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For details on how to build the "Audio-Minder," see page 7

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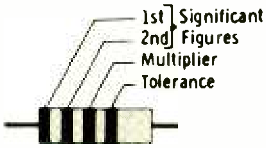
COLOR BAND SYSTEM



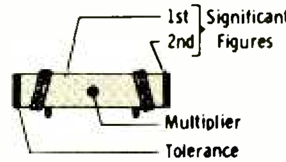
Resistors With Black Body Color Are Composition, Non-Insulated.
Resistors With Colored Bodies Are Composition, Insulated.
Wire-Wound Resistors Have The 1st Digit Color Band Double Width.

RESISTOR CODES (RESISTANCE GIVEN IN OHMS)

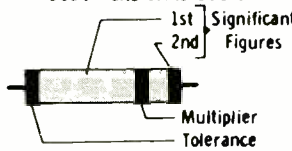
COLOR	DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	1	±20%
BROWN	1	10	±1%
RED	2	100	±2%
ORANGE	3	1000	±3% •
YELLOW	4	10000	GMV•
GREEN	5	100000	±5% (EIA Alternate)
BLUE	6	1000000	±6%•
VIOLET	7	10000000	±12 1/2%•
GRAY	8	.01 (EIA Alternate)	±30% •
WHITE	9	.1 (EIA Alternate)	±10% (EIA Alternate)
GOLD		.1 (JAN and EIA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

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

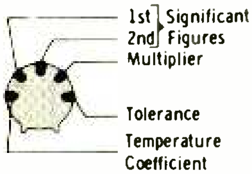
BODY-END-DOT SYSTEM



BODY - END BAND SYSTEM



DISC CERAMICS (5-DOT SYSTEM)



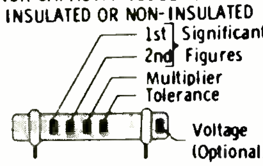
DISC CERAMICS (3-DOT SYSTEM)

CERAMIC CAPACITOR CODES (CAPACITY GIVEN IN pF)

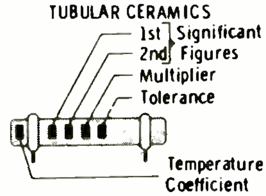
COLOR	DIGIT	MULTI-PLIER	TOLERANCE 10 pF or LESS	TOLERANCE OVER 10MMF	TEMPERATURE COEFFICIENT PPM/°C	EXTENDED RANGE TEMP. COEFF. SIGNIFICANT FIGURE	EXTENDED RANGE TEMP. COEFF. MULTIPLIER
BLACK	0	1	±2.0 pF	±20%	0(NPO)	0.0	-1
BROWN	1	10	±0.1 pF	±1%	-33(N033)		-10
RED	2	100		±2%	-75(N075)	1.0	-100
ORANGE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

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

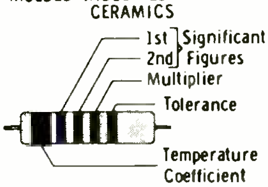
HIGH CAPACITY TUBULAR CERAMIC INSULATED OR NON-INSULATED



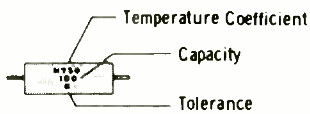
TEMPERATURE COMPENSATING TUBULAR CERAMICS



MOLDED-INSULATED AXIAL LEAD CERAMICS

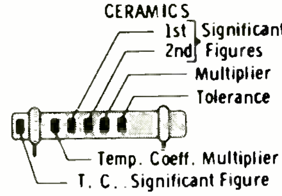


TYPOGRAPHICALLY MARKED CERAMICS

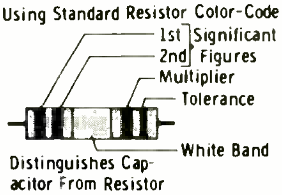


JAN LETTER	TOLERANCE 10 pF or LESS	TOLERANCE OVER 10 pF
C	±0.2 pF	
D	±0.5 pF	
F	±1.0 pF	±1%
G	±2.0 pF	±2%
J		±5%
K		±10%
M		±20%

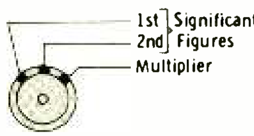
ENTENDED RANGE T.C. TUBULAR CERAMICS



MOLDED CERAMICS
Using Standard Resistor Color-Code

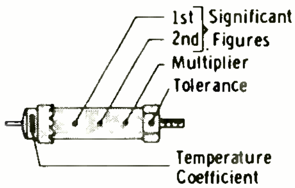


BUTTON CERAMICS

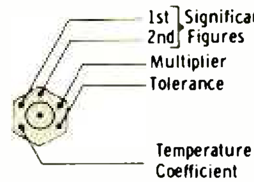


Viewed From Soldered Surface

STAND-OFF CERAMICS



FEED-THRU CERAMICS



MOLDED MICA CAPACITOR CODES
(Capacity Given In pF)

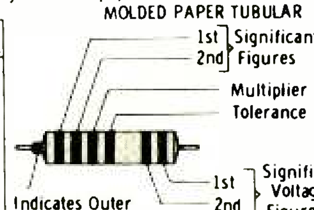
COLOR	DIGIT	MULTI-PLIER	• TOLERANCE	CLASS OR CHARACTERISTIC
BLACK	0	1	20%	A
BROWN	1	10	1%	B
RED	2	100	2%	C
ORANGE	3	1000	3%	D
YELLOW	4	10000		E
GREEN	5		5% (EIA)	F(JAN)
BLUE	6			G(JAN)
VIOLET	7			
GRAY	8			I(EIA)
WHITE	9			J(EIA)
GOLD		1	5%(JAN)	
SILVER		.01	10%	

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

MOLDED PAPER CAPACITOR CODES
(Capacity Given In pF)

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

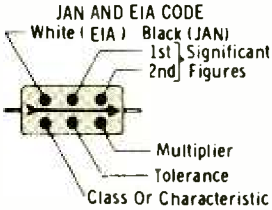
MOLDED PAPER TUBULAR



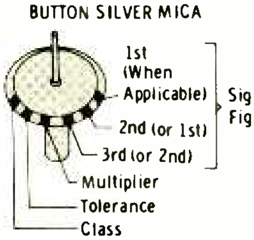
Indicates Outer Foil. May Be On Either End. May Also Be Indicated By Other Methods Such As Typographical Marking Or Black Stripe.

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

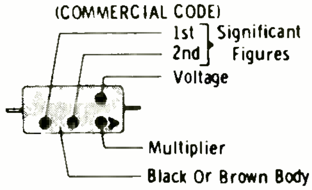
CURRENT STANDARD JAN AND EIA CODE



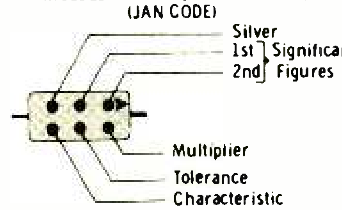
BUTTON SILVER MICA



MOLDED FLAT PAPER CAPACITORS (COMMERCIAL CODE)



MOLDED FLAT PAPER CAPACITORS (JAN CODE)



BUILD THE HI-FI/TV AUDIO-MINDER

- SHUTS A C POWER WHEN AUDIO ENDS
- ADJUSTABLE TIME DELAY
- CONVENTIONAL TIMER USE
- CONNECTS TO SPEAKER

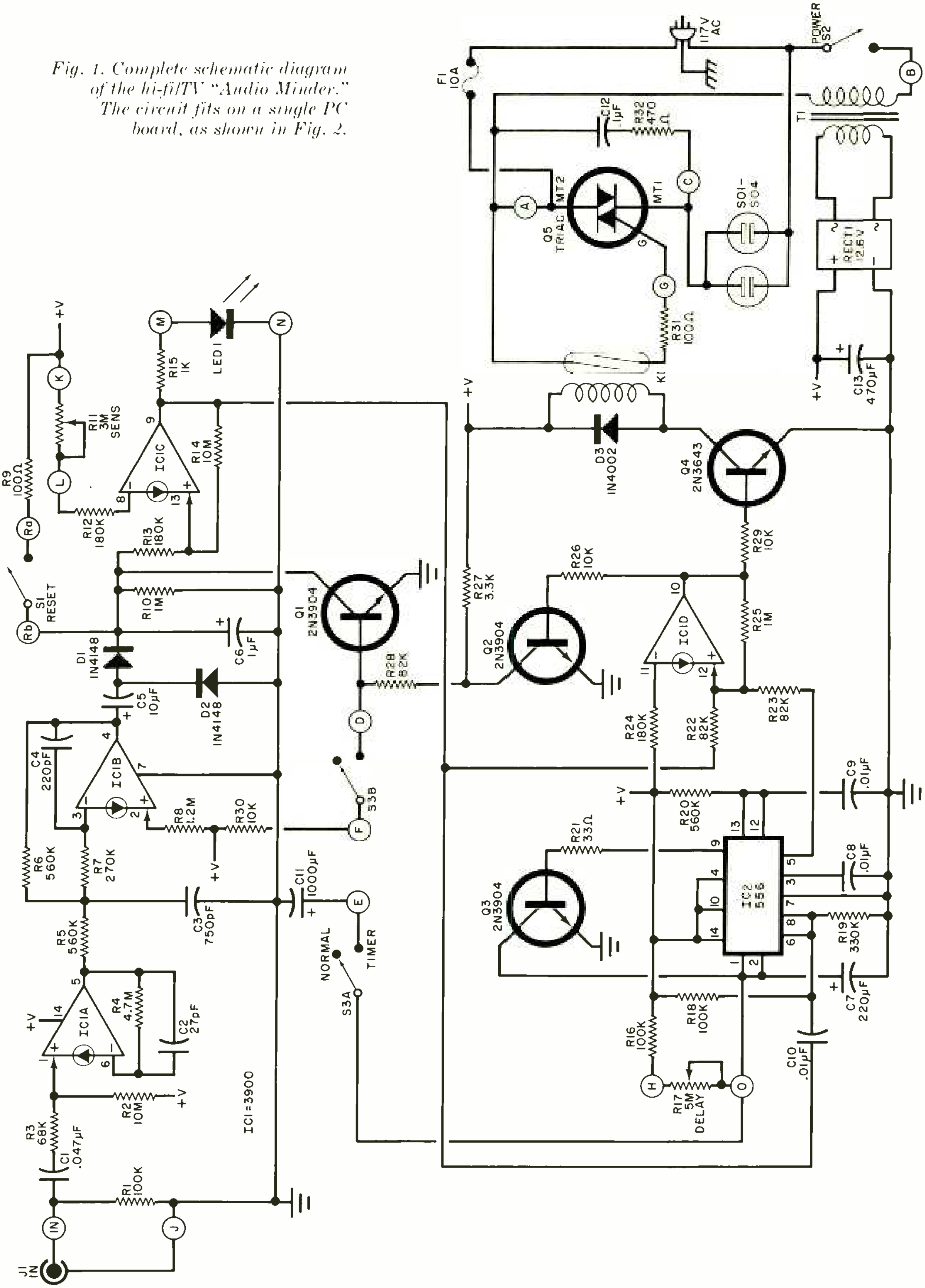
BY CURT KOBYLARZ

IF YOU EVER left an expensive stereo system or a TV receiver operating all night because you forgot to shut it off, take heart. Here is a low-cost, automatic shutoff controller for home entertainment equipment that does *not* require any internal circuit changes or connections. Shutoff is activated by the absence of an audio signal, not by a pre-set time interval, as with mechanical devices. Accordingly, the controller can be connected to speaker terminals or to a tape output monitor jack.

