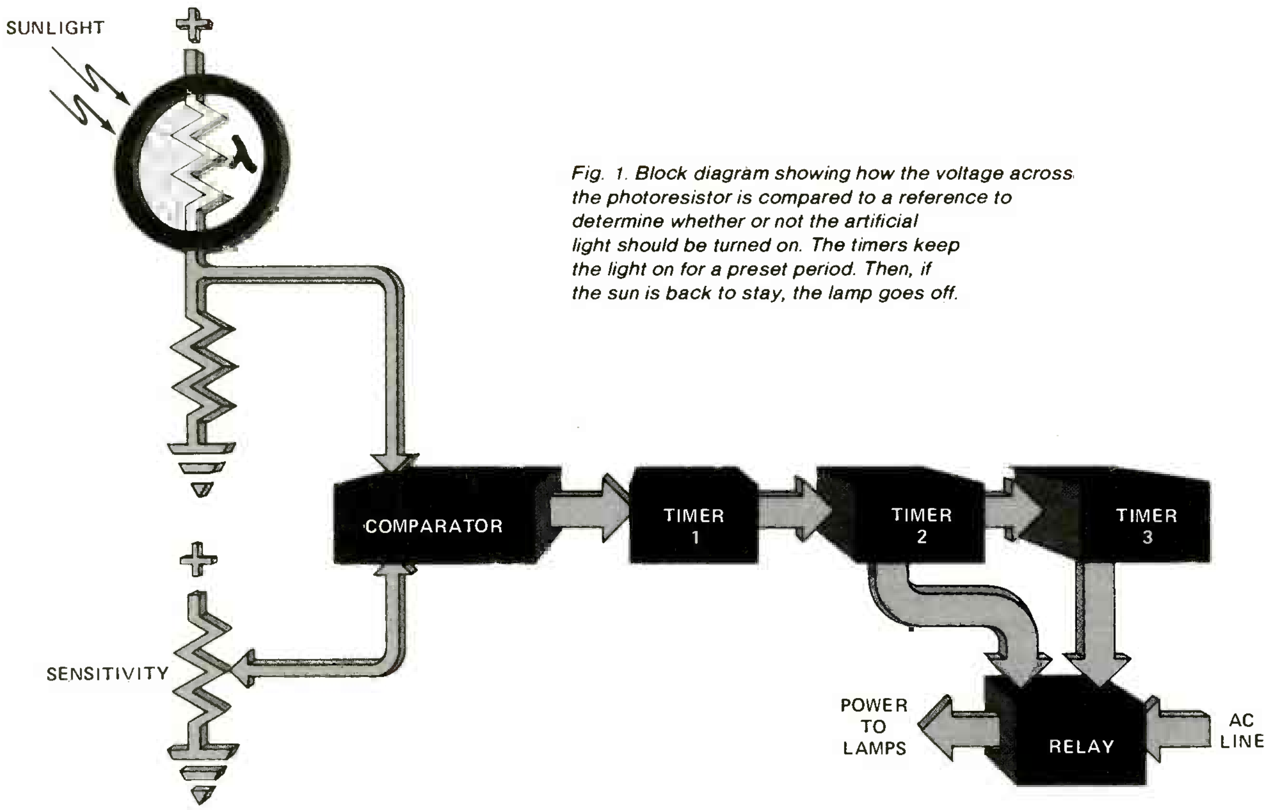


Fig. 1. Block diagram showing how the voltage across the photoresistor is compared to a reference to determine whether or not the artificial light should be turned on. The timers keep the light on for a preset period. Then, if the sun is back to stay, the lamp goes off.

R13-C7. Timer 3 also energizes the relay via *D2*.

When timer 3 times out, relay *K1* is de-energized if the *IC1* output went high since timer 3 started. However, if the low light condition returned and *IC1* went low again, timer 1 will turn on again, and the cycle starts over. If timer 1's delay is sufficiently less than timer 3's, timer 2 will turn on before timer 3 can time out and the relay will remain energized.

IC4B is used as a switch debouncer, and prevents timers 2 and 3 from being triggered when the power is first applied. This timer is used to momentarily reset both halves of *IC5* (via *C9* and *C12*) during the one second or so period just after the power is applied to the circuit.

A conventional 6-volt battery eliminator can be used to supply the 45 or 70 mA needed by the circuit. A 24-hour clock timer can then be used to power the battery eliminator so that the light controller operates only during daylight hours.

Switch *S1* places the controller into either TEST or OPERATION status. The only difference between these two conditions is that the timer delays are only a few seconds in the TEST mode. This latter mode is used mainly to adjust sensitivity control *R1*. *LED1* will glow in TEST so the lamps do not have to be connected to *S01*. When the unit is not in the test mode, the LED will not operate.

Switch *S3* permits the unit to be used for much more than just a light controller. For initial testing as a light controller, *S3* should be positioned as shown with *R3* grounded.

Construction. The controller can be built on perf board, or a pc board can be fabricated. Sockets can be used for the ICs if desired. Once built, the circuit can be mounted within a selected enclosure with only the three switches, *R1, J1, LED1*, and lamp power socket *S01*, mounted on an outside surface. A 6-volt power supply can also be mounted within the enclosure. The ac power line can exit via a grometted hole at the rear.

Adjustment. Plug the photoresistor into *J1*, and place it so that its light-sensitive surface is receiving direct sunlight. Place *S1* in the TEST position, then *S2* to RESET, then RUN. Adjust *R1* in small steps until a small amount of shade caused by your hand (12 or more inches away from *PC1*) causes *LED1* to turn on. Allow sufficient time between each *R1* adjustment for timer 1 to time out. If it does not time out, place *S2* in RESET, back *R1* off, and try again.

When you have adjusted *R1* to your satisfaction, place *S1* in the OPERATION position and connect the lamps to *S01*. Control *R1* may have to be re-adjusted under actual overcast conditions. Note that a little hysteresis is present in *IC1* and if *R1* is adjusted "too tight", the controller will not turn the lamps off even when full sunlight appears.

While it was designed primarily as a light controller, the unit can be used to control other ac loads depending on the type of sensor plugged into *J1*. For example, replacing *PC1* with a temperature sensor, the controller could be used to turn on heating elements after ignoring momentary *high* temperatures. Using the same probe but placing *S3* in the REVERSE position, which switches the relative positions of *R3* and the external probe in their voltage divider configuration—the controller can be used to turn on exhaust fans while ignoring sudden *low* temperatures.

It is possible that some user modification of potentiometer *R1* and *R3* might be necessary if probes having different resistance characteristics from those of *PC1* are used. Also, if even the small amount of hysteresis present in *IC1* cannot be tolerated, experiment with different valued resistors for feedback resistor *R2*. ◇

The LM 339 A Great Comparator

Four independent comparator circuits on one chip can be used in a variety of analog and digital applications

BY CLEMENT S. PEPPER

THE KEY WORD to describe the 339 quad comparator is *versatility*. This device can interface a slow-moving analog signal to almost any logic family, will drive a LED, detect high- and/or low-voltage limits and can be used as a monostable oscillator.

What makes the 339 so versatile? Consider its power requirements as an example. The chip will work from a single dc source between 2 and 32 volts, or a split power supply from ±1 to ±18 volts. Current drain is a meager 0.8 mA, independent of supply voltage.

The common-mode range includes ground, even when operated from a single supply. With a typical input bias current of 25-nanoamperes, a 3-nanoampere offset and a 3-mV input offset voltage, the input can "look" at almost any source impedance without loading.

The 339 output stage is an npn transistor having an uncommitted collector so that an external pullup resistor can be used with a supply voltage different than that used by the remainder of the device. You can even hard-wire the outputs in an OR configuration. The transistor output stage will sink up to 20 mA, but you may have to live with a high saturation voltage (with 4 mA it is 250 mV). The output is compatible with TTL (fanout of 2), DTL, ECL, MOS and CMOS.

The 339 chip contains four identical comparators, and is available from many parts suppliers at prices as low as $1 each.

Device Operation. The pinout for the 339 is shown in Fig. 1A. The numbers across each row indicate the noninverting and inverting inputs with the associated outputs for each of the four comparators in the chip.

A basic comparator is shown in Fig. 1B. Here, the input signal V_{IN} is compared with a fixed reference V_{REF}. Whenever the input signal exceeds the reference level by just a couple of millivolts, the output (V_O) goes high. This action is illustrated by the associated waveforms.

Unfortunately, such a basic circuit can oscillate during the transition period, and although this might present a problem with slow analog signals, it would cause no trouble for the fast transition times associated with digital signals. This can be averted by using a small amount of positive feedback as shown in Fig. 1C. The feedback not only speeds up the transition, but adds a little hysteresis. Feedback resistor R_F is typically a high value, 10 megohms for example.

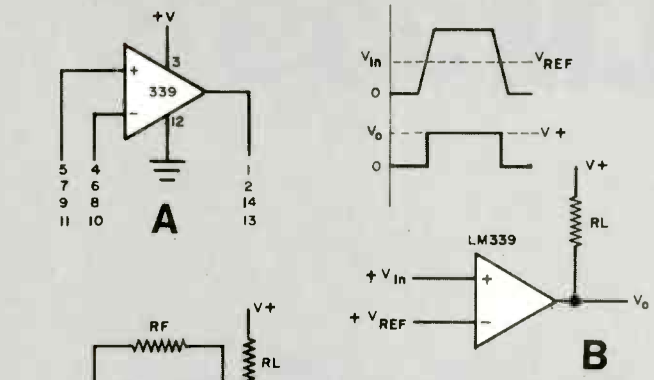
While hysteresis can eliminate the transient oscillation, it can also be put to work in a useful manner such as "cleaning up" input waveforms, acting like a Schmitt trigger. However, most Schmitt triggers lack adjustability, and further along in this article, we will illustrate a 339 Schmitt trigger that does not have this problem.

Analog-to-Digital Interface. The input for a frequency counter is a good example of an analog-to-digital interface (not to be confused with an A/D converter as used in computers).

The input of a frequency counter must be capable of accepting a wide variety of signals, slow or fast, and provide a signal compatible with the digital counter circuits that follow. Also, since the input levels can span a broad range of levels, sensitivity adjustments are required. Then there must be a "threshold" established either to reject noise, or possibly to match a digital source. Such a circuit is shown in Fig. 2A.

Sine-wave performance (10 kHz) is shown in Fig. 2B with a 3-volt rms input and Fig. 2C with 1-volt rms input. This circuit has been used with excellent results to 1 MHz.

CMOS to TTL Translation. The circuit shown in Fig. 2A is also useful for translating various logic families. For this application, two series-connected 1N914 diodes may be substituted for the 2000-ohm potentiometer. This estab-



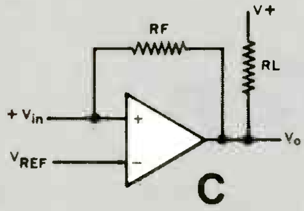


Fig. 1. Pinout of the LM339 (A). Comparator with basic waveforms (B). Comparator with feedback resistor for faster switching action (C).

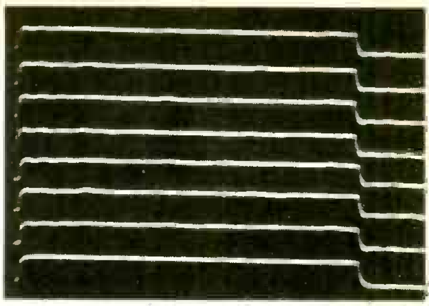
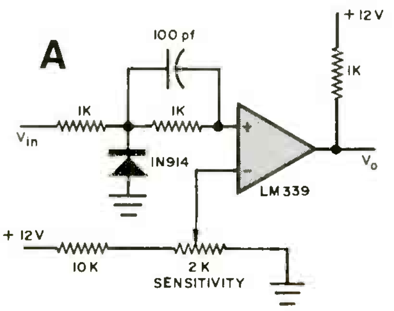


Fig. 3. Outputs of two separate 339 packages (four at top, four at bottom) show excellent matching.