An adjustable delay system avoids premature shutoff, providing the user with enough time to change a record on a manual record player or a reel of tape on a recorder before the system is turned off. Shutoff time range is 50 seconds to 20 minutes after the signal level has dropped below a predetermined setting. At about 60,000 ohms impedance, the controller will not load most circuits. Noise filtering is provided to remove AM and FM interstation hiss to ensure against false shutoff triggering when using either of these signal sources.

Furthermore, the controller can be used as a standard non-audio timer for

Fig. 1. Complete schematic diagram of the hi-fi/TV "Audio Minder." The circuit fits on a single PC board, as shown in Fig. 2.



PARTS LIST

All capacitors disc or Mylar unless otherwise noted.
C1—0.047 µF capacitor
C2—27-pF capacitor
C3—750-pF capacitor
C4—220-pF capacitor
C5—10-µF, 15-volt electrolytic capacitor
C6—1-µF, 15-volt electrolytic capacitor
C7—220-µF, 15-volt electrolytic capacitor
C8,C9,C10—0.01-µF capacitor
C11—1000-µF, 15-volt electrolytic capacitor
C12—0.1-µF, 200-volt capacitor
C13—470-µF, 25-volt electrolytic capacitor
D1,D2—1N4148 diode
D3—1N4002 diode
F1—10-ampere fused and holder
IC1—LM3900 quad op-amp
IC2—556 dual timer
J1—Phono connector
K1—Reed relay, 500-ohm, 12-volt coil, normally open contacts
LED1—Any light-emitting diode
Q1,Q2,Q3—2N3904
Q4—2N3643
Q5—Triac, 20-A, 200 PIV
RECT1—Full-wave rectifier bridge
All resistors ¼-watt, 10% unless otherwise noted.
R1,R16,R18—100,000-ohm resistor
R2,R14—10-megohm resistor
R3—68,000-ohm resistor
R4—4.7-megohm resistor
R5,R6,R20—560,000-ohm resistor
R7—270,000-ohm resistor
R8—1.2-megohm resistor
R9—100-ohm resistor
R10,R25—1-megohm resistor
R11—3-megohm linear potentiometer ("Sensitivity")
R12,R13,R24—180,000-ohm resistor
R15—1000 ohm resistor
R17—5-megohm linear potentiometer ("Delay")
R19—330,000-ohm resistor
R21—33-ohm resistor
R22,R23R28—82,000-ohm resistor
R26,R29,R30—10,000-ohm resistor
R27—3300-ohm resistor
R31—100-ohm, ½-watt resistor
R32—470-ohm, ½-watt resistor
S1—Pushbutton switch, momentary contact, normally open ("Reset")
S2—Spst switch ("Power")
S3—Dpdt switch ("Normal/Timer")
SO1 to SO4—Ac power receptacle (sockets)
T1—Transformer: 12.6-volts, 300-mA, PC mount
Misc.: Suitable cabinet, heat-sink material, IC sockets (optional), strain relief, press-on type, mounting hardware, etc.
Following are available from WEI, 4921 N. Sheridan Rd., Peoria, Illinois 61614: complete kit (SO-1) includes all components, PC board, metal case with walnut cover, power cord, ac receptacles, etc. at $39.95; PC board (SO-2) at $6.00; metal case/cover (SO-3) at $8.50. All orders postpaid. Illinois residents please add 5% sales tax. Allow four weeks for delivery.

any electrical appliance, TV receiver, etc. up to its rated 1200 watts. In this mode, the controller will turn power off at a pre-set time ranging from 10 minutes to two hours. The complete circuit is shown in Fig. 1.

How It Works. The selected audio input is applied via phono connector, *J1*, to the first amplifier and filter *IC1A* where it is amplified and filtered with roll-off occurring about 1.25 kHz at −6 dB per octave. The second stage, *IC1B*, is a two-pole filter whose cutoff frequency is approximately 1 kHz with unity gain. The two stages combined roll off is about 18 dB per octave to remove noise and filter out any high-frequency hiss if an FM or TV station goes off the air (if this is to be the audio source).

The filtered signal is rectified to a dc level by *D1*, *D2*, and *C6*, with *R10* "bleeding" the charge from capacitor *C6* when a signal is not present. *IC1C* is used as a comparator having fast "snap action" (positive feedback) so that when the rectified signal applied to the non-inverting (+) input exceeds the level set by the SENSITIVITY control, *R11*, the output switches off very rapidly. Note that the 3900 op amps used here are current devices rather than voltage devices represented by conventional op amps, therefore all voltages must be converted to currents. This will explain why high-value resistors are used in many places in this circuit.

When *IC1C* output is high (audio signal present), *LED1* is turned on and current-limited by *R15*. The *IC1C* output signal also turns on the OR gate formed by *IC1D* which, in turn, causes *Q4* to saturate and draw current through the coil of the reed relay, *K1*. With the reed relay contacts closed, gate power is applied to the triac, *Q5*, and power is present across the multiple power sockets, *SO1* through *SO4*. This turns on any equipment connected to these sockets.

When the input audio signal either disappears or falls below the pre-set SENSITIVITY threshold, comparator *IC1C* switches off very rapidly. This action also starts one of the timers in *IC2* whose output (pin 5) keeps the OR gate operating until the timer times out. Power remains on the four sockets. If another audio signal should appear within the time-out interval, the second timer within *IC2* will generate a 5-millisecond pulse which will turn on *Q3* and discharge the main timing capacitor *C7*. This resets *IC2* back to zero and ensures that the last audio signal is always the one that begins the time-out delay. Transistors *Q1* and *Q2* act as a "quench" circuit by grounding the comparator signal an instant before shutdown. This is necessary because some audio power amplifiers generate a "thump" when turned off and this may retrigger the timer and never allow system shutdown.

Reed relay *K1* is necessary for complete isolation between the circuit and the triac. Snubbers circuit *C12* and *R32* protect *Q5* from line transients and surges generated when inductive loads (such as the power transformers in high-wattage power amplifiers) are suddenly switched off. The triac should be heat-sinked.

The timer function is determined by the setting of NORMAL/TIMER switch *S3*, which disables the input circuit by turning on the "quench" transistor, *Q1*, and connecting a larger capacitor (*C11*) in parallel with the main timing capacitor *C7*. Potentiometer *R17* sets the timer delay in either case, although the range for NORMAL and TIMER positions of *S3* is different.

Construction. The circuit is easily assembled on a single PC board, as shown actual size in Fig. 2, which also shows the component installation. Connections to off-board components are made via the lettered pads on the foil pattern. Note that some resistors are mounted "end up."

The triac is mounted on a metal bracket, which acts as the heat sink, and mounted as selected within the cabinet. If a metal case is used, make sure that the triac is electrically isolated, but thermally bonded to the heat sink. Use at least 18-gauge wire between the triac, power outlet sockets, and the power line. A three-wire line cord is recommended with the ground (green) lead connected to the metal chassis. Almost any type of cabinet may be used.

The switches, *J1*, potentiometers, and *LED1* can be mounted on the front panel, while the four controlled sockets can be mounted on the rear apron. Although four controlled power outlets are used, more can be added provided that the triac can handle them.

Operation. The selected audio input signal can be taken from the tape monitor output of either channel (use a "Y" connector if necessary), or di-

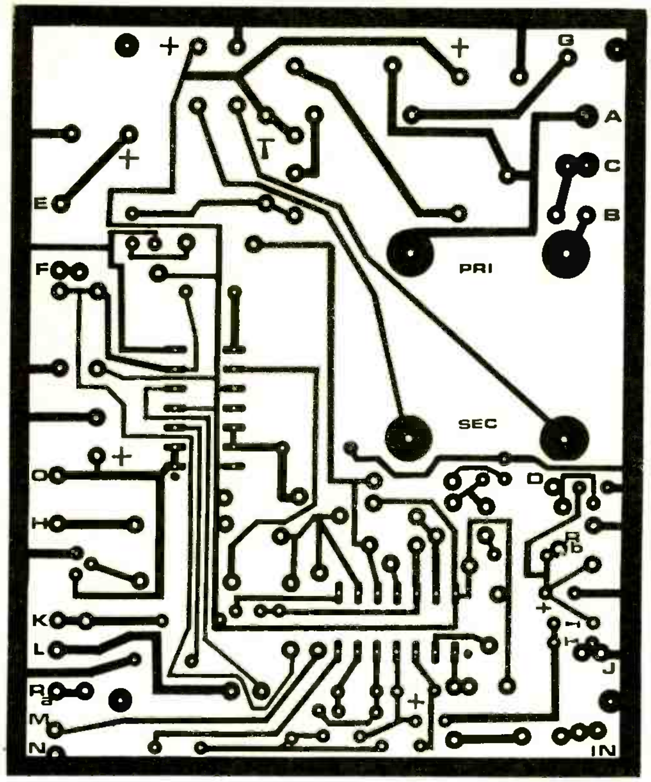
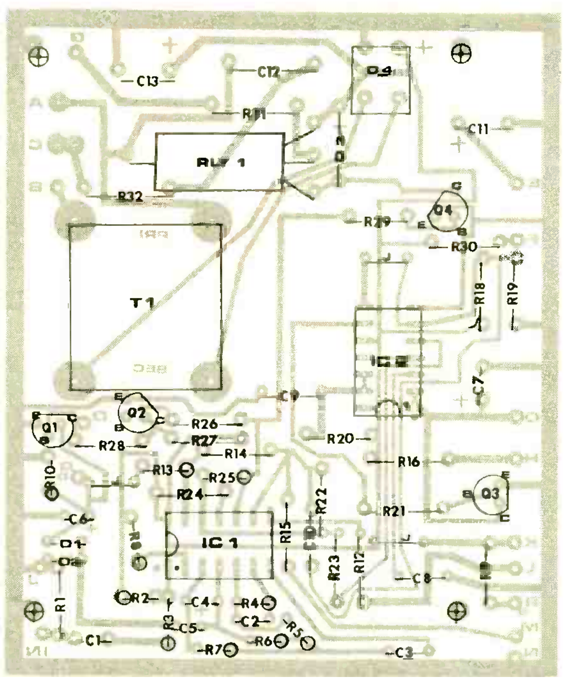


Fig. 2. The printed-circuit board's foil pattern is shown at left, while the flop side below illustrates component installation. Note that resistors installed on pads with a drawn circle are to be mounted end up.



rectly off the speaker terminals of either channel. The monitor output has the advantage of a constant level irrespective of volume control settings so the SENSITIVITY control need be set only once.

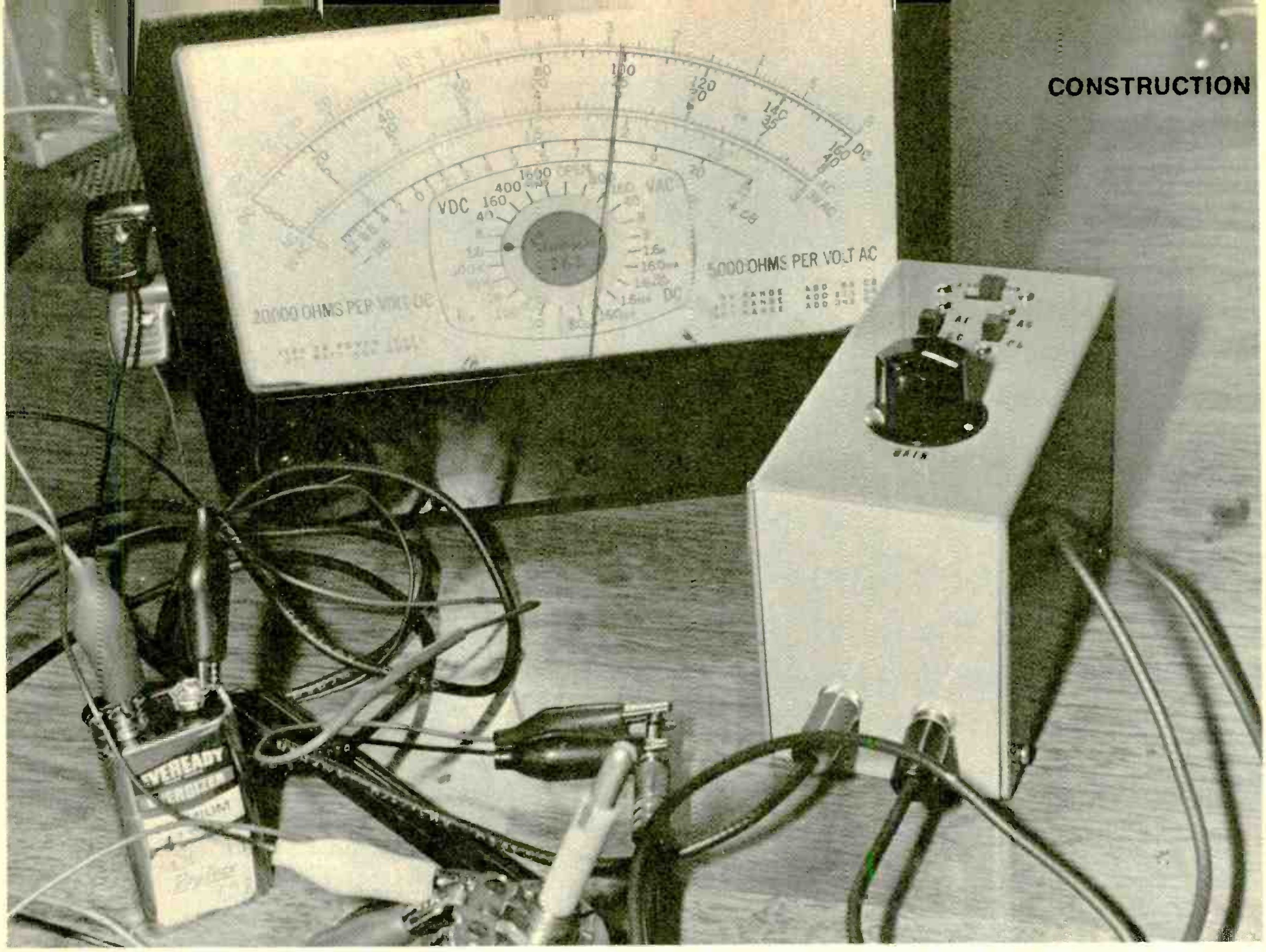
Connect the selected devices (tuner, amplifier, etc.) to the controlled sockets *SO1* through *SO4* and turn on their power switches. Connect the controller to the power line, place *S3* in the NORMAL position, and turn POWER switch *S2* on. Place both potentiometers in their mid positions, then depress RESET pushbutton *S1*. *LED1* should glow and the ac outlets should be energized. With no signal connected to *J1*, *LED1* will go out after *C6* discharges, but the delay timer will keep the outlets energized, until it times-out—determined by DELAY potentiometer *R17*.

Connect the selected signal source to *J1*, reset the controller, and adjust SENSITIVITY control *R11* until the LED remains on continuously. The DELAY potentiometer is adjusted as required. When the input signal is removed, the system should shut down after the delay period.

To shut down the system when an FM or TV station is used as the signal source and the station goes off the air, use the following setup procedure. Tune in the station and adjust the SENSITIVITY control until the LED just goes out, then bring it back until the LED remains on most of the time. Tune the receiver off-station for the hiss and observe that the LED goes out. The system is now adjusted so that it will automatically shut down after a station goes off the air for the night.

Use of the tape monitor output for the signal source is necessary when headphones are being used and the amplifier is disabled from the speakers. Since the input impedance of the controller is approximately 60,000 ohms it will not load the signal to the tape deck.

For use as a timer, place *S3* in the TIMER position, set the DELAY time as desired (10 minutes to 2 hours), and operate the RESET pushbutton *S1*. In this case, the input is not being monitored; the ac outlets will be de-energized only after the selected time interval has been reached. This mode is used to turn off any appliances or TV receiver automatically.



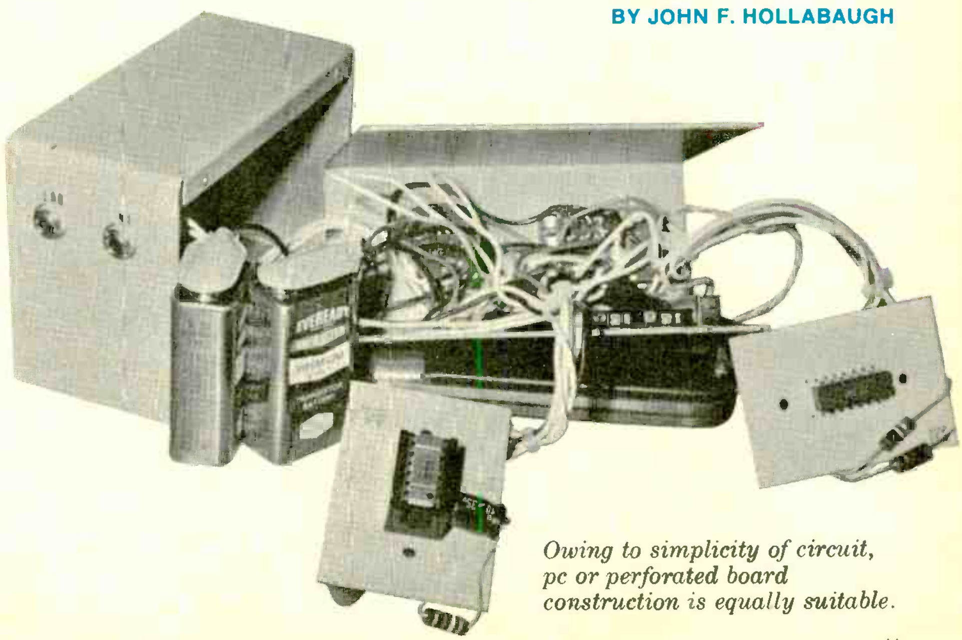
Measure Low Millivolts with a Multimeter

Range expander increases sensitivity by X10 or X100

BY JOHN F. HOLLABAUGH

HAVE you ever needed a simple device that would let you expand the ranges of your multimeter so that you could measure low-millivolt ac and dc voltages? Perhaps you need a small amplifier for checking out the high-level inputs of an audio amplifier. Well, the decade meter range expander described here will do both and more.

The decade range expander can be used to increase the usefulness of a multimeter by adding ranges divided by 10 and 100. It can also be used on decibel scales, subtracting 20 or 40 dB from the existing ranges in your VOM. Use the expander as a sensitive signal tracer to obtain quantitative measurements of the signal level at points of interest, or to read voltage amplifier stage gain directly in decibels on your



Owing to simplicity of circuit, pc or perforated board construction is equally suitable.