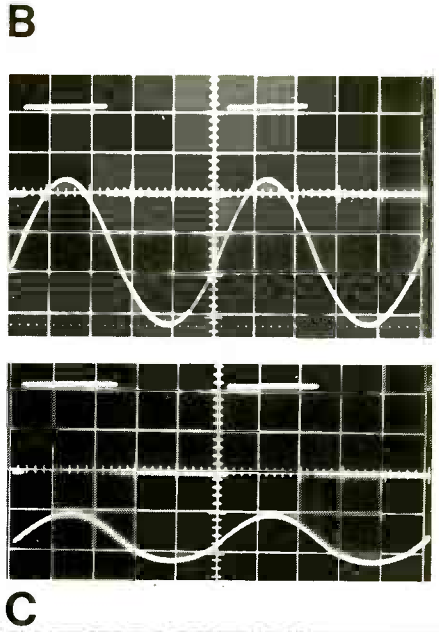
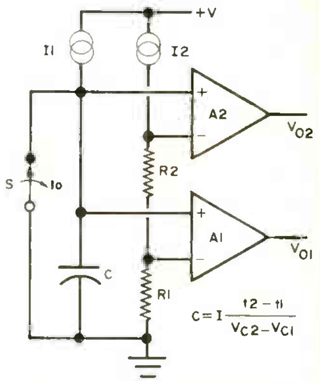
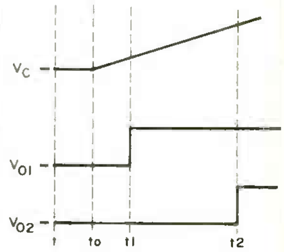


Fig. 2. Counter input circuit (A). Output with 10-kHz, 3-volt input (B) and 10-kHz, 1-volt (C). Outputs are upper traces, with 5 V/div. Sine waves are at 2 V/div.



A



B

lishes a 1.4-volt reference compatible with both TTL and CMOS operating from a 5-volt supply. The 1000-ohm pullup resistor connected at the output has to be connected to the TTL 5-volt supply.

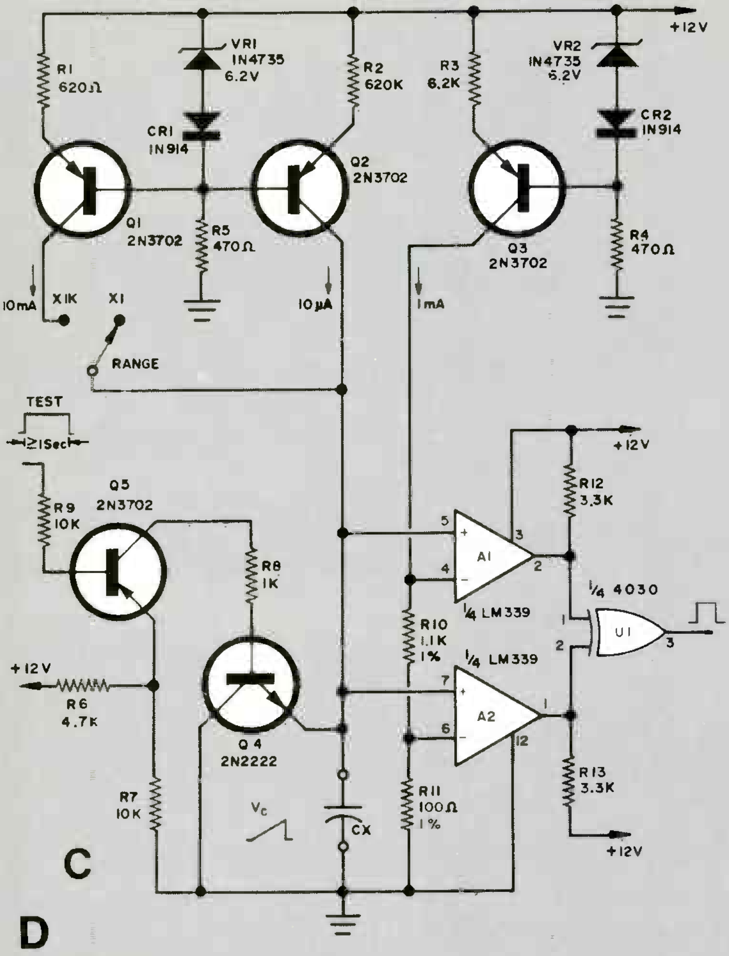
During the design of an 8-input oscilloscope circuit, the author connected eight such circuits, with all eight inputs connected to a source having a pulse 8-microseconds wide. The upper four traces of Fig. 3 came from one 339 package, while the lower four traces came from another 339 package. Actual time variations are about 200 nanoseconds. This illustrates the quality of diffusion techniques these days.

High and Low Limit Detection. Two comparators working together sense the low and high limits in the simplified capacitance measuring scheme shown in Fig. 4A. The unknown capacitor (*C*) is charged from a constant-current source (*I1*). This results in a linear charging ramp whose slope is proportional to the capacitance (Fig. 4B). The limit voltages are 0.10 and 1.10 volts, so that the measurement becomes that of the time required to charge the capacitor to this higher voltage.

In the complete circuit (Fig. 4C), the addition of an exclusive-OR gate yields a pulse whose width is scaled to the value of the capacitor. Scope traces of a typical measurement are shown in Fig. 4D. The capacitance can be determined from the width of the pulse.

Earlier in this article, hysteresis was mentioned as one way to get high and low limit detection, such as used in a Schmitt trigger. The circuit shown in Fig. 5A uses a single comparator which does not have the precision of the dual comparator approach but is useful with looser tolerance circuits.

Although the circuit appears tricky, it is easy to understand. First, you have to know the desired upper and lower switching voltages. Then, select a zener



C

D

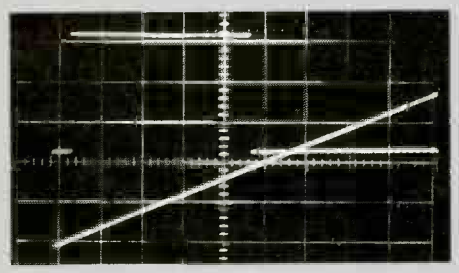


Fig. 4. Basic capacitance measuring circuit (A) and timing diagrams (B). Complete circuit (C) and output for 4.7 μF (D).

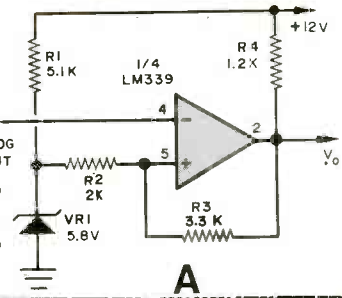
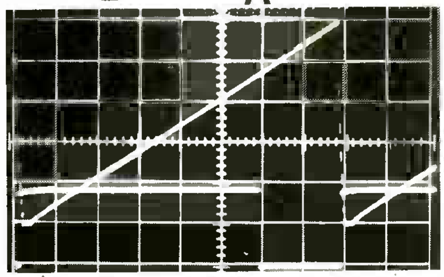
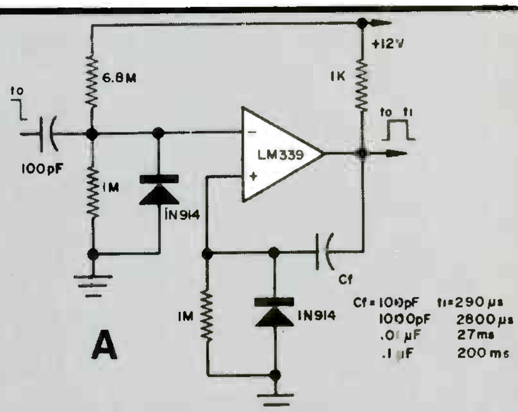


Fig. 5. High/low limit detector (A). Waveforms (B) show switching action.

A

B





A

B

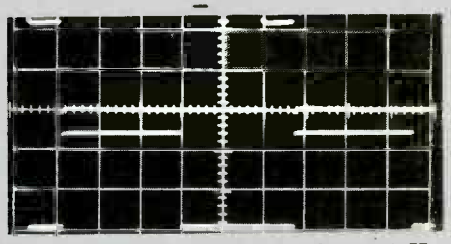


Fig. 6. Monostable circuit (A). In (B) 1710-Hz input is at top, output below (5 V/div).

diode that falls midway between these voltages. Part of the problem comes when trying to get a zener diode of the correct value since zeners come in specific voltages. Therefore, pick the closest value. Select *R1* for 5 to 10 mA of zener current.

When the 339 output is low, some of the current through *R1* flows through *R2* and *R3* into the output. We can safely assume that none flows into the noninverting (+) input. Pin 5 of the 339 will now be lower than the zener.

With the 339 output high, current flows through *R4*, *R3* and *R2* into the zener diode.

Although we will not go into a detailed circuit analysis, the "trick" here is to select the resistor values. In the circuit shown in Fig. 5A, the switching points are 7.7 and 4.0 volts. Build the circuit and vary the resistor values to get a feel for circuit operation. A typical waveform is shown in Fig. 5B.

Monostable. The circuit for a 339 monostable is shown in Fig. 6A, with an output waveform shown in Fig. 6B.

The inverting (−) input of the comparator is biased about 1.25 volts positive by the 6.8-megohm and 1-megohm voltage divider.

Triggering occurs on a negative-going input which forces the inverting input below ground. The 1N914 diode limits this to one diode drop. The resulting positive-going output is fed back to the noninverting (+) input, and the timing is determined by the discharge time of the feedback capacitor C_F and the 1-megohm resistor. This time is proportional to the capacitance value for the ranges shown in Fig. 6A.

Although this circuit may require some "tweaking" to achieve specific monostable action, it is useful to know about if you have an unused comparator in your design and require a monostable. ◇

BY LAWRENCE R. LAFLER

A Low-Cost Emergency Broadcast System Monitor

Add-on circuit monitors the output of a broadcast receiver and sounds an alarm when an EBS warning signal is received

THE National Weather Service and the Civil Defense Agency, in conjunction with local broadcasters and other authorities, maintain an emergency warning system to alert the public in case of impending natural disaster or national defense emergency. This system consists of a network of AM and FM radio stations that will interrupt their normal programs to broadcast an emergency bulletin immediately after an official severe weather or Civil Defense warning is issued. You have probably heard tests of this emergency broadcast system (EBS) on local radio stations. During such tests, and in the event of an actual alert, participating stations broadcast a special two-tone signal used to activate warning devices at other radio stations and at regional Civil Defense offices.

For less than $25.00, you can build a circuit that will respond to the EBS alerting signal. This project receives signals from the earphone jack of a standard broadcast receiver and, in response

to the special EBS tones, actuates a Sonalert or similar audible alarm or a relay. For around-the-clock protection, the EBS Monitor and the radio to which it is connected can be left activated continuously. If an emergency occurs, the alarm could save your life.

How it Works. The EBS alert signal consists of simultaneous tones at 853 Hz and 960 Hz broadcast for 22.5 seconds. This unlikely combination of frequencies and its long duration make it easy to distinguish the warning signal from speech and music. (Its waveform is shown in Fig. 1.)