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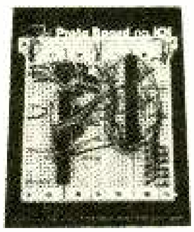
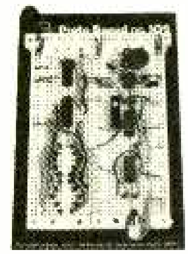
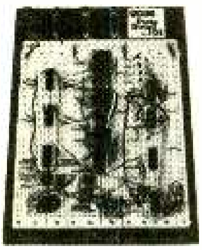


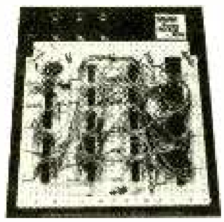
PB-101—940 solderless tie points: ten 14-pin DIP capacity. Two QT-35S breadboarding sockets plus four QT-35B bus strips. Excellent for audio and smaller digital projects. Measures 4.5" wide x 5.8" long x 1.4" high (114 x 147 x 35mm); weighs 9 oz. (.26 Kg). **Price: $29.95**



PB-102—1240 solderless tie points: twelve 14-pin DIP capacity. Two QT-47S breadboarding sockets, three QT-47B and one QT-35B bus strips. You'll want this one for intermediate digital needs, more complex audio projects among other things. Measures 4.5" wide x 7" long x 1.4" high (114 x 178 x 35mm); weighs just 10 oz. (.31 Kg). **Price: $39.95**



PB-103—2250 solderless tie points: twenty-four 14-pin DIP capacity. Three QT-59S breadboarding sockets, four QT-59B and one QT-47B bus strips plus four 5-way binding posts. For all but the very largest circuits. Lets you build calculators, interfaces, complex switching circuits, etc. Measures 6" wide x 9" long x 1.4" high (152 x 229 x 35mm); weighs 1.25 lb. (.57 Kg). **Price: $59.95**



PB-104—3060 solderless tie points: thirty-two 14-pin DIP capacity. Four QT-59S breadboarding sockets, seven QT-59B bus strips plus four 5-way binding posts. It's the largest breadboard we made for the largest projects you care to tackle—a CPU, encoder, complex display . . . just about anything. Measures 8" wide x 9.8" long x 1.4" high (203 x 248 x 35mm); weighs 1.75 lb. (.79 Kg). **Price: $79.95**

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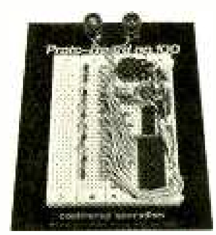
PB-6 Kit—630 solderless tie points: six 14-pin DIP capacity. Most economical way to take advantage of Proto-Board speed and convenience. One pre-assembled QT-47S breadboarding socket, two assembled QT-47B bus strips, four 5-way binding posts, metal ground/plane/base-plate, all required hardware. 10 minute assembly with pliers and screwdriver. Measures 6" long x 4" wide x 1.4" high (152 x 102 x 34mm); weighs 7 oz. (.20 Kg). **Price: $15.95**



PB-100 Kit—760 solderless tie points: ten 14-pin DIP capacity. 21% larger capacity than PB-6 Kit. Comes with two pre-assembled QT-35S breadboarding sockets, one assembled QT-35B bus strip, two 5-way binding posts, pre-drilled and screened base-plate, non-marring feet and all required hardware. Fast 10 minute assembly. Measures 4.5" wide x 6" long x 1.4" high (114 x 152 x 35mm). Weighs 7.5 oz. (.21 Kg). **Price: $19.95**

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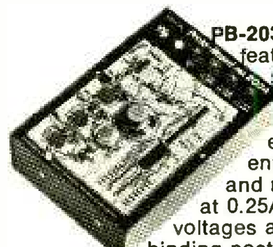
PB-203—2250 solderless tie points: twenty-four 14-pin DIP capacity. *The Ultimate!!* All Proto-Board features *plus* short-proof, fused 5VDC, 1A regulated power supply with only 10mV ripple and noise at 0.5A; on-off toggle switch and pilot light. Three QT-59S breadboarding sockets plus four QT-59B and one QT-47B bus strips. Power supplied via two of the four 5-way binding posts. It all adds up to lots of capacity plus the proper DC voltage for most digital and many analog IC's. Measures 9.75" long x 6.6" wide x 3.25" high (248 x 168 x 83mm). Weighs 5 lb. (2.27 Kg). For 117 VAC, 50/60 Hz (220 VAC, 50/60 Hz; also available at slightly higher cost). **Price: $75.00**



PB-203A—*The Ultimate . . . plus!!* All the features of the PB-203 including regulated 5VDC supply *plus* additional power supply flexibility (separate regulated +15VDC and −15VDC, 0.5A supplies, each with internally and independently adjustable output voltage; ripple and noise of + and −15V supplies, 10mV at 0.25A). Connections for 3 power supply voltages and ground available at four 5-way binding posts. Same size as PB-203; weighs 5.5 lb. (2.5 Kg). For 117 VAC, 50/60 Hz (220 VAC, 50/60 Hz; also available at slightly higher cost). **Price: $120.00**

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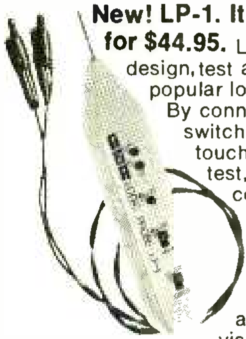

New! LP-1. It digs up a lot of information for $44.95. Logic Probe 1 is a compact, versatile design, test and trouble-shooting tool for all popular logic families and digital applications. By connecting the clip leads, setting a switch to the proper logic family and touching the probe to the node under test, you get an instant picture of circuit conditions.

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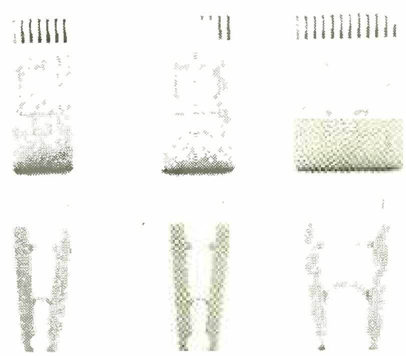

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*U.S. Pat. No. 3,914,007

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PC-14-	18	7.75	14.75
PC-14-	24	8.00	15.00
PC-14-	30	8.25	15.25
PC-14-	36	8.50	15.50
PC-16-	12	8.25	15.75
PC-16-	18	8.50	16.00
PC-16-	24	8.75	16.25
PC-16-	30	9.00	16.50
PC-16-	36	9.25	16.75
PC-24-	12	12.00	25.00
PC-24-	18	12.25	25.25
PC-24-	24	12.50	25.50
PC-24-	30	12.75	25.75
PC-24-	36	13.00	26.00

NOTE: S=single clip (on one end of cable); D=dual clips (on both ends of cable). When ordering Proto-Clip units with cable, include Part No., cable length and Single (S) or Dual (D)—for example: PC-16-24-D is 24" cable with a PC-16 at both ends.

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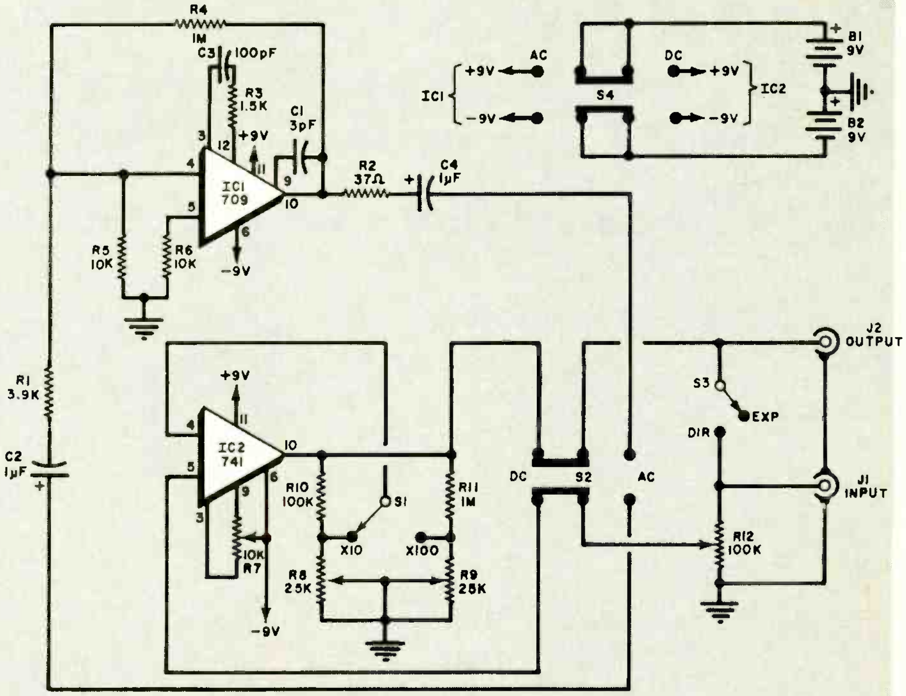
PARTS LIST

B1, B2—9-volt battery
C1—3-pF capacitor
C2, C4—1-μF, 15-volt electrolytic capacitor
C3—100-pF capacitor
IC1—709 operational amplifier
IC2—741 operational amplifier
J1, J2—Phono jack
R1—3900-ohm, ¼-watt resistor
R2—37-ohm, ½-watt resistor
R3—1500-ohm, ¼-watt resistor
R4, R11—1-megohm, ¼-watt resistor
R5, R6—10,000-ohm, ¼-watt resistor
R7—10,000-ohm trimmer potentiometer
R8, R9—25,000-ohm trimmer potentiometer
R10—100,000-ohm
R12—100,000-ohm linear potentiometer
S1—Spdt toggle or slide switch
S2—Dpdt slide or toggle switch
S3—Spst toggle or slide switch
S4—4-position, double-throw slide switch
Misc.—Chassis box, 9-volt transistor battery clips, shielded cable and audio phono plugs (for test cables), IC sockets or Molex Soldercons®, pc board or perforated phenolic board and solder clips, hookup wire, solder, hardware, control knob, etc.



Two operational amplifiers (IC1 and IC2) form heart of expander.

meter. You can even use the range expander to measure the output voltage of a phono cartridge. Try that with an ordinary multimeter.

About the Circuit. The range expander makes use of two operational amplifier IC's (*IC1* and *IC2* in the schematic), exploiting the particular advantages of the types 709 and 741 op amps. A monolithic amplifier using bipolar transistors appears to the signal being processed as a series of resistances and shunting capacitances. An RC system like this forms a phase-shift network that at some frequency will cause the amplifier to oscillate.

Compensation is required to insure low gain at the frequency at which oscillation occurs. The 741 op amp is unconditionally compensated. (Gain is reduced to unity at the point where oscillation is possible.) The 709 op amp is not internally compensated, requiring external components to obtain the necessary compensation. However, it can be compensated for frequencies up to 1 MHz, while the 741 is restricted to a top-end frequency of about 1 kHz by its internal compensation.

The 741 op amp has provisions for input offset nulling, which makes it operate well as a dc amplifier. In the range expander, the 741 (*IC2*) is used as a dc amplifier with output nulling and a feedback network that minimizes drift. The 741 has input overvoltage protection and output short-circuit protection, while the 709 has neither. To provide input overvoltage and output short-circuit protection for the 709, *R1* and *R2* are used.

The 709 (*IC1*) in the range expander is compensated for a 40-dB gain up to about 200 kHz by *C1*, *C3*, and *R3*. It has a feedback network consisting of *R4* and *R5*. Both ac and dc amplifiers (*IC1* and *IC2*) have a common vernier control (*R12*) that can be used where exact values of gain are not required.