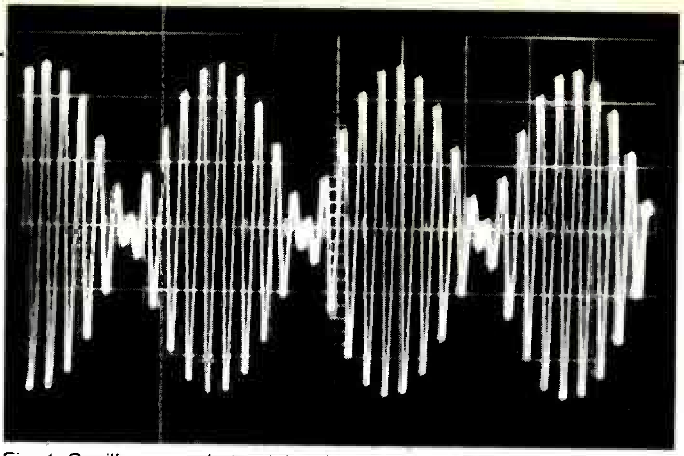
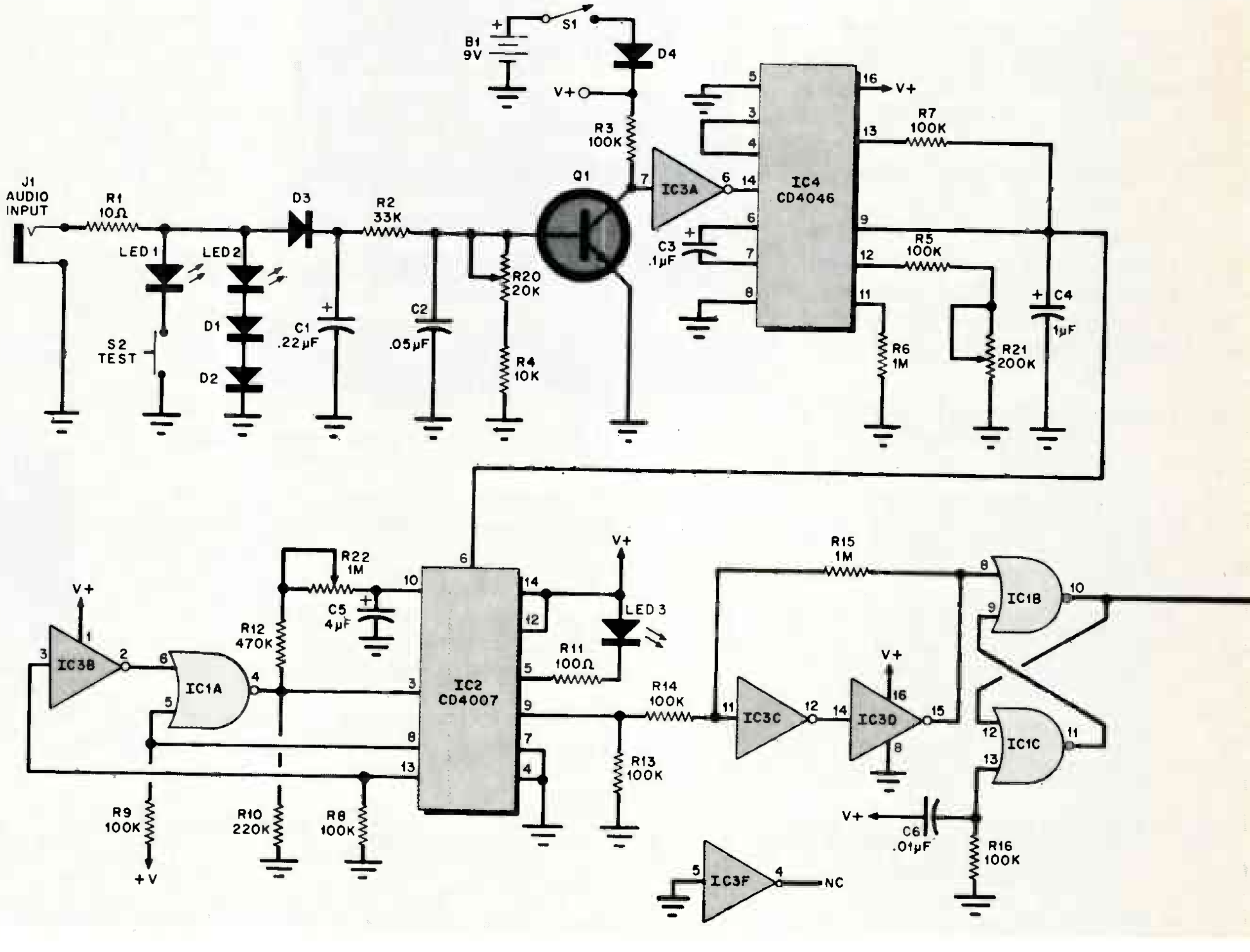


Fig. 1. Oscilloscope photo of the alert signal of the Emergency Broadcast System. It consists of two tones at 853 Hz and 960 Hz broadcast for 22.5 seconds.

Commercial EBS alerting devices employ a separate tone decoder for each of the two audio frequencies and a time-delay circuit that triggers an alarm only when the two frequencies are present for 15 seconds or more. This is an expensive approach requiring a large battery power source. To minimize cost and battery drain without sacrificing performance, this project employs a single CMOS phase-locked loop (PLL) to detect the presence of both frequencies. Three other CMOS integrated circuits perform most of the remaining functions. The circuit, which is shown schematically in Fig. 2, is such an energy miser that it will operate in its listening mode for more than one year on a single 9-volt transistor battery.

The one PLL is able to detect the two discrete audio tones by responding to the 107-Hz difference between their two frequencies. This 107-Hz difference tone can be separated from the rest of the alert signal by rectifying and filtering the signal. Diode *D3*, capacitors *C1* and *C2*, resistors *R2* and *R4*, and potentiometer *R20* perform this function.

Transistor *Q1* amplifies the 107-Hz difference signal and, with the help of inverter *IC3A*, converts it to a square wave that is then applied to the input (pin 14) of *IC4*, the phase-locked loop. The loop acts as a frequency-to-voltage converter that can be programmed to respond to a narrow band of frequencies called the *lock range*. Over this lock range, the output (pin 9) of the phase-locked loop will be a voltage that increases as the frequency of the input signal increases. For an input frequency



outside of the lock range, the PLL output voltage will approach either 0 or 9 volts, depending on whether the input frequency is above or below the lock range. Capacitors *C3* and *C4*, together with resistors *R5*, *R6*, and *R7*, and potentiometer *R21* limit the lock range of the PLL to between 100 and 115 Hz. When a 107-Hz signal is applied to the input of the PLL, its output voltage will be approximately 4.5 volts. This output voltage level can, therefore, be interpreted as an indication that a 107-Hz input frequency is present.

At this point in the circuit, a network is needed that will have a logic 1 output when its input is approximately 4.5 volts, and a logic 0 output when its input is either greater than or less than 4.5 volts. Integrated MOSFETs contained in *IC2* together with inverter *IC3B* and NOR gate *IC1A* form such a network. Thus, the presence of the EBS alert signal causes the output of *IC1A* (pin 4) to go high. However, difference frequencies close to 107 Hz that are occasionally contained in voice, music and noise can also cause the output of *IC1A* to momentarily go high. False alarms due to these normal audio components can be avoided by requiring that the output of *IC1A* be high for at least 15 seconds before the circuit triggers alarm.

This delay is obtained by having the output of *IC1A* charge capacitor *C5* through resistors *R12* and *R22* before the logic level is passed to the next portion of the circuit. As *C5* charges, the voltage at pin 9 of *IC2* increases. Eventually it reaches the level required to switch from logic 0 to logic 1 the output of the Schmitt trigger made up of inverters *IC3C* and *IC3D* and resistors *R14* and *R15*. The output (pin 15) of the Schmitt trigger is connected to the input of the alarm trigger flip-flop consisting of NOR gates *IC1B* and *IC1C*. When the output of the Schmitt trigger switches to logic 1, the output of the alarm trigger flip-flop (pin 10) switches from logic 1 to logic 0. Once this happens, the output of the flip-flop will remain low even if the output of the Schmitt trigger returns to logic 0.

The logic 0 appearing at the output of the flip-flop activates the oscillator made up of NOR gate *IC1D* and inverter *IC3E*. This oscillator generates a square wave that alternately turns *Q2* on and off, activating alarm *A1*.

The circuit contains a few other components whose functions should be noted. Capacitor *C6* and resistor *R16* generate a positive pulse which resets the alarm trigger flip-flop each time power switch *S1* is closed. This assures that the alarm will be silent when power is applied to the circuit. Light-emitting diodes *LED1* and *LED2* indicate when the audio output of the broadcast receiver that drives the circuit is at the proper level. The receiver's output should be adjusted so that, when TEST switch *S2* is closed, *LED1* flickers on and off but *LED2* remains dark. If volume is too low, neither LED will flicker. If volume is too high, both LEDs will flicker. Diode *LED3* is used to indicate when a 107-Hz signal is being detected. It glows whenever the output of NOR gate *IC1A* is at logic 1. Diode *D4* prevents damage to the circuit that would otherwise occur if the battery leads were to become inadvertently reversed.

Construction. The EBS Monitor is most easily assembled using a printed circuit board. The full-size etching and drilling guide for a suitable printed circuit board is shown in Fig. 3. Its corresponding parts placement guide appears in Fig. 4. Mount the integrated circuits using sockets or Molex Soldercons rath-

PARTS LIST

A1—Solid-state audible warning device (Mallory SC-628 Sonalert or similar)
B1—9-volt transistor battery
C1,C7—0.22-μF, 15-volt tantalum capacitor
C2—0.05-μF, Mylar capacitor
C3—0.1-μF, 15-volt tantalum capacitor
C4—1-μF, 15-volt axial-lead aluminum electrolytic capacitor
C5—4-μF, 15-volt axial-lead aluminum electrolytic capacitor
C6—0.01-μF disc ceramic capacitor
D1 through D4—1N4001
IC1—CD4001 quad 2-input NOR gate
IC2—CD4007 dual complementary pair plus inverter
IC3—CD4009 hex inverter
IC4—CD4046 phase-locked loop
J1—Miniature phone jack
LED1—Green light-emitting diode
LED2—Red light-emitting diode
LED3—Yellow light-emitting diode
Q1—2N3904 npn silicon transistor
Q2—2N4402 pnp silicon transistor
The following are ¼-watt, 5% tolerance carbon-composition fixed resistors unless otherwise specified.
R1—10 Ω
R2—33 kΩ
R3, R5, R7, R8, R9, R13, R14, R16—100 kΩ
R4—10 kΩ
R6, R15—1 MΩ
R10—220 kΩ
R11—100 Ω
R12—470 kΩ
R17—3.9 MΩ
R18—2.2 MΩ
R19—1 kΩ
R20—20-kΩ, linear-taper, pc-mount trimmer potentiometer
R21—200-kΩ, linear-taper, pc-mount trimmer potentiometer
R22—1-MΩ, linear-taper, pc-mount trimmer potentiometer
S1—Spst switch
S2—Normally open, momentary-contact pushbutton switch
Misc.—Printed circuit board, suitable enclosure, IC sockets or Molex Soldercons, battery retainer and connecting clip, hookup wire, two-conductor cable, miniature phone plugs, hardware, etc.

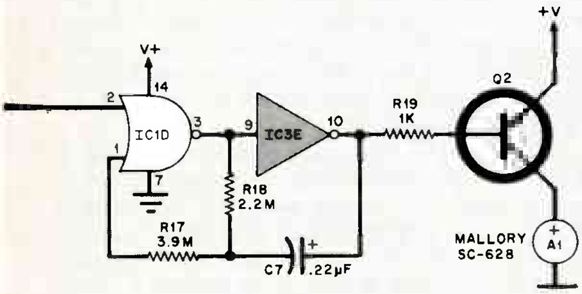


Fig. 2. The circuit in the project uses a CMOS phase-locked loop to detect the presence of the alert signal. The CMOS components cause little battery drain so that the monitor can be in use constantly.

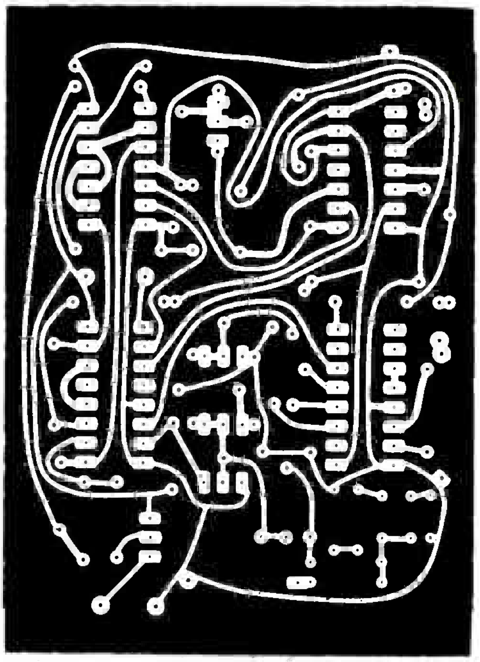
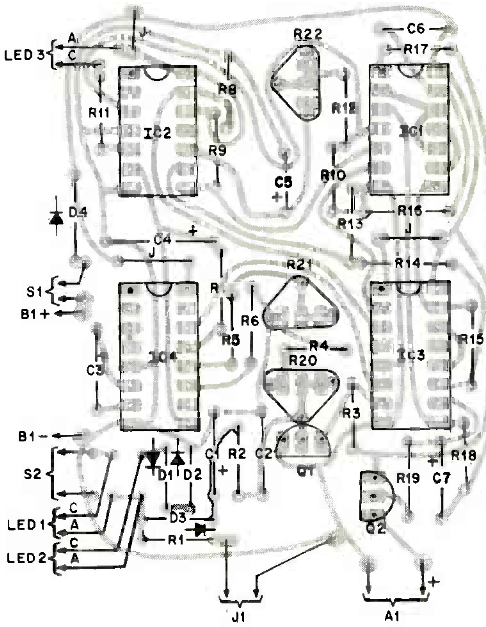


Fig. 3. Actual-size etching and drilling guide for a suitable printed circuit board.

Fig. 4. Component layout for the monitor's printed circuit board is shown below.



er than soldering them directly to the board. This makes replacement of defective ICs infinitely easier and eliminates the possibility of damaging them during soldering. Be sure to observe polarities and pin basings when you mount the diodes, transistors, LEDs, ICs, and electrolytic capacitors.

The LEDs should be mounted off the board so that they can project through the front panel of the enclosure that is employed to house the project. The switches should also be mounted on the front panel. Connect the LEDs and switches to the pc board using flexible hookup wire. Input jack *J1* should be mounted on the rear of the enclosure and connected to the board using two-conductor cable. Fasten a retaining clip for the 9-volt battery to the enclosure and connect suitably long leads from the appropriate foil pads to a 9-volt battery clip. Then install the battery and snap the connecting clip in place. Finally, prepare a two-conductor patch cord of convenient length terminated with miniature phone plugs at each end.

Alignment. There are only three adjustments that must be made before the EBS Monitor is ready for service. Potentiometer *R20* must be adjusted so that, when the audio output of the broadcast receiver is at the proper level and the EBS signal is present, a 107-Hz square wave will be applied to the input of the PLL. Potentiometer *R21* must be adjusted so that the lock range of the PLL is centered around 107 Hz. Third, potentiometer *R22* needs to be set so that, once *LED3* begins to glow, there will be a 12- to 18-second delay before the alarm sounds. The easiest way to make these adjustments is to first make a recording of the EBS alert signal when a local radio station is conducting an EBS test. Use a high-quality cassette or open-reel tape recorder that has an earphone or line-level output jack. After you have recorded the two-tone signal, patch the output of the recorder to the project's input jack and proceed as follows.

First, connect a voltmeter between pin 14 of *IC4* and the circuit ground. Then close switch *S1* and play back the EBS alert signal. (Rewind and repeat this step as necessary so that the tone is present during all of the remaining steps.) Hold switch *S2* closed and adjust the recorder's output level until *LED1* glows but *LED2* remains dark. Vary potentiometer *R20* until the voltmeter reads 3 to 5 volts dc. Vary potentiometer *R21* until *LED3* glows most or all of the time that the tone is present. Vary potentiometer *R22* until the delay between the application of the tone and the activation of the audible alarm is between 12 and 18 seconds. The delay can be reduced by moving the wiper of *R22* toward capacitor *C5* as viewed from the top of the board.

Use. Your EBS monitor is ready for service. Apply power to both the project and the broadcast receiver with which it will be used. Tune in a local radio station that participates in the Emergency Broadcast Service, has a strong signal in your area, and broadcasts 24 hours a day. If possible, choose an FM station, because static interference during an electrical storm will be less severe and the operation of the Monitor will be more reliable.

Patch the output of the receiver to input jack *J1* and, if necessary, adjust the output level so that *LED1* flickers in step with the demodulated signal when *S2* is depressed but that *LED2* remains dark. When the project is operating in its listening mode, *LED3* should flicker on occasionally. As long as it flashes brightly, the battery is in good condition. As the battery becomes weaker and needs replacing, *LED3* will diminish in brightness.

Take advantage of the broadcaster's EBS tests to check the circuit periodically for proper operation. These tests are never conducted at night, so you will not be disturbed by false alarms if you leave the project in its listening mode while you sleep. When the alarm sounds, remove power from the project and disconnect the patch cord from the output jack of your broadcast receiver. You will then be able to hear the emergency message that follows. ◇

Build a
Diode Temperature Probe

Low-cost sensor gives temperature reading on a DMM

IF YOU own a digital multimeter (DMM), it can be made to give temperature readings for a small expenditure in parts and effort. When a small forward bias is applied to a conventional silicon diode, the voltage drop across the diode junction changes at a rate of about 1.25-mV/°F (2.24-mV/°C). Thus, a low-cost and readily available diode such as the 1N914 can be used as a temperature probe.

The bridge circuit shown in Fig.1 works in conjunction with the sensor diode and a DMM on the 200-mV (low temperature) or 2-volt (high-temperature dc voltage ranges. The displayed digits are the temperature. Note that in Fig. 1, two values are shown for *R2*, *R4*, *R6*, and *R7*. The values in parenthesis are for Celsius operation, while the others are for Fahrenheit. Capacitor *C1* is used to bypass stray signals that may be picked up on the leads.

Construction. The circuit can be assembled on a small printed-circuit or perforated board. The small circles at *C1* indicate the need for a pc pad, or WireWrap pin to make the connections to the remote diode.

To make the temperature probe safe for liquid immersion, the arrangement shown in Fig. 2 is used. Preform a short length of vinyl tubing, fill it with epoxy, and "thread" it up the diode leads to make contact with the diode body. Allow the epoxy to thoroughly cure. If desired, a length of heat-shrink tubing may be used. In either case, leave a short length of diode lead exposed for soldering to the flexible cable.

Slide a short length of heat-shrink tubing over the covered diode leads, solder each diode lead to the flexible cable, and then fit the tubing over the solder joint. Shrink the tubing to make a tight fit.

Calibration. The resistance values for *R2-R4* and *R6-R7* are not critical, but their *ratios* are. Perform the following calibration tests before changing any resistance value.

Potentiometer *R3* balances the bridge to indicate 32°F (0°C) at this temperature. Potentiometer *R5* is used to reduce the 1.25 (2.24) mV/degree to exactly 1 mV/degree and is also used to set the upper range point.

With *R3* and *R5* at their center of rotation, immerse the diode probe in a container of finely shaved or crushed ice. Adjust *R3* to produce a DMM indication of 32 (°F) or 0 (°C). Place the DMM in the 2-volt dc range, immerse the probe in a container of boiling water, and adjust *R5* for a DMM indication of 212 (°F) or 100 (°C).

If you find that *R3* is at one end of its rotation, add a parallel resistor in the megohm range across either *R2* or *R4*, depending on the location of the wiper of *R3*. If *R5* is at one end of its rotation, add a parallel resistor (also in the megohm range) across *R6* or *R7*. If desired, a 10-turn trimmer potentiometer can be used for each of the fixed resistors and preset for the correct ratios.

Since the DMM will also indicate negative voltages, it will similarly indicate temperatures below those at which it is calibrated. Also, the diode can operate at temperatures above 212°F, which is about the limit for the plastic insulation used for the diode leads, so a plastic with a higher temperature rating can be used to liquid-proof the sensor. Or, without such protection, the sensor can be used for dry, or contact, temperature measurements. ◇

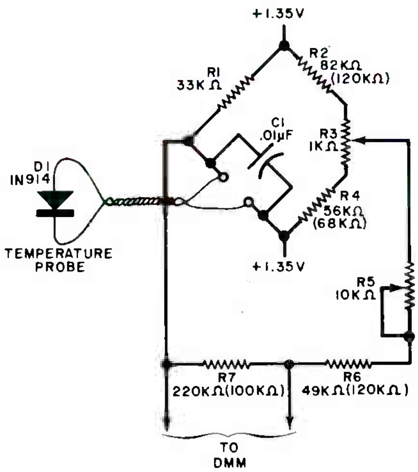


Fig. 1. Diode is one leg of a Wheatstone bridge connected to DMM.

PARTS LIST

C1—0.01-μF disc capacitor
D1—1N914 silicon diode
R1—33 kΩ, ½-W resistor
R2—82 kΩ (F) or 12 kΩ (C) ½-W resistor
R3—1-kΩ pc-mount potentiometer
R4—56 kΩ (F) or 68 kΩ (C) ½-W resistor
R5—10 kΩ pc-mount potentiometer
R6—49 kΩ (F) or 120 kΩ (C) ½-W resistor
Misc.—1.35-volt battery and holder, vinyl or heat-shrink tubing, flexible two-conductor cable, epoxy, solder, etc.

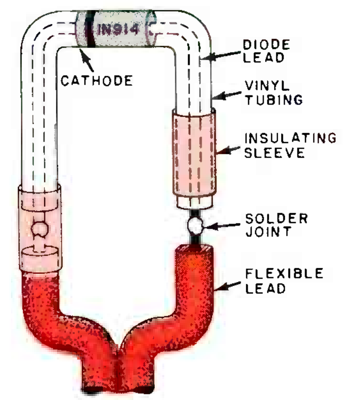


Fig. 2. To make probe immersible, vinyl tubing is added around leads.

Measure Weak Direct Currents with the Sensitive Micro Meter

BY I. QUEEN

Low-cost op-amp system can measure solar-cell output and currents in other low-level circuits.

IF YOU PLAN to measure the output of a solar cell under low-light conditions, to work with micropower ICs, or otherwise experiment with weak-current circuits, you'll need a sensitive current meter. The Sensitive μ Meter presented here will allow you to measure direct currents as small as a fraction of a microampere. Moreover, it is not subject to the disadvantages associated with standard panel microammeters—high cost, fragile movements, and relatively high internal resistance.

The project employs an operational amplifier to increase the sensitivity and effectively decrease the input impedance of a moderately priced, readily available 0-to-50 microammeter. It has three switch-selected scales; 0 to 0.5 μ A; 0 to 5 μ A; and 0 to 50 μ A. The circuit can be powered by a supply furnishing as little as ±2 or +4 V, and can be constructed for about $15.

Circuit Operation. A simple circuit for current-measuring applications is shown in Fig. 1. When an input current *I* is applied to the inverting input of the op amp, an inverted output signal is generated by the op amp. If the gain of the operational amplifier is very high, we can consider that the entire input current flows through feedback resistor *R*. An output voltmeter *M*, which is calibrated in terms of *I*, measures the product *IR*. The voltage drop across the operational amplifier is practically zero (the output voltage divided by the op amp's open-loop gain).

The schematic of the Sensitive μ Meter is shown in Fig. 2. Switch *S2* selects the range and determines the feedback resistance of the stage. When the switch is in its center (off) position, the feedback resistance is *R3*, one megohm. An input current of 0.5 μ A will cause the output of the op amp to be 0.5 volt above ground when only *R3* is in the feedback loop.

This output voltage will cause full-scale deflection of 0-to-50-microammeter *M1* if the effective resistance between the output terminal of the operational amplifier and the negative terminal of the meter is 10,000 ohms. The internal resistance of the meter specified in the parts list is 1620 ohms, so the balance of the required resistance is supplied by *R4*. This trimmer potentiometer is adjusted for full-scaie deflection of the meter movement when the op amp output is at +0.5 volt.

The project is most sensitive when *S2* is in its center (off) position and the feedback resistance is one megohm. In this operating mode, full-scale deflection of the meter corresponds to an input current of 0.5 μ A. Higher-current ranges are obtained by shunting *R3* with other resistors to lower the overall feedback resistance. This is accomplished by placing *S2* in one of its two other positions. When the range switch is placed in its 5 μ A position, the parallel combination of *R1* and *R3* causes the meter to deflect to full scale if the input current is five microamperes. Similarly, placing *S2* in its 50 μ A position shunts *R3* with *R2* and causes full-scale deflection of the meter movement when an input current of fifty microamperes exists.

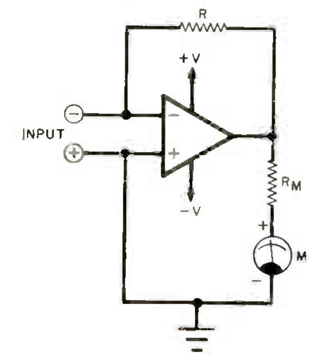


Fig. 1. Schematic of simple current-measuring circuit.

Two shorting switches are included in the circuit. Switch *S1* shorts the input of the project. It is used in conjunction with potentiometer *R5* to zero the meter movement. The other switch (*S3*) is used to short the terminals of *M1* when the meter is not being used. This minimizes mechanical shocks to the meter movement when the project is being transported. Diodes *D1* and *D2* protect the project from excessive input voltages. Jack *J2* provides access to *M1* so that the meter can be used in isolation from the rest of the project.

You might wonder why the circuit provides for a 0-to-50-microampere scale when meter movement, *M1*, covers this range on its own. The following exercise performed by the author will illustrate the need for such a scale. A solar cell was connected across input jack *J1* and illuminated so that the Sensitive μ Meter indicated a current of 50 μ A. The cell was then connected to *J2* and its output current measured using *M1* alone. It indicated a current of 1 μ A.

The reason for this discrepancy between the two readings is that *M1* presents a higher resistance to the solar cell when it is used independently than the project as a whole does. It is desirable to keep the internal impedance of a current-measuring instrument as low as possible. Thus, it is better to employ the project as a whole (as opposed to *M1* or a similar meter alone) in the measurement of currents up to 50 μ A.