The incoming signal (or voltage) is applied via *J1*, while the mode of operation (ac or dc) is selected with *S2*. Switch *S1* permits selection of X10 or X100 in the dc mode, while switch *S3* applies power to either the *IC1* or the *IC2* circuit. The final switch, *S3*, permits the range expander to be bypassed when in the DIR position. In this position, it routes the incoming signal at *J1* directly to output jack *J2*. (Note: When *S3* is in the DIR position, *S4* can be switched to off to conserve battery life.)

Construction. Assembling the range expander is relatively easy, owing to the simplicity of the circuit. The entire circuit can be easily accommodated inside a 4 in. by 2¾ in. by 2 in. metal utility box, with the four switches and vernier control *R12* mounted on the top of the box for convenience.

You can use a printed circuit board of your own design or perforated phenolic board and solder clips for mounting the *IC1* and *IC2* amplifier circuits inside the box. Jacks *J1* and *J2* can be mounted at one end of the box.

When the circuit has been fully assembled and all parts are mounted in place, use dry-transfer letters to label the control, switches, and jacks.

Calibration. With the range expander switched to DC (both *S2* and *S4* must be set to this position) and *R12* set for maximum sensitivity, connect a multimeter set to a low-voltage range across *J2*. Adjust *R7* for a zero indication on the multimeter's scale.

Connect a variable-output power supply or a potentiometer in parallel with a 1.5-volt battery to *J1* and adjust the supply or pot for a 0.1- to 0.5-volt indication on the multimeter's scale. Adjust *R8* for an indication of 10 times the reading of the input voltage level. (Use the multimeter to monitor both the input and output voltage levels.)

Now, decrease the output voltage of the power supply (or battery/pot setup) again for a meter reading of 0.1 to 0.5 volt and switch *S1* to the X100 position. Adjust *R9* for a reading of 10 times the previous meter reading. With the input disconnected, recheck the null produced by adjustment of *R7*. If necessary, readjust the null. ◈

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*Summary of survey results on request.

Making Noises with the 555 IC Timer

One popular chip can be the heart of a variety of circuits.

BY MICHAEL S. ROBBINS

THE 555 IC timer can be used to generate a wide variety of tones and noises. Some have been described before. But, here are other applications for this versatile, easily obtainable IC, whose output is a harmonic-rich square wave. As shown in the sketches, very few components external to the IC are required.

Basic Tone Generator. The circuit for a basic variable-frequency tone generator using a small permanent-magnet speaker is shown at (A). The volume can be controlled by using the 20-ohm potentiometer in the speaker circuit. With the values shown, the output frequency is continuously variable over an approximate range of 76 Hz to 22 kHz.

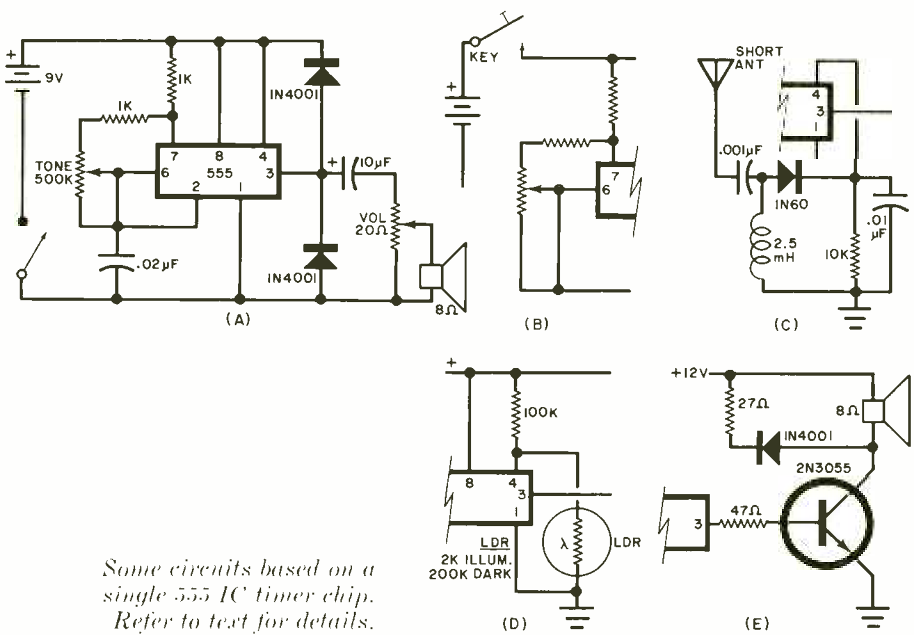
Code Practice Oscillator. The circuit shown at (B) is a CPO with adjustable tone and volume controls. The rest of the circuit is the same as that in (A). The speaker can be replaced with headphones if desired.

CW Monitor. The CW amateur radio operator often finds that having an audio signal to go with his code transmission is very helpful. A circuit to do this is shown at (C). The r-f signal on the short antenna is rectified and applied to pin 4 of the IC. When the positive pulse appears at pin 4, the tone generator turns on. The circuit should be assembled in a small shielded enclosure with only the short antenna protruding.

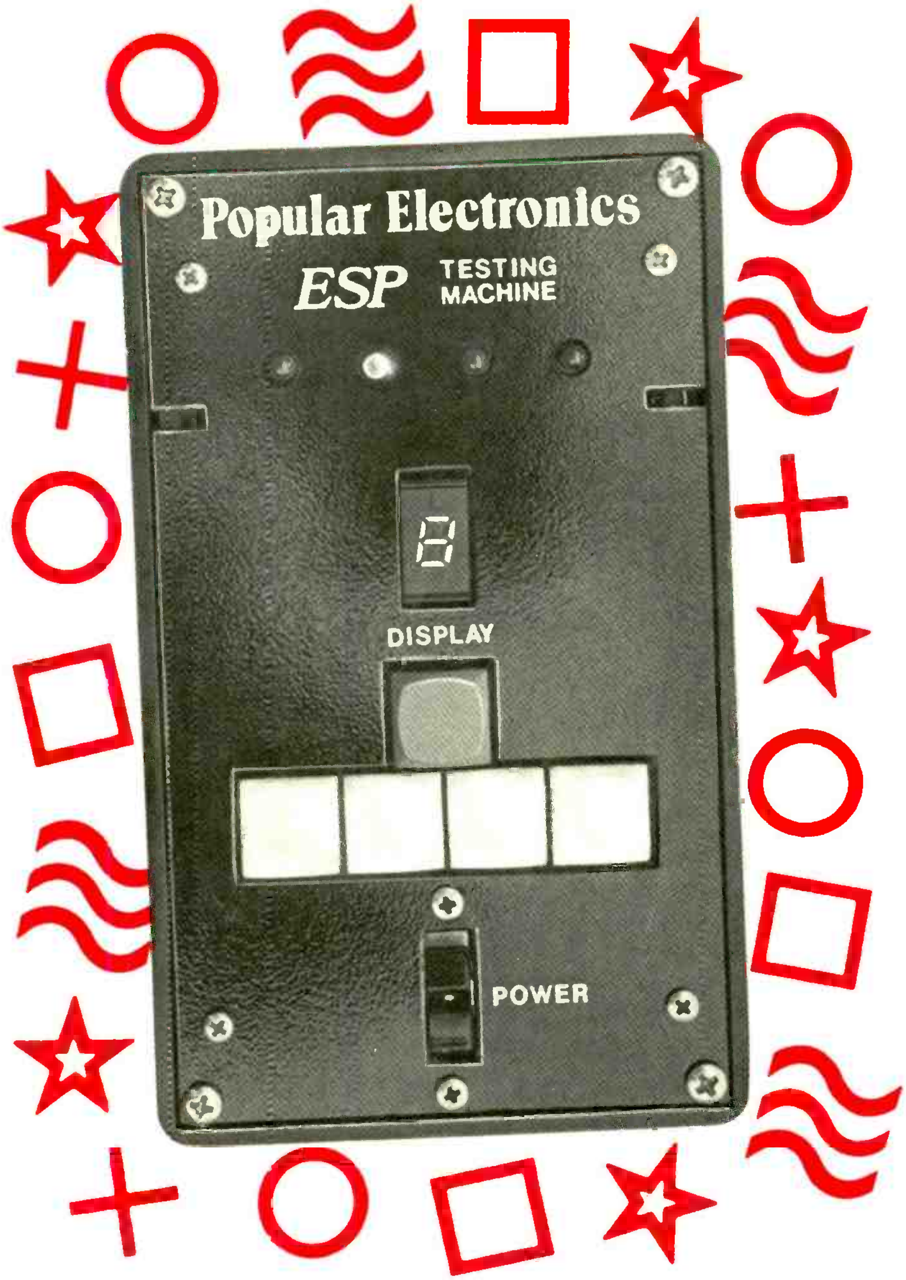
Electric-Eye Annunciator. A compact doorway alarm for stores and other applications can be built around the 555. It eliminates the need for the usual relays and chimes. In the circuit shown at (D), a cadmium-sulfide LDR and a light source (such as a flashlight powered by an ac supply) will bias the reset transistor within the IC. With the LDR illuminated, there is a very low voltage at pin 4. When the light beam is interrupted, the resistance of the LDR rises rapidly, placing the positive voltage on pin 4. When this happens, the 555 breaks into oscillation and provides a "screaming" tone.

Louder Noises. Though the 555 is capable of driving a small speaker at high volume, louder noises are possible. In the circuit shown at (E), the output circuit on pin 3 is replaced with a switching amplifier. With a 12-volt battery (lantern or vehicle type), the output is an ear-piercing (approximately 10 watts) square wave into the 8-ohm trumpet speaker.

Construction. Any of the circuits described here can be assembled on perf board or on a small pc board. No special precautions are required if the supply is kept within 12 volts and the resistor between the positive supply and pin 7 of 555 is 1000 ohms or more. ◈



Some circuits based on a single 555 IC timer chip. Refer to text for details.



BUILD AN

ESP TESTING MACHINE

Experiment with a young science and provide entertainment too!

BY IRA H. SPECTOR

OVER forty years ago, Dr. J.B. Rhine, of the Duke University Parapsychology Laboratory, began the first thorough scientific research into extrasensory perception (ESP). In those days, testing for ESP consisted of thousands of card-guessing experiments in which subjects would try to pick the exact order of a deck of cards to see how close they could come. Since a certain amount of "hits" were expected by chance, Dr. Rhine and his associates were only interested in those individuals who could consistently achieve scores that were significantly above chance. Those persons provided the experimenters with overwhelming evidence of the existence of ESP.