There is another significant advantage to the use of the Sensitive μ Meter as opposed to a microammeter alone. Due to the clipping action of protective diodes *D1* and *D2*, the maximum output voltage of the op amp on any of the three ranges is

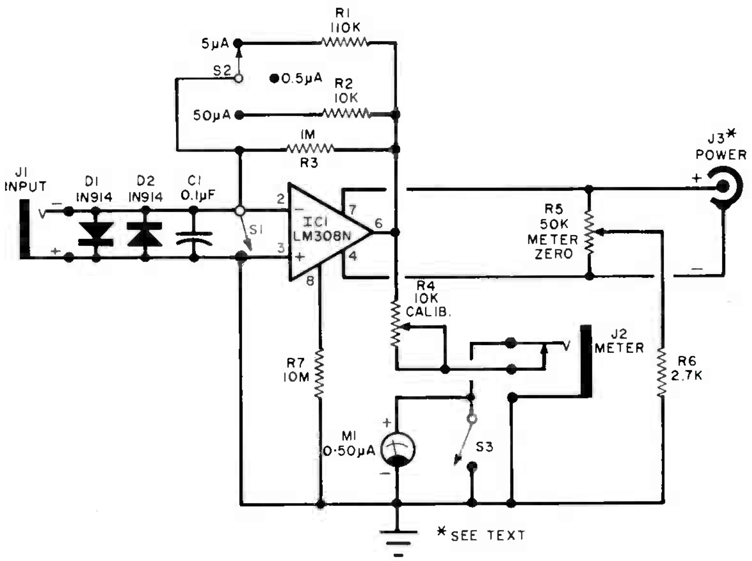


Fig. 2. The gain of the operational amplifier and, hence, the range of the meter are determined by the amount of resistance in the feedback circuit.

PARTS LIST

C1—0.1-µF disc ceramic
D1,D2—1N914 diode
IC1—LM308N operational amplifier
J1—Open-circuit miniature phone jack
J2—Closed-circuit subminiature phone jack
J3—Phono jack (must be insulated from project enclosure)
M1—0-to-50-µA meter movement (Radio Shack No. 22-051 or equivalent)
The following are ¼-watt, 5%-tolerance carbon-composition fixed resistors, unless otherwise specified:
R1—110,000 ohms (can be a series connection of 100,000 ohms and 10,000 ohms)
R2—10,000 ohms
R3—1 megohm
R4—10,000-ohm, linear-taper trimmer potentiometer
R5—50,000-ohm linear-taper potentiometer
R6—2700 ohms
R7—10 megohms
S1,S3—Spst toggle switch
S2—Spdt toggle switch with center-off position
Misc.—Suitable enclosure, perforated or printed circuit board, IC socket, circuit board spacers, machine hardware, control knob, hookup wire, solder, etc.

approximately 0.7 volt. This corresponds to less than a 50% overload of meter movement *M1*, one that is highly unlikely to cause any permanent damage to the movement. An unprotected microammeter, on the other hand, can easily be "zapped" by the inadvertent application of high current overloads, a fact to which more than one electronics experimenter can ruefully attest.

Power for the circuit is furnished by an external supply via phono jack *J3*. Note that the shell of this power jack must be insulated from chassis ground. The operational amplifier specified for use as *IC1* is an LM308, a precision op amp that can be used with supply voltages ranging from ±2 to ±20 volts. Accordingly, a supply capable of furnishing bipolar voltages within these extremes (or a single-ended one rated at 4 to 40 V) should be employed to power the Sensitive µ Meter. Potentiometer *R5* is connected across the supply to allow zeroing of the meter movement under no-input conditions (*S1* closed) for any suitable supply voltage.

Construction. The project is relatively simple, so the use of a perforated board and point-to-point wiring is an acceptable assembly technique. Alternatively, the project can be constructed using wrapped-wire or printed circuit connections. The author housed his prototype in a 4" × 2" × 1½" (10.2 × 5.1 × 3.8 cm) aluminum utility box. A Radio Shack No. 22-051 0-to-50-microammeter was used for *M1*. This meter fits the enclosure with only a slight amount of overlap at the edges. Of course, a larger enclosure can be employed if it is preferred over the one selected by the author.

An LM307 operational amplifier can be used for *IC1* in place of an LM308 if pin 3 is connected to project ground through the parallel combination of a 30,000-ohm resistor and a 0.1-µF disc ceramic capacitor. This op amp will provide performance comparable to that of the LM308 if the circuit is modified as just described. Other operational amplifiers can also be used if variations in pinouts and possible compensation requirements are taken into account.

Calibration and Use. Connect a suitable power supply to *J3*, observing polarities. Then close *S1*, place *S2* in its 0.5 µA position, and open *S3*. Set the wiper of *R4* halfway between the two extremes of its travel and adjust potentiometer *R5* for a zero reading on meter movement *M1*. Then open *S1* and place *S2* in its 50 µA position. Connect a suitable source of weak dc current to the input jack of the project using a length of shielded cable terminated with a miniature phone plug. A 1.5-volt battery and a series-connected 1-megohm potentiometer can be used as a source of low-level dc.

Depending on the capabilities and sensitivity of the test equipment available to you, monitor either the current at *J1* or the voltage at the output of the operational amplifier. Adjust the amplitude of the input current so that it equals 50 µA. Alternatively, monitor the output voltage of the op amp and adjust the amplitude of the input current until the voltmeter reads +0.500 volt. Then adjust trimmer potentiometer *R4* to obtain a full-scale (50 µA) reading on *M1*.

The Sensitive µ Meter is now calibrated and ready for use. In view of its high sensitivity, it is a remarkably stable instrument. At the start of each measuring session, the meter should be zeroed by adjusting potentiometer *R5*. It should not be necessary to continually touch up this adjustment if a battery or regulated line-powered supply is used in conjunction with the project.

Thanks to the protective action of *D1* and *D2*, the meter movement is relatively immune from damage caused by current overloads. Overloads should still be avoided, however, especially severe ones that could damage the protective diodes. Finally, remember that it is good practice to keep shorting-switch *S3* closed when the project is not being used. This will damp the meter movement and minimize the effects of physical shock upon it.

TWO LOW-COST
AUTOMOBILE PROJECTS

1. SIMPLE LOW-COST CHARGER KEEPS AN AUTOMOTIVE-TYPE BATTERY IN PEAK SHAPE

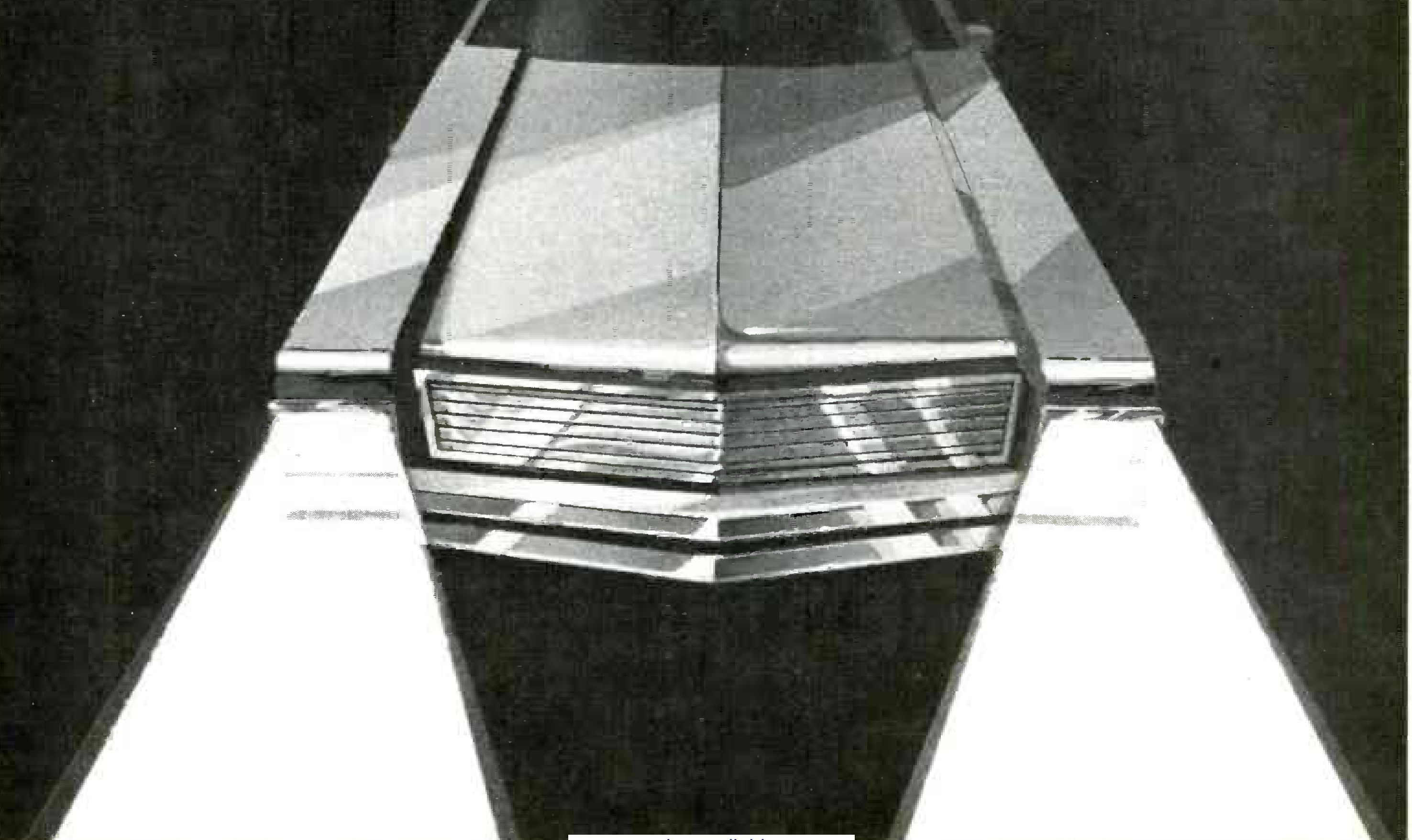
BY CASS R. LEWART

THIS simple 12-volt automotive battery booster/trickle charger provides a choice of charging rates to suit battery condition. Set to FULL CHARGE, it will restore a partially discharged battery overnight; when set to TRICKLE CHARGE, it will maintain the battery at peak capacity for an extended time. A built-in LED glows only when the charger is delivering current to the battery. (The circuit is shown in Fig. 1.)

Circuit Operation. The output of *T1* is rectified by diodes *D1* and *D2*. Pulsating dc is delivered to the battery via a cable to the cigarette lighter connector in the vehicle. Switch *S1* is used to choose between FULL CHARGE (approximately one ampere) and TRICKLE CHARGE (50-mA). Indicator *LED1* is in series with its current limiter, *R4*. The fuse protects against short circuits.

Construction. The entire circuit can be mounted in a small metal enclosure, using multilug terminal strips to support the components. Point-to-point wiring can be used. The ac line cord and the output cable should be passed out of the enclosure via grommetted holes. A plug that fits the vehicle's cigarette lighter should be connected to the output cable. Make sure the polarity is correct.

Operation. Plug the ac line cord into a convenient outlet and plug the output cable into the cigarette lighter connector. Select either a FULL or TRICKLE charge via *S1*, and verify that the LED glows in either position of *S1*. If the LED does not glow, clean the contacts on the plug and the cigarette lighter and try again. If this fails, check for a wiring error. Should the battery be completely discharged (dome light does not light



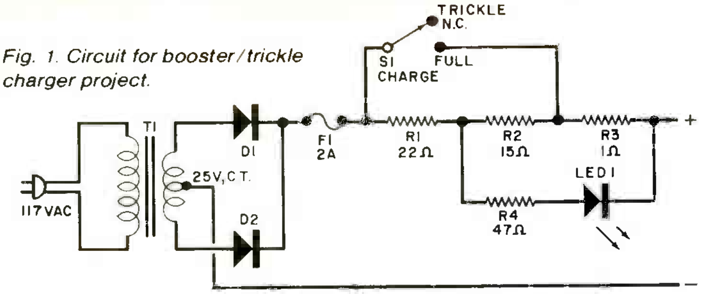


Fig. 1. Circuit for booster/trickle charger project.

PARTS LIST

D1,D2—3-A, 50-V diode (Radio Shack 276-1141 or similar)
F1—2-A fuse and holder
LED1—Red light emitting diode
R1—22-Ω, 2-W resistor
R2—15-Ω, 2-W resistor
R3—1-Ω, 10-W resistor (Radio Shack 271-131 or similar)
R4—47-Ω, ½-W resistor
S1—Spst switch
T1—25-V, 2-A CT transformer (Radio Shack 273-1512 or similar)
Misc.—Suitable enclosure, multi-lug terminal strips, line cord, output cable, suitable cigarette lighter plug, mounting hardware.

up), use the TRICKLE CHARGE position of *S1* for one to two hours. Less than 8 to 9 volts from the battery at the end of this time means that it must be replaced. If the voltage is about 12 volts, place *S1* in the FULL CHARGE position. ◇

2. ALARM SOUNDS IF YOUR HEADLIGHTS OR PARKING LIGHTS ARE ON WITH THE IGNITION OFF

BY C. R. BALL

HAVE you ever walked away from your car, left your lights on, and returned later to discover that your battery has run down? The circuit described here will end this problem. It will sound an alarm if you turn off your car's ignition while the headlights or parking lights are on. The alarm ceases when the lights are turned off.

Circuit Operation. The circuit, shown in Fig. 1 is based on a 555 timer IC. Diodes *D1* and *D2* are arranged as an OR gate so that either will pass positive voltage from its anode to *IC1*. Diode *D3* blocks reverse current when the ignition alone is on. When the ignition and either the headlights or parking lights are on, little or no potential difference exists across the powerpins of *IC1*, which remains inoperative.

If either the headlight or parking light circuit is alive, and the ignition line is off, the dc circuit for *IC1* is complete. The oscillator starts, and sounds a warning tone via the loudspeaker. The tone's frequency may be changed by varying the values of *R1*, *R2*, or *C1*. Resistor *R3* sets the loudness, and its value may be altered as desired.

Zener diode *ZD1* may be required to provide a threshold to prevent the alarm from operating if there is a small potential difference in the dc supply circuit during normal operation. To determine the necessity and/or value of *ZD1*, with the headlights and ignition both on, measure the voltage between points H and I. If the voltage is more that 1.4 volts, the zener is required. The zener voltage should be slightly higher than the excess over 1.4 volts. For low voltages, one or more forward-biased silicon diodes can be substituted for the zener. Each silicon diode drops about 0.7 volt.

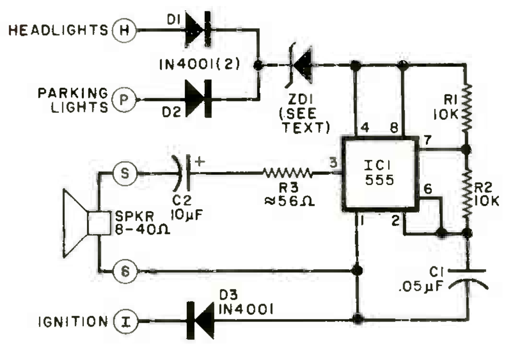
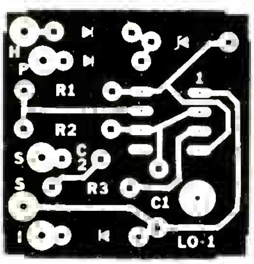


Fig. 1. With ignition off, and the headlights and parking lights on, alarm will sound.

PARTS LIST

C1—0.05-μF, 50-V Mylar capacitor
C2—10-μF, 50-V electrolytic
D1, D2, D3—1N4001 or similar
IC1—555 timer
R1, R2—10,000-Ω, ¼-watt
R3—selected for volume, nominally 56 ohms
SPKR—3.2-to-8-ohm, 2" speaker
ZD1—see text
Misc.—Suitable enclosure, interconnecting cables, mounting hardware.
Note: Available from BallABS, Box 703, Duluth, GA 30136: kit of all parts except ZD1 and case (LO-1K) for $10.50 plus shipping. Also available: pc board (LO-1) for $2.50, assembled and tested without case (LO-1A) $25.00.



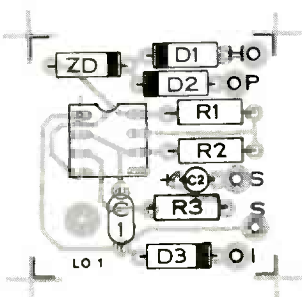


Fig. 2. Etching and drilling guide and component installation is at left.

Construction. The system can be assembled on a small piece of perf board, or on the pc board whose foil pattern is shown in Fig. 2. After completion, the board can be mounted in a small enclosure. Check the polarities of the IC and all diodes before applying power.

The small speaker is connnected to the two pads marked S, the pad marked I is connected to the vehicle ignition lead (after the ignition switch), the pad marked H connects to the headlight power line, and the pad marked P goes to the parking light line.

To allow the lights to be used with the ignition off, an spst switch can be connected in series with *D3* to defeat the alarm. If this switch is used, make sure that it is clearly identified so that it can be closed for normal operation. ◇

AUTOMATIC LINE VOLTAGE REGULATOR

When your line voltage nosedives, this circuit gives a 6-volt boost

BY HERBERT ELKIN *

DO YOUR lights go dim, does your TV picture shrink and lose brightness, or are your ac appliances acting as though they're just plain tired? You may be living in an area subject to "brownouts" (low power-line voltage), and the solution to your troubles could well be some form of voltage regulation.

The automatic line voltage regulator described in this article will automatically raise power-line voltage by about six volts whenever it drops below a preset level. When the line voltage returns to normal, the compensation automatically drops out. (See Fig. 1.)

Circuit Operation. Filament transformer *T1* is connected with its 6.3-volt secondary in series with the primary so that the two voltages add. Relay *K1* taps an output from the primary alone or from the combined windings. The remainder of the circuit senses the output voltage and sets (or resets) *K1* to switch the extra winding in or out as needed.

As can be seen from Fig. 1 and the waveforms of Fig. 2, capacitor *C1* follows the swings of the fraction of the power-line voltage developed across the *R2* portion of voltage divider *R1-R2*. Potentiometer *R2* is adjusted so that the peak voltage across *C1* just reaches the firing level of neon lamp *I1* when the voltage across *R1-R2* reaches the level where automatic compensation is not required. The neon lamp breaks down and applies a positive pulse to the gate of *SCR1*, causing the SCR to turn on and hold relay *K1* in the position that directs the normal line voltage to the output. The SCR, then turns off when the power-line voltage passes through zero. The neon lamp fires on each positive half cycle, allowing its glow to be used as a "normal" line voltage indication. During the negative half cycles, diode *D1* clamps *C1* to circuit ground, thus keeping the neon lamp "off" and preventing the negative pulse from being applied to the SCR gate.

Because its drive switches on and off at power-line frequency, relay *K1* would normally "chatter". Capacitor *C4*, connected across the relay coil, prevents this problem as it charges when the SCR fires to provide both filtering (due to rectification of the ac voltage by *SCR1*),

*Loral Electronic Systems, Yonkers, NY.

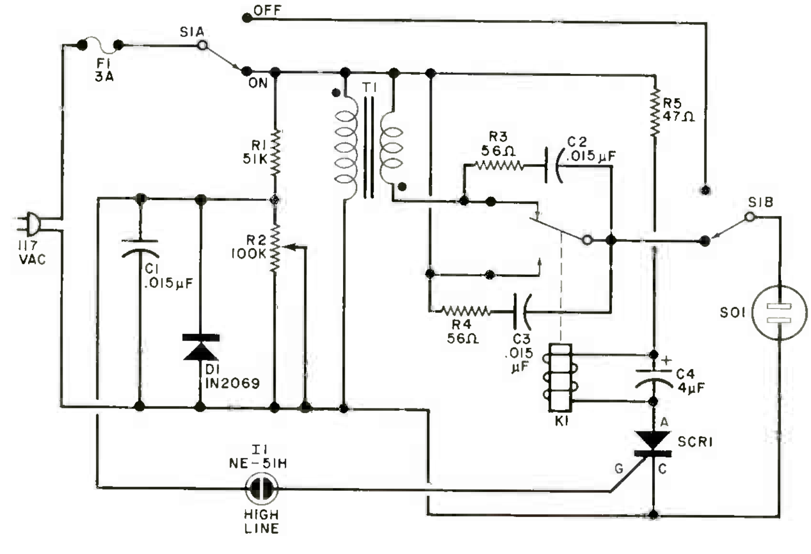


Fig. 1. When line voltage drops, K1 adds the 6.3-V secondary of T1 in series with the line to raise the output at SO1.

PARTS LIST

C1,C2,C3—0.015-μF, 400-volt ceramic capacitor
C4—4-μF, 250-volt electrolytic
D1—1N2069, 1-ampere, 200-PIV rectifier
F1—3-ampere, slow-blow fuse with holder
I1—NE-51H neon lamp assembly (Dialco 95-0463-0931-211 or similar)
K1—2pdt, 48-volt, 2500-ohm relay (Sigma 62R2-48DC-SCO or similar)
R1—51,000-ohm, ½-W, 10% resistor
R3,R4—56-ohm, ½-W, 10% resistor
R5—47-ohm, ½-W, 10% resistor
R2—100,000-ohm, multi-turn pot.
S1—2pdt switch
SCR1—4-ampere, 200-PIV silicon controlled rectifier
T1—6.3-V 3-A, filament transformer
Misc.—Ac receptable (SO1), terminal strip, suitable enclosure, spacers, mounting hardware, etc.

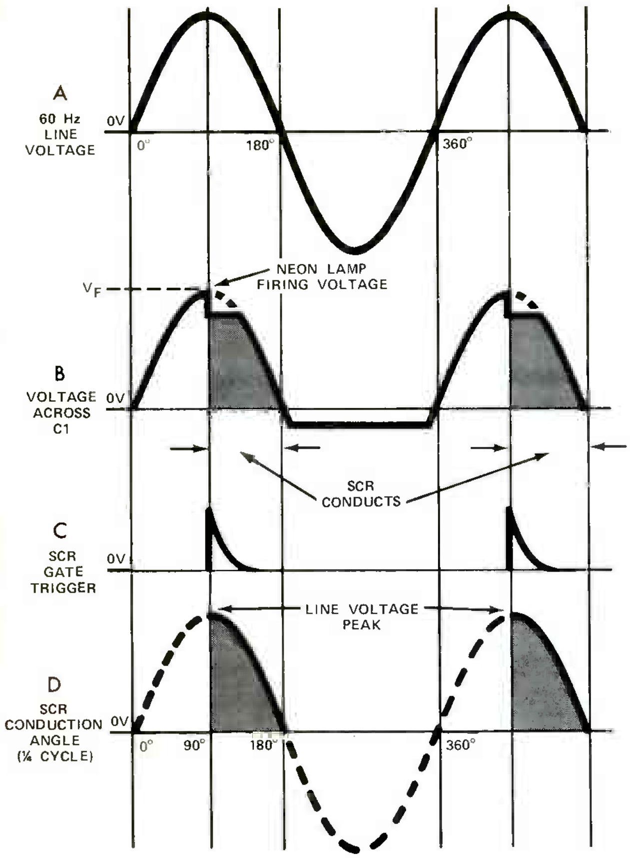


Fig. 2. Waveform at (A) is line voltage; (B) is voltage across C1; (D) is SCR conduction angle.

Interior photo of the prototype regulator. Components can be mounted on pc or perf board.

and relay-coil holding current when the SCR is off.

The networks consisting of *R3-C2* and *R4-C3* form arc-suppression circuits to minimize relay contact pitting, while *R5* limits SCR surge current to a safe value. Using the parts shown in Fig. 1, appliances drawing up to 350 VA can be controlled. For higher power, a larger transformer and a relay with heavier contacts can be used. Make sure that fuse *F1* is a slow-blow type to accommodate any turn-on surge currents. To bypass the compensation circuit, switch *S1* can be set to OFF.

Construction. With the exception of transformer *T1*, output socket *SO1*, neon lamp assembly *I1*, and on/off switch *S1*, all components can be mounted on a small pc board—or a perf board, using point-to-point wiring. The board can be mounted in any type of enclosure that can accommodate all of the components. The line cord exits through a grommetted hole.

A terminal strip with *nongrounded* lugs must be used for the transformer leads and ac power connections. If a metal enclosure is used, it is important that it be isolated from *both* sides of the power line to prevent a shock hazard.

The windings of *T1* can be phased using the setup shown in Fig. 3. Temporarily connect one secondary lead to one side of the primary as shown. Very carefully (to avoid shock), measure and note the voltage appearing across the transformer primary alone. This is the line voltage. Then measure the voltage across the combined primary/secondary and note that it is 6.3 volts higher. If the voltage indication is *less* than the noted line voltage, phasing is incorrect. Exchange the two secondary leads and repeat the above test. When the combined voltage is higher than the line voltage, you know that the transformer leads are properly phased.

Calibration. To adjust the low-voltage trip point, a source of variable line voltage is required. (A Variac or similar device will do.) Adjust the power-line input for 110 volts—or whatever voltage you wish the relay to trip at—and connect an ac voltmeter across the contacts of *SO1*. Vary potentiometer *R2* until neon lamp *I1* glows and note that as this happens the relay is activated, which means that the voltage is not boosted, and the ac voltmeter across *SO1* registers 110 volts.