For today's advanced parapsychological research projects, the trend is away from card guessing. Recent ESP testing machines provide a test, automatically keep score, and can be interfaced with other instruments for determining psysiological and psychological correlates of extrasensory perception.

The ESP Testing Machine described here incorporates many of these features. It is a portable, battery-operated device that allows the experimenter to test for all three types of ESP—telepathy, clairvoyance, and precognition. Additionally, it's a fun game for entertainment purposes.

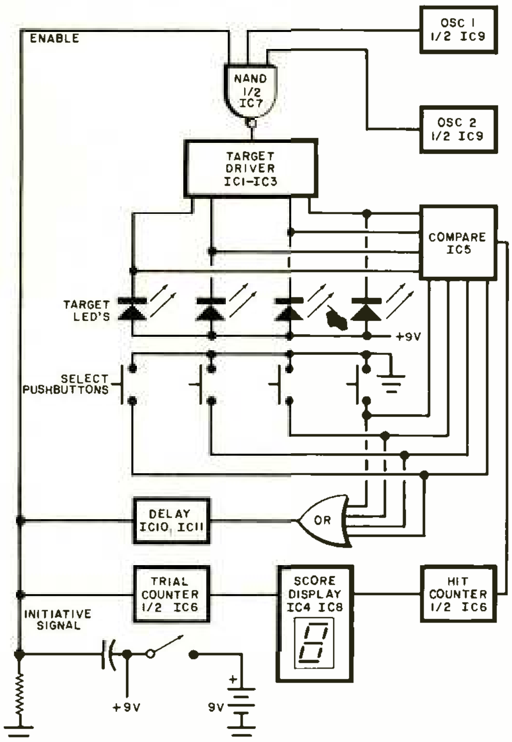
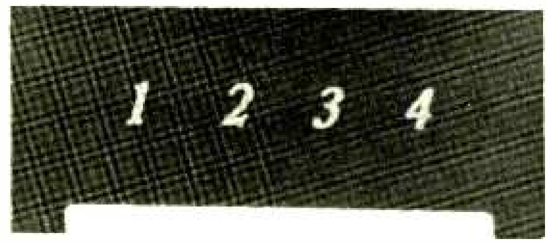
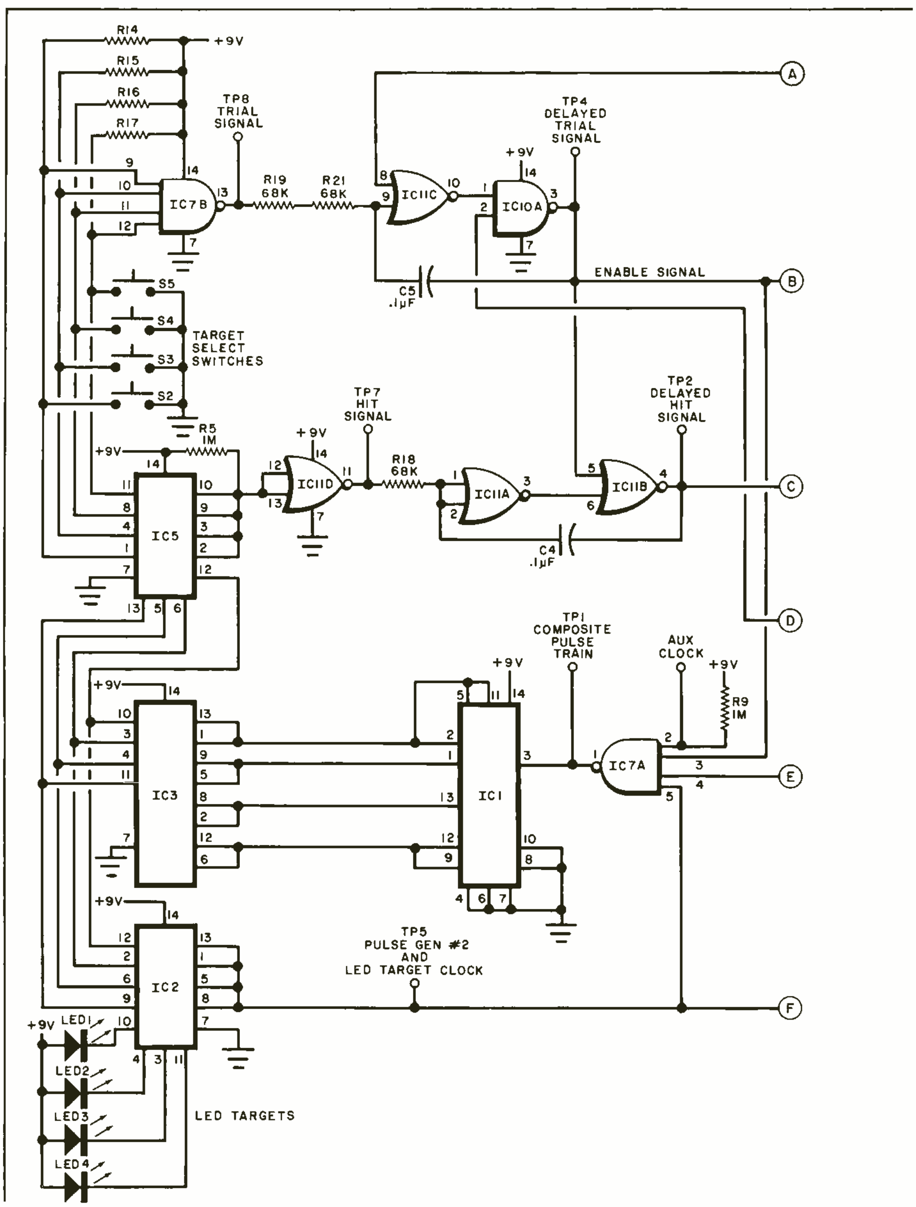


Fig. 1. Logic diagram of Testing Machine. Two oscillators are gated to turn on one LED at random. When switch for lighted LED is pressed, a hit is shown on the display.



Piece of opaque plastic is cut to fit on top of chassis to form the vision barrier.



General Description. The ESP Test Machine consists of four light-emitting diodes (LED's) which serve as ESP "targets." There are four corresponding target select pushbuttons. An internal random-number generator selects one of the LED's for illumination behind a small partition so that the target is not visible to the subject.

Although the procedure varies according to the type of ESP under investigation, the general objective is for the subject to achieve a "hit" by pressing the pushbutton corresponding to the hidden target. After each trial, the random-number generator automatically selects the next target. When ten trials are completed, the number of hits is automatically displayed by a numeric indicator. A manual-display pushbutton is also provided to allow immediate feedback of the score anytime during the test run.

Since there are four equally probable target choices, the probability of a hit during any trial is 25%. Therefore, in ten runs (100 trials), the chance score is 25 hits. Test scores which regularly deviate significantly from chance are considered evidence of ESP.

Circuit Operation. The basic logic circuit is shown in Fig. 1. When power is first turned on, an initiating signal generated by an RC circuit turns on a single, randomly selected LED.

When one of the four pushbuttons is depressed, an enable signal is generated. This goes through a delay to a three-input NAND gate formed by half of *IC7*. The other two inputs to the NAND gate come from a pair of non-synchronized pulse-generator oscillators *(IC9)*. When the NAND gate is enabled, it allows two non-synchronized pulse trains to clock the target driver made up of *IC1, IC2, IC3*. This causes the LED's to illuminate in a 1-2-3-4 sequence at a random rate. At this speed of operation, the four LED's will all glow weakly. When the selected push-button is released, the enable signal is removed from the NAND gate (after a random delay), and only one of the LED's will remain lit.

Each time the enable signal is generated, it also clocks the trial counter *(IC6)*. After counting up to 10 trials, this counter generates a stop signal which turns on the seven-segment readout to display the number of "hits." It simultaneously turns off all four LED's. In the case of 10 consecutive hits, the logic produces a capital letter "H" on the seven-segment readout. To start a new test run, the power is turned off and then on again.

If the operated pushbutton corresponds to the illuminated LED, a comparator *(IC5)* generates a signal which is counted by the hit counter to form the display on the readout.

The length of the enable signal is a function of the time that one of the selection pushbuttons is held down. The delay in the circuit depends on the amount of bounce that occurs when the switch is operated. This adds human and mechanical randomizing elements to the target selection.

The actual circuit of the machine is shown in Fig. 2.

Construction. The ESP Testing Machine uses a double-sided pc board. The layout of components is shown in Fig. 3.

In working with the CMOS IC's, be sure that they do not come in contact with anything that can build up a static charge. Keep them in their conducting foam until ready for installation and handle them only by their non-pin edges. Use a small, low-wattage soldering iron with a grounded tip and observe the notch index for proper positioning.

Install the four white (*S2* through *S5*) and one red *(S1)* pushbutton switches on the Display Side of the

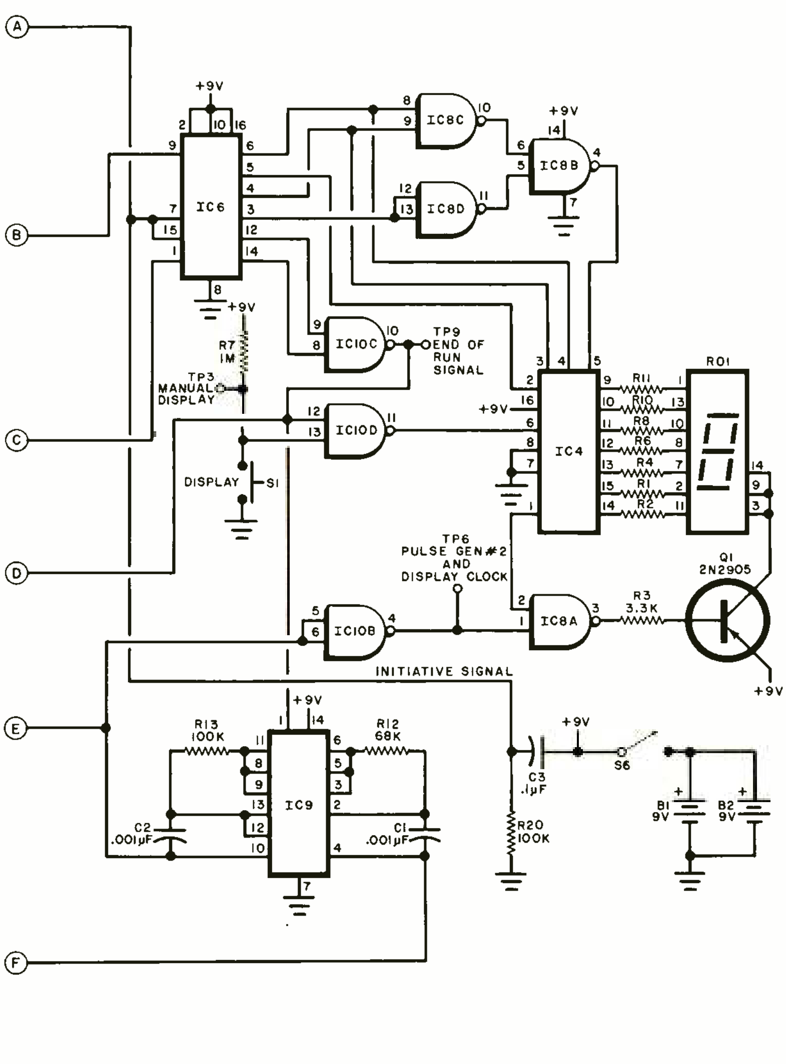
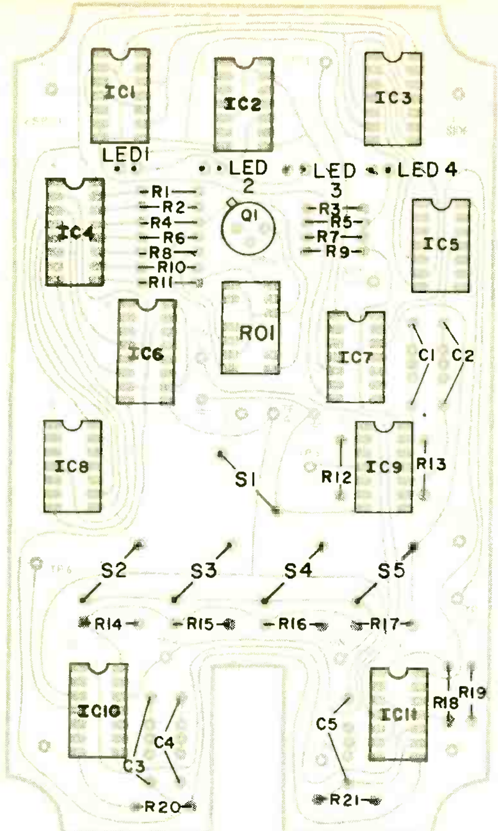


Fig. 2. Complete schematic for the ESP Testing Machine is shown above and on opposite page. The circuit is powered by two 9-volt batteries. CMOS logic units are used to reduce drain on batteries.

PARTS LIST

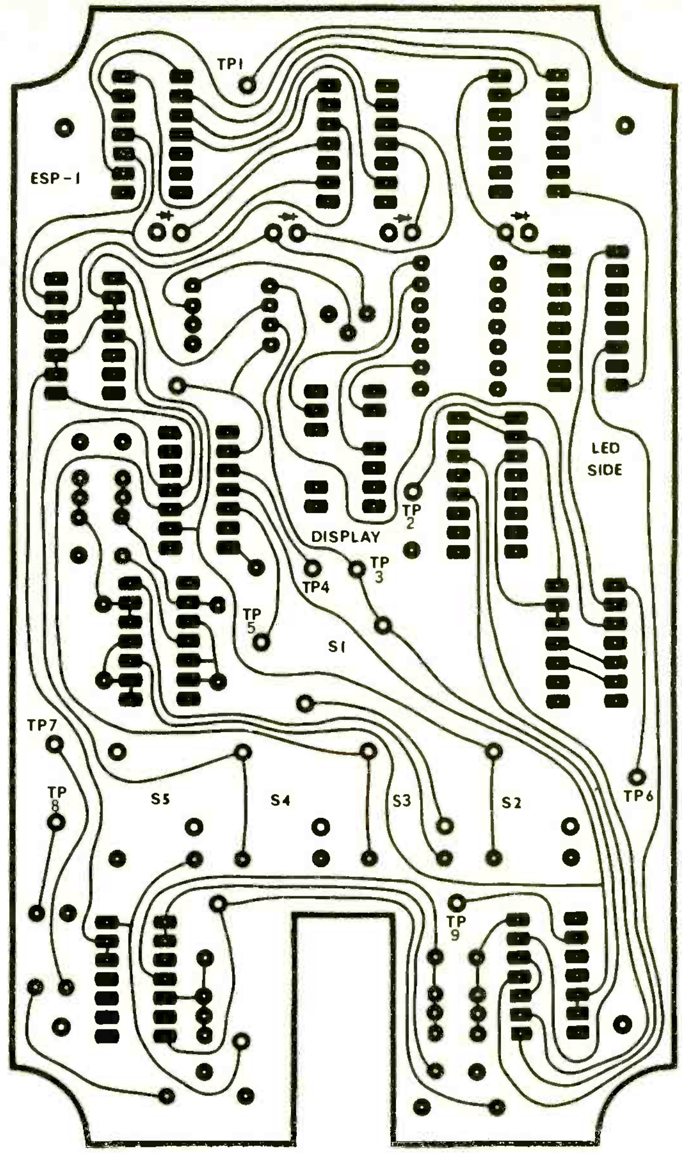
B1,B2—9-volt battery
C1,C2—0.001-µF, 20% mica, Mylar, or ceramic capacitor
C3-C5—0.1-µF, 20% Mylar or ceramic capacitor
IC1—4013 CMOS dual-D flip-flop
IC2,IC8-IC10—4011 CMOS quad 2-input NAND
IC3,IC11—4001 CMOS quad 2-input NOR
IC4—4055 CMOS 7-segment decoder/driver
IC5—4016 CMOS quad bilateral switch
IC6—MC14520CP CMOS dual binary up-counter
IC7—4012 CMOS dual 4-input NAND
LED1-LED4—Light-emitting diode (Monsanto MV-5024 or similar)
Q1—2N2905 transistor
R1,R2,R4,R6,R8,R10,R11—560-ohm, ¼-watt, 10% resistor
R3—3300-ohm, ¼-watt, 10% resistor
R5,R7,R9,R14-R17—1-megohm, ¼-watt, 10% resistor
R12,R18,R19,R21—68,000-ohm, ¼-watt, 10% resistor
R13,R20—100,000-ohm, ¼-watt, 10% resistor
R01—7-segment LED readout (Litronix DL-707 or similar)
S1—Spst momentary pushbutton switch (red) (Oak 415-399592-LP or similar)
S2-S5—Spst momentary pushbutton switch (white) (Oak 415-399596-LP or similar)
S6—Spst alternate-action rocker switch (Arcolectric C-400 or similar)
Misc.—Case (H.H. Smith 2255), cover (H.H. Smith 2256), plastic for target partition, battery holders (2), battery connectors (2), mounting hardware, etc.

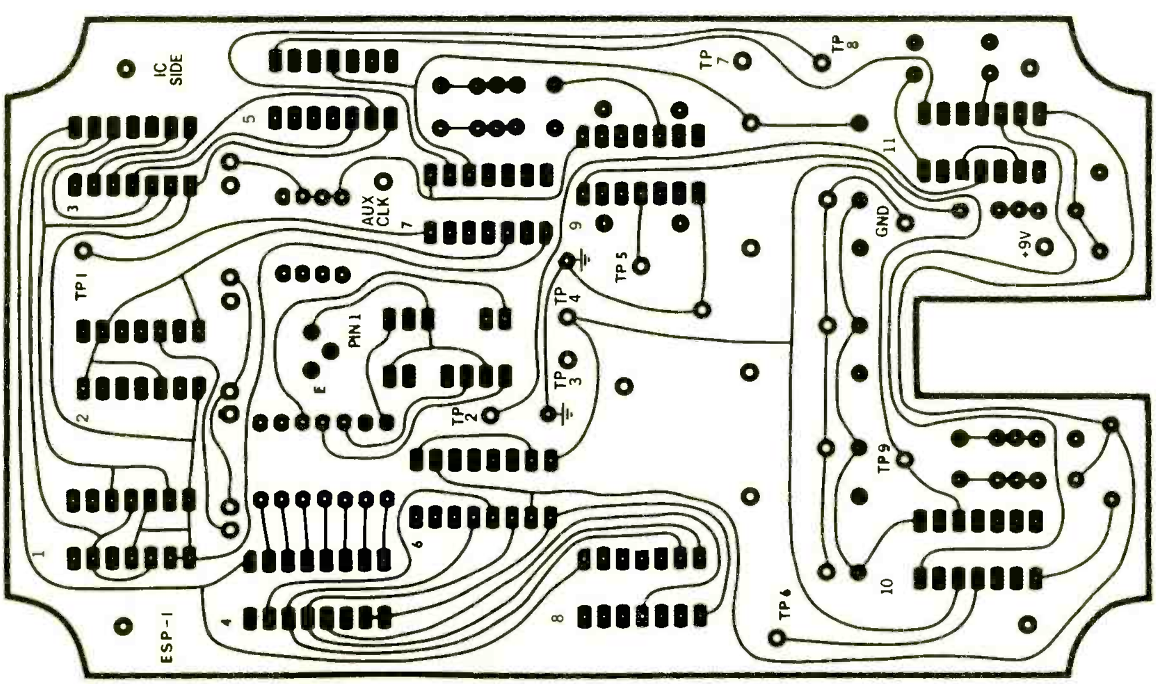
Note 1—The following are available from Paratronics, 150 Tait Ave., Los Gatos, CA 95030: etched and drilled pc board (ESP-1PC) at $13.50; finished and labeled panel, case, and target partition (ESP-1PP) at $10.50; complete kit of parts (less batteries) (ESP-1KN) at $59.50; assembled and tested unit (ESP-1AT) at $69.50. California residents please add 6% sales tax. Add 5% for air shipping inside U.S.; 10% outside U.S.



NOTE: LED1-LED4, RO1, & S1-S5 ON SIDE OPPOSITE IC'S

Fig. 3. Component layout for pc board (above) and full-size foil patterns for construction right and below.





board, along with the seven-segment readout. Mount the four LED's so that their bases are about ⅛" above the board. Use short lengths of bare wire, soldered on both sides of the board, for the test points.

Mark the cover of the plastic box so that it can be drilled and cut to allow the six switches, *RO1*, and LED's to protrude. The pc board is mounted on the front panel using 3/16 inch spacers. The power switch *(S6)* is mounted directly to the front panel and fits into the cutout on the board.

The chassis cover should also have two slots, one on each side, between the LED's and the readout. A piece of opaque plastic should be cut so that it will fit into the slots on each side. This forms a vision barrier so that the person operating the pushbuttons cannot see the LED's. Mark the barrier with the numbers 1, 2, 3, and 4 on each side, keeping in mind that on one side the numbers must read from left to right, and right to left on the other.

Complete the wiring in accordance with Fig. 2.

Checkout. Turn on the power and observe that only one of the four LED targets is illuminated. Press the DISPLAY button and note that the numeral "0" appears on the readout. Then press the target select pushbutton opposite the illuminated LED and notice an immediate mixing of the targets. Upon release of the pushbutton, one of the four LED's will be lighted for the next target. Press the DISPLAY button again and note that the numeral "1" appears on the readout. Continue this procedure until numerals "1" through "9" have been checked out. On the tenth hit, the letter "11" should automatically appear and further trials should be inhibited.

If trouble occurs, first be sure that the batteries are fresh. Further troubleshooting will be aided by the use of the test points labeled on the pc board and shown in Fig. 2.

One Final Note. In the event that some readers view the subject of ESP incredulously, consider the following. The prestigious IEEE (Institute of Electrical and Electronics Engineers) at one of its annual conventions held a seminar at which researchers presented professional papers outlining their work in ESP and related subjects. The session was attended by several hundred enthusiastic electronics engineers. ◈

ESP TESTING PROCEDURES

General Principles. It is desirable to experiment in a quiet, comfortable room with subdued lighting. Take the test slowly, allowing enough time during each trial to develop a "feel" for the correct target. Use the DISPLAY pushbutton for immediate feedback when you think you are performing well.

Try to correlate any psychological factors (mood, approach, etc.) or physiological factors (tiredness, physical comfort, etc.) with test scores to see if patterns emerge. Use the figures in the Performance Chart to evaluate your scores.

Always keep the target partition in place during tests and always press the target select button for at least ½ second to ensure the registering of your trial and to provide extensive randomizing of the various targets.

Testing for Telepathy. Mental telepathy is the transferring of information from one individual to another without the use of the five senses. The procedure for conducting a telepathy test is as follows:

1. Place the ESP Testing Machine on a table between the subject (receiver) and the sender. Make sure that the machine is oriented so that the targets are visible only to the sender.
2. When the power is turned on and the initial target is illuminated, the sender concentrates on the *number* on the target partition that corresponds to the target selected by the machine.
3. The subject should then try to get a mental image of the correct number and press the corresponding target select pushbutton. The subject should never look at the sender during the test to avoid "sensory leakage."
4. Repeat this procedure until ten trials are complete and the score is displayed.

Note: You may want to substitute other target material for the numbers on the partition to see how scores are affected. Use letters, colors, pictures—anything that you fell will enhance the visualization process.

Testing for Clairvoyance. Clairvoyance is the perception of objects without the use of the five senses. The procedure is as follows:

1. Position the ESP Testing Machine so that the targets are not visible to anyone. This precaution avoids the possibility of "telepathic leakage."
2. Turn on the power and try to visualize which target is illuminated. Then press the appropriate pushbutton.
3. Continue this procedure until the run is complete and the score is displayed.

Testing for Precognition. Precognition is the prediction of future events that cannot be inferred from present knowledge. The procedure is:

1. Write down a list of future events that cannot be inferred from present knowledge. The procedure is:
1. Write down a list of ten numbers from among the target integers 1, 2, 3, and 4. Use any sequence which you "feel" will be selected by the machine when you actually perform the test.
2. Turn on the power and press the target select pushbuttons in accordance with the chosen sequence. When the last number is entered, you score will automatically be displayed.

Other Tests. The use of the ESP Testing Machine with other electronic equipment will permit a more detailed investigation of the nature of ESP. For example, if ham radio equipment is available, telepathy-over-distance tests can be performed either to verify or challenge previous results indicating that telepathy performance is unaffected by distance. If high scores are achieved, it would be an indication that the telepathy signal was not appreciably affected by distance.

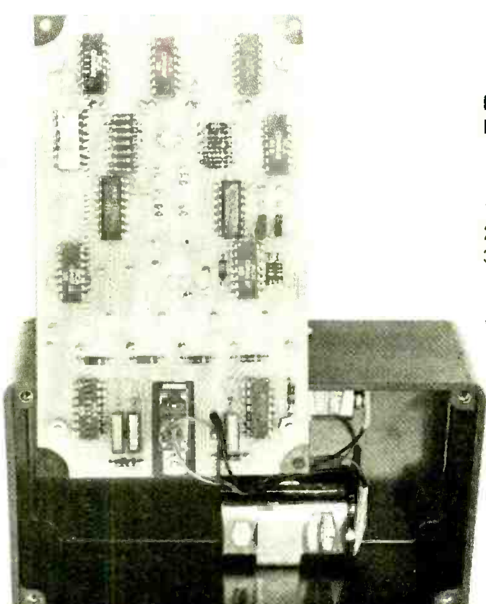


Photo shows the pc board and the enclosure for ESP Machine.

PERFORMANCE CHART

No. of Runs*	Chance Score	Good Score (Odds 20:1)	Excellent Score (Odds 100:1)
10	25	34	36
20	50	62	66
30	75	90	94

*10 trials in each run.

7400N TTL

SN7400N*	16	SN7459A	25		
SN7401N	16	SN7460N	22	SN74154N*	1.00
SN7402N	21	SN7470N	45	SN74155N	99
SN7403N	16	SN7472N	39	SN74156N	99
SN7404N*	18	SN7473N*	37	SN74157N	99
SN7405N	24	SN7474N*	32	SN74160N	1.25
SN7406N	20	SN7475N*	50	SN74161N	99
SN7407N	29	SN7476N*	32	SN74163N*	99
SN7408N	25	SN7479N*	5.00	SN74164N	1.10
SN7409N	25	SN7480N	50	SN74165N	1.10
SN7410N*	18	SN7482N	98	SN74166N	1.25
SN7411N	30	SN7483N	70	SN74167N	5.50
SN7412N	33	SN7485N	89	SN74170N	2.10
SN7413N	45	SN7486N	39	SN74172N	8.95
SN7414N	70	SN7488N	3.50	SN74173N	1.50
SN7416N	35	SN7489N	2.25	SN74174N	1.25
SN7417N	35	SN7490N*	45	SN74175N	99
SN7420N	21	SN7491N	75	SN74176N	90
SN7421N	33	SN7492N	49	SN74177N	90
SN7422N*	49	SN7493N*	49	SN74180N	99
SN7423N	37	SN7494N	79	SN74181N	2.49
SN7425N	29	SN7495N	79	SN74182N	95
SN7426N	29	SN7496N	89	SN74184N	1.95
SN7427N	37	SN7497N*	4.00	SN74185N	2.20
SN7429N	42	SN74100N*	1.00	SN74186N*	5.00
SN7430N	26	SN74107N	39	SN74187N	6.00
SN7432N	31	SN74121N*	39	SN74188N	3.95
SN7437N	27	SN74122N	39	SN74190N	1.19
SN7438N	27	SN74123N*	70	SN74191N	1.25
SN7439N	25	SN74125N	60	SN74192N*	89
SN7440N	15	SN74126N	60	SN74193N*	89
SN7441N	89	SN74132N	1.09	SN74194N	1.25
SN7442N	59	SN74136N	95	SN74195N	75
SN7443N	75	SN74141N	1.15	SN74196N	1.25
SN7444N	75	SN74142N*	4.00	SN74197N	75
SN7445N	75	SN74143N*	4.50	SN74198N	1.75
SN7446N	81	SN74144N*	4.50	SN74199N	1.75
SN7447N*	69	SN74145N	1.15	SN74200N	5.59
SN7448N	79	SN74147N	2.35	SN74279N*	.90
SN7450N	26	SN74148N	2.00	SN74251N	1.79
SN7451N	27	SN74150N	1.00	SN74284N	6.00
SN7453N	27	SN74151N	79	SN74285N	6.00
SN7454N	20	SN74153N	89	SN74367N	75

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CD4007	25	CD4042	1.90	74C42N	2.15
CD4009	59	CD4044	1.50	74C73N	1.50
CD4010	59	CD4046	2.51	74C74	1.15
CD4011	25	CD4047	2.75	74C90N	3.00
CD4012	25	CD4049	79	74C95N	2.00
CD4013	47	CD4050	79	74C107N	1.25
CD4016	56	CD4051	2.95	74C151	2.90
CD4017	1.35	CD4053	2.95	74C154	4.00
CD4019	55	CD4060	3.25	74C157	2.15
CD4020	1.49	CD4066	1.75	74C160	3.25
CD4022	1.25	CD4069	45	74C161	3.25
CD4023	25	CD4071	45	74C163	3.00
CD4024	1.50	CD4081	45	74C164	3.25
CD4025	25	CD4511	2.50	74C173	2.60
CD4027	69	CD4518	2.50	74C193	2.75
CD4028	1.65	74C00N	39	74C195	2.75
CD4029	2.90	74C02N	55	MC4044*	4.50
CD4030	65			MC14016*	56

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LM300H	80			LM1310N	2.95
LM301H	35			LM1351N	1.65
LM301CN	35			LM1414N	1.75
LM302H	75			LM1458C	65
LM304H	1.00	LM370N	1.15	LM1496N	95
LM305H	95	LM373N	3.25	LM1556V	1.85
LM307CN	35	LM377N	4.00	LM2111N	1.95
LM308H	1.00	LM380N	1.39	LM2901N	2.95
LM308CN	1.00	LM390CN	1.05	LM3065N	69
LM309H	1.10	LM381N	1.79	LM3900N	55
LM309K	99	LM382N	1.79	LM3905N	60
LM310CN	1.15	NE501K	8.00	LM3909*	1.25
LM311H	90	NE510A	6.00	LM5556N	1.85
LM311N	90	NE531H	3.00	MC5558V	1.00
LM318CN	1.50	NE536T	6.00	LM7525N	90
LM319N	1.30	NE540L	6.00	LM7535N	1.25
LM320K-5	1.35	NE550N	79	8038B*	4.95
LM320K-5.2	1.35	NE555V*	45	LM75450	49
LM320K-12	1.35	NE560B*	5.00	75451CN	39
LM320K-15	1.35	NE561B*	5.00	75452CN	39
LM320T-5*	1.75	NE562B*	5.00	75453CN	39
LM320T-5.2	1.75	NE565H*	1.25	75454CN	39
LM