Carefully rotate *R2* until the neon lamp just extinguishes and the relay deenergizes. The ac voltmeter across *SO1* should move up to approximately 116.3 volts. Slowly increase the input voltage level until the neon lamp lights and note that the ac voltmeter indicates about 112 volts. Set the trip point wherever you want it to occur.

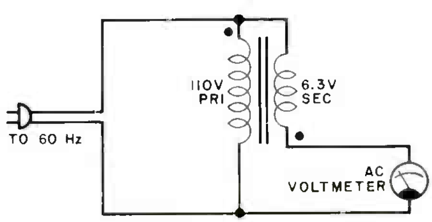
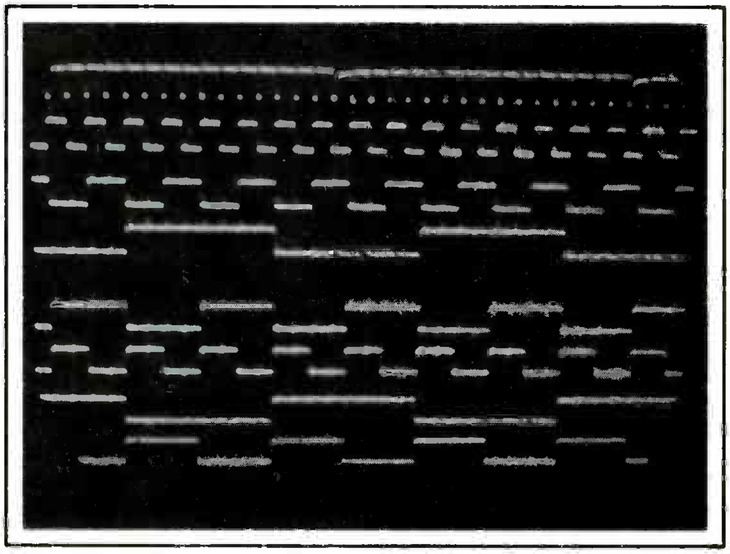


Fig. 3. Meter should read 6.3 V above line with transformer connected as shown.

In Conclusion. This project represents a simple, inexpensive way to provide some compensation for low power-line voltage. Its regulation is somewhat coarse, but is sufficient for most home appliances. Note that, since relay *K1* interrupts power briefly while switching in the booster winding, the circuit may not be suitable for use with sensitive devices such as computers or digital clocks. ◇

A low-cost circuit provides up to 16 logic displays on single-trace oscilloscopes

HOW ORDINARY OSCILLOSCOPES CAN DISPLAY MULTI-CHANNEL LOGIC SIGNALS



BY LES SOLOMON

DIGITAL logic circuits, whether they are in a simple counter or a complex computer, are formed from interlocking networks of gates and flip-flops. Observing such circuits as they operate is possible with a logic probe, a dc voltmeter, or a scope. But since a logic probe or voltmeter can monitor but one signal at a time and the operation of digital circuits depends on the time relationships between a large number of signals, these instruments are of little help. A dual-trace scope does little better as it can be used to monitor only two signals.

What is needed is a way to monitor many signals simultaneously. The obvious solution, a logic analyzer, is costly. However, by taking advantage of some low-cost, readily available ICs, it is possible to construct a very inexpensive logic state analyzer that can display eight vertically displaced discrete traces on a conventional single-trace scope. Each trace will display the signals present on a selected input line. Thus, the timing of up to eight different points within a circuit can be simultaneously observed. The basic circuit is shown in Fig. 1.

Circuit Operation. The "heart" of the circuit is a 1-of-8 data selector that can accept eight TTL inputs and, via an internal address decoder, place one of the eight at a time on the chip output line. The inputs are selected by applying a digital code from 000 to 111 to the three address inputs of the data selector. When the enable pin (7) is held low, the chip operates normally.

The three address lines are driven from a counter (a divide-by-sixteen 7493, a decade 7490, or almost any other counter). When the clock input is driven, the three address outputs cycle continuously through the digital code.

The eight traces are developed from the three address lines by a rudimentary D/A converter formed by *R1, R2,* and *R3* connected to the upper end of *R5.* When an address line goes high, current flows through the associated resistor and *R5* to ground, developing a voltage across *R5.* With the circuit shown, an 8-step waveform is present for application to the scope vertical input.

Note the relationship between the weighted outputs of the counter and the associated resistors. If the scope horizontal sweep is properly adjusted, eight discrete traces will appear on the display. As a point of interest, slightly reducing the value of *R1* will produce a small gap between the upper and lower four traces so that two "nybbles" can be displayed.

Resistor *R4* is connected between the output of the data selector and the D/A converter. The value of this resistor determines the amplitude of the data selector output signal. Scope sync can be taken from the system clock or from other points in the countdown chain. If the clock is very fast, a 7490/7493/or equivalent divider can be used ahead of the main counter.

Eight traces are usually the limit for observation on a 5" scope CRT. However, if your scope has sufficient writing speed and you wish to display 16 traces, substitute a 74150 (1-of-16 data selector) for the 74151. Add an 8000-ohm resistor to the new address line and the top of *R5.* Note that theoretical resistor values are specified in the circuit. Use nearest standard values.

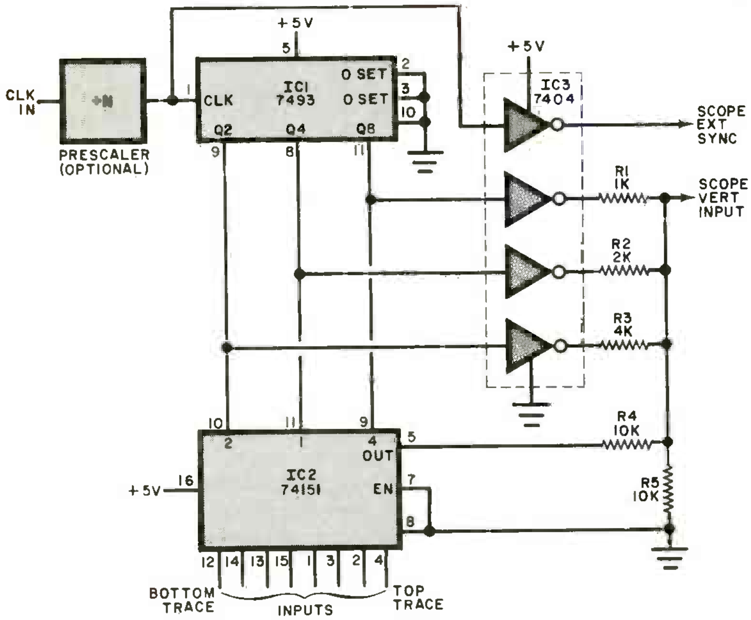
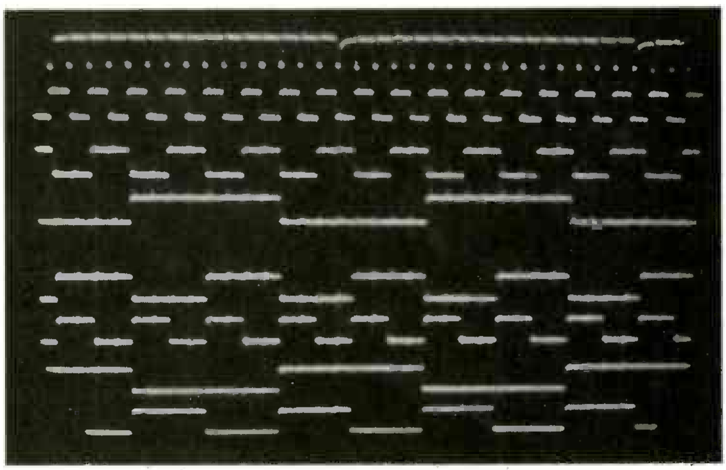


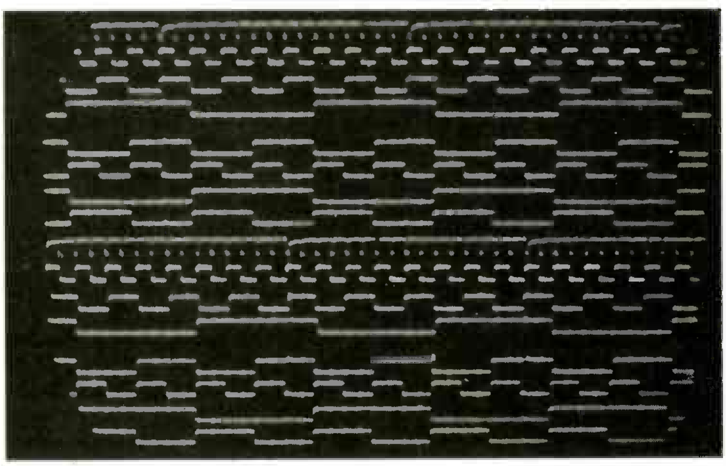
Fig. 1. Rudimentary D/A converter creates an eight-step wavefrom. Scope sweep adjustment produces eight traces.

PARTS LIST

IC1—7493 divide-by-16 counter
IC2—74151 1-of-8 data selector
IC3—7404 hex inverter
R1—1000-ohm, ½-watt resistor
R2—2200-ohm, ½-watt resistor (see text)
R3—4700-ohm, ½-watt resistor (see text)
R4,R5—10,000-ohm, ½-watt resistor
Misc.—Optional prescalers; oscilloscope connectors; color-coded 8-lead ribbon cable; grommets; suitable enclosure; miniature test clips; 14- or 16-pin IC clamp-on; machine hardware; hookup wire; solder; etc.



Display of eight traces from a typical counter.



Sixteen-trace synthethis using a dual trace scope.

Construction. The simple circuit can be assembled on a small perforated (or a home-made pc) board, leaving room for two or three optional ICs. The basic circuit consists of IC1, IC2, IC3 and the five resistors.

Once assembled, the board can be mounted in a small enclosure; and, if desired, a low-power 5-volt supply can be added. Since the basic circuit requires about 72 mA, the analyzer can be powered from the circuit under test.

The scope sync and vertical input connectors can be mounted anywhere on the enclosure, while the 8-lead ribbon cable (one lead for each data selector input) exits via a grommetted hole. The +5-volt, ground, and clock leads exit via their own protected hole.

The 11 leads can be terminated as desired. The prototype used miniature test clips (Radio Shack 270-372, Calectro F2-916, or similar) to make the closely spaced IC pin connections. To examine a single IC, a 14- or 16-pin IC clamp-on may be used. When using such a clamp-on, the +5 volts and ground can be taken from the IC. Some form of identification must be used on each of the eight data leads.

Use. Connect the status analyzer to the +5 volts, ground, and clock of the circuit under test. Connect the analyzer ground and output to the scope ground and vertical input, and the sync to the scope external sync input. With operating power applied, adjust the scope sweep for eight discrete traces.

Any or all of the eight analyzer inputs can be connected to the logic under test. Adjust the scope sweep and sync for a stable display. Once this is done, the value of *R4* can be selected for the desired signal height on the traces. To avoid confusion, make sure that the signals do not overlap. Resistor *R5* can be selected for a convenient signal level input for the scope.

Although this circuit is realized with TTL chips, a resourceful experimenter could build one using CMOS logic, following the same approach. ◊

BY M. T. VALESCU

AN APPLIANCE "OFF" REMINDER

A low-cost project provides an audible alert when an appliance indicator light goes off

IT IS often useful—sometimes vital—for the user of an appliance to know if and when it ceases to operate, whether by design or due to a power failure. Usually, this is not difficult to accomplish, since most appliances are equipped with indicator lights that show when they are working. But if the appliance is not in direct view, keeping track of it can be a great annoyance.

One solution to this problem is to use an electronic "eye" that senses the radiation from the indicator light and sounds an alarm when it is interrupted. For convenience, only the sensor is required to be physically at the monitoring point; the alarm can be located where it is easily heard.

The Lights-Out Alert described here provides the answer. It is battery powered and reliable; can be built from low-cost components; and is usable with almost any sort of power-on light indicator.

Circuit Operation. As shown in Fig. 1, phototransistor *Q1* and Darlington-connected *Q2* form a high-gain optical-to-electrical transducer that drives a charge pump made up of *Q3* and *Q4* and associated components.

When no light strikes *Q1*, its resistance should be high enough so that *Q2* is cut off. Any slight leakage from *Q2* should produce less than 0.7 volt across *R1*—not enough to turn on *Q3*. Assuming that capacitor *C1* has been discharged by the operation of *S1*, *Q4* also lacks the voltage required to turn it on. Thus, all four transistors are off and current from the battery is almost nil.

When light strikes *Q1*, its resistance drops, depending on the illumination level, and *Q2* is turned on. The voltage developed across *R1* turns *Q3* on provided *C1* is discharged. Thus *Q4* is driven deeper into cutoff. Current flows through *Q3* and *R2* to charge *C1*. When the voltage across *C1* rises to within 0.7 volt of that across *R1*, *Q3* is cut off. This condition will last as long as transistor *Q1* is illuminated.

When the illumination ceases, the voltage across *R1* drops. Since *C1* is charged high enough to reverse-bias *Q3*, this transistor cuts off and turns on *Q4*. Discharge current from *C1* now flows through *R2* and *Q4* to drive alarm *A1*.

After some time (about one minute per 10,000 microfarads of *C1*), *C1* becomes discharged and the alarm turns off. The circuit is then ready for the next illumination period, with no current drawn from *B1*. Switch *S1*, in conjunction with *R3*, provides manual silencing of the alarm. This switch should not be operated during the charging cycle of *C1* because this will tend to deplete the battery's charge.

Construction. The circuit consists of two physically independent sections—the light-sensitive portion and the alarm/power package, with the two interconnected by a length of flexible four-conductor cable.

The four transistors and two resistors that form the photosensor can be assembled on a small piece of perforated board or a small printed-circuit board. Make sure that the sensitive face of *Q1* is in the clear so that light can pass through a hole in the case and shine on this surface. Select a low-leakage device for *Q2*. If phototransistor *Q1* is a low-gain device (units vary with manufacturer), increase the value of *R1*. However, to avoid false alarms do not make the circuit too sensitive.

The board can be mounted in a small enclosure having a hole drilled so that external light can fall on the sensitive face of *Q1*. Another small hole can be used for the four-conductor cable. The alarm/power elements are mounted in a separate enclosure with holes near the alarm so that it can be heard.

To test the project, expose the photosensitive surface of *Q1* to an ordinary household light bulb at a distance of about 18 inches. When the light source is removed, the alarm should sound for approximately one minute. Changing the value of *C1* changes the alarm-on time. The alarm can be silenced by operating switch *S1*. ◇

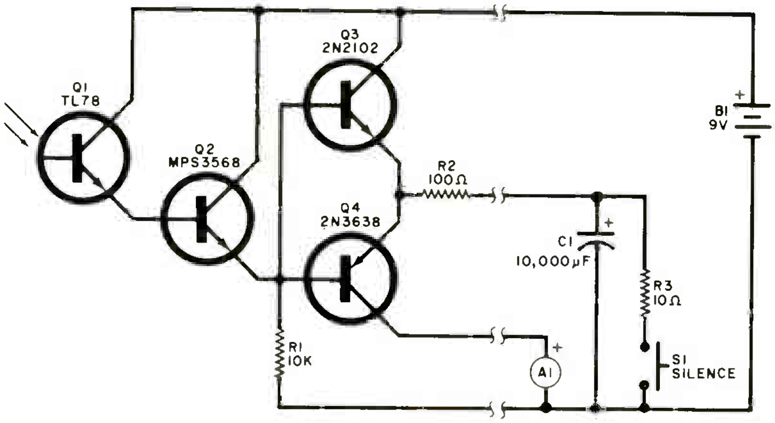


Fig. 1. Phototransistor Q1 senses when the light impinging on it goes off. The signal is then amplified to energize alarm A1.

PARTS LIST

A1—Alarm (Sonalert SC628 or similar)
B1—9-volt battery
C1—10,000-μF, 10-V capacitor (see text)
Q1—TL78 phototransistor (Radio Shack FPR-100)
Q2—MPS3568 transistor (Radio Shack S0015)
Q3—2N2102 transistor (Radio Shack S5026)
Q4—2N3638 transistor (Radio Shack S0029)
R1—10,000-Ω, ¼-W resistor
R2—100-Ω, ¼-W resistor
R3—10-Ω, ¼-W resistor
S1—Normally open pushbutton switch
Misc.—Length of four-conductor cable, suitable enclosures, perf board, printed-circuit board, mounting hardware, etc.

Using the 4060 as a Timer

BY T.A.O. GROSS

MENTION timing circuits, and most people tend to think of the ubiquitous 555 IC. While the 555 is excellent for most timing applications, other devices are worthy of consideration. These are the CMOS CD4060A and SCL4060AB 14-stage ripple-carry binary counters from RCA and Solid State Scientific, respectively.

Among other advantages, the 4060-series devices can be less expensive to implement in a given application because they require less critical and less expensive resistors and capacitors. A second advantage is that 4060-series devices can deliver a number of output frequencies from the same RC components; the 555 delivers only one.

Technical Details. In a 555 timer circuit, external frequency-determining resistor and capacitor values must be selected to produce the desired oscillator frequency directly. As a result, in many cases where relatively long time constants (low frequencies) are desired, the RC product requires the use of bulky, expensive electrolytic capacitors with, often, inaccurate values and high losses. Devices of the 4060-series use oscillator frequencies much higher than what is required at the output. The oscillator frequency goes through a 14-stage binary counter that divides it by as much as 16,384 (2^{14}) before it is used as the final timing frequency.

Using a much higher oscillator frequency than the 555 timer to obtain the same timing frequency the 4060 has a correspondingly smaller RC product. Hence, there is no need to use inaccurate and unstable electrolytic capacitors or humidity-sensitive, very-high-value resistors.

While the CD4060A and SCL-4060AB are interchangeable in most cases, the two are different. In the CD

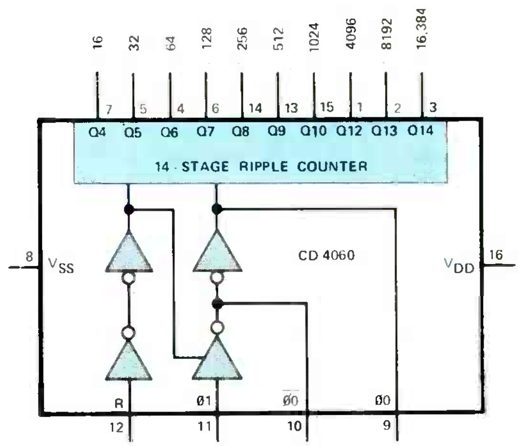


Fig. 1. Internal schematic arrangement of the RCA CD4060 timer integrated circuit.

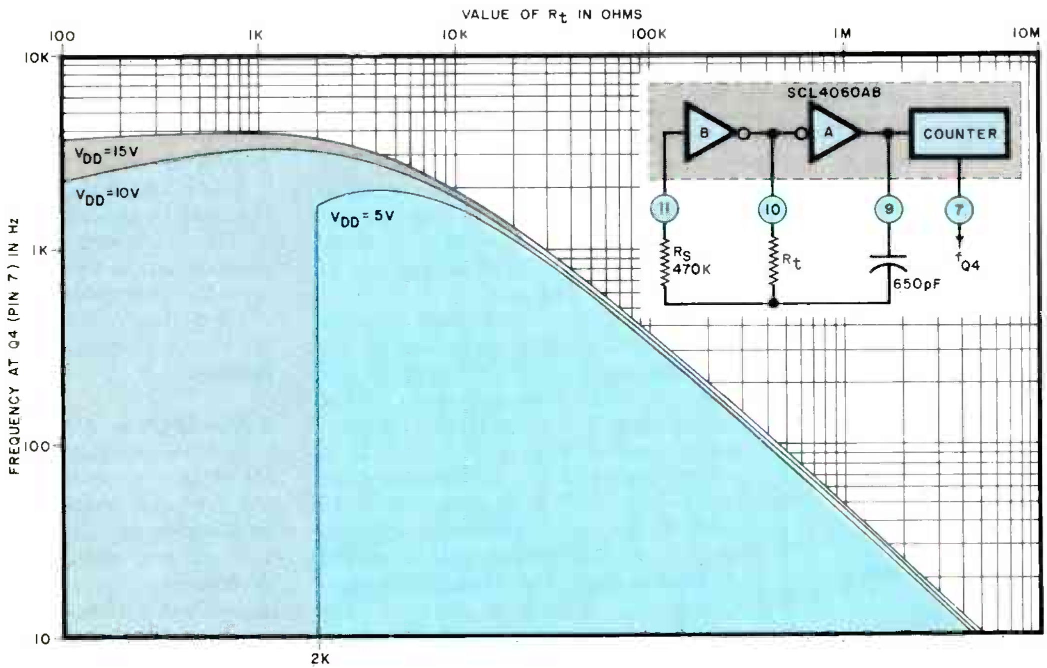


Fig. 2. With low values of timing resistor, R_t, the frequency of the circuit can vary with applied dc operating voltage.

device, the oscillator is keyed by the reset input, whereas in the SCL device, the reset operates on the dividers, leaving the oscillator in continuous operation.

Basic internal logic of the CD4060A is shown in Fig. 1. Two of the four inverters serve as the active elements of the internal oscillator whose output is passed through the 14-stage ripple-carry binary counter. Oscillator frequency is set by an RC network, or an external crystal oscillator can be connected to pin 9 to eliminate the need for the internal oscillator. When the internal oscillator is used, the input at pin 12 is provided to reset the counter to zero and disable the oscillator.

It is not necessary to use all 14 stages of division. As shown in Fig. 1, you can select division factors of 16, 32, 64, 128, 256, 512, 1,024, 4,096, 8,192, or 16,384, simply by picking off the output from the appropriate pin of the IC.

Timing resistance values of 4060-series devices should not be less than 10,000 ohms to avoid changes in frequency with changes in applied dc operating voltages. As can be seen in Fig. 2, the frequency/resistance function reverses at about 4500 ohms with a 5-volt supply and at 1300 ohms using 10 volts.

The frequency calculation formula for the 4060 given in manufacturer application notes is $F = 1/(2.2R_tC_t)$, where R_t and C_t are the values of the timing resistor and capacitor. This formula assumes V_{DD} is 10 volts, C_t is greater than 100 pF; R_t is greater than 1000 ohms, and R_s is larger than 10 times R_t. (R_s is the external stabilizing resistor, as shown in the inset schematic diagram in Fig. 2.) In this author's experience, this formula is accurate only when R_t is greater than 50,000 ohms. With values less than 50,000 ohms, observed frequency was lower than predicted by the formula.

Data given in Fig. 2 was obtained at the pin-7 (÷16) output from an SCL4060AB. With time delays of more than a few hours, it was determined that use of R_s is not necessary.

Practical Timer. Shown schematically in Fig. 3 is the circuit for a practical 1-minute timer built around a 4060-series device. A 330,000-ohm resistor and 0.01-μF capacitor are doing a job that would require a 60-megohm/microfarad *RC* product in a 555 circuit. and

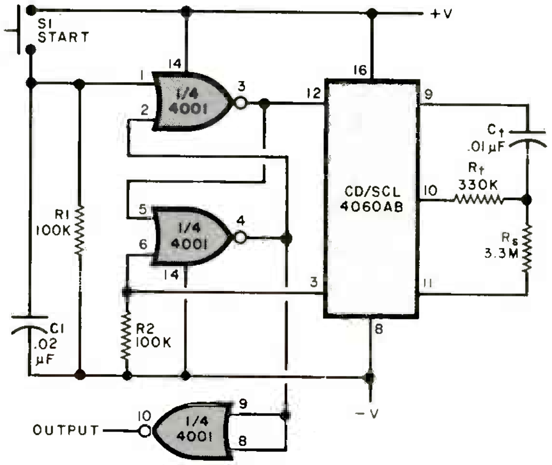


Fig. 3. With the values shown, this circuit has a one-minute delay period. The output strobe goes high after timeout.

Momentary closure of START switch *S1* causes the set-reset flip-flop made up from two gates in a 4001 quad 2-input NAND IC to produce a high output at pin 12 of the 4060. After the timing interval (oscillator frequency) determined by R_t and C_t, pin 3 of the 4060 goes low and toggles the flip-flop to stop the counter. At the same time, the output of the bottom 4001 gate, held low during the timing interval, goes high. (Since the 4001 contains four on-chip gates, the fourth gate can be paralled with the output stage to provide more driving current for an external circuit.)

Much longer timing intervals can be obtained by cascading the pin-3 output of the 4060 with a 4020, a 14-stage counter that is similar to the 4060 but lacks the internal oscillator.

Capacitor *C1* and resistor *R1* improve the circuit's immunity to noise and are optional.

Summing Up. Once you start working with 4060-series devices, you will probably think of them as often as you do the 555 for your timing applications. Their easy implementation into circuit designs and reduced demands on frequency-determining resistors and capacitors make them particularly attractive where costs must be kept down and hardware space is at a premium. And they offer a number of different output frequencies from a given RC network that gives them an important advantage over single-frequency-only timing devices. ◇

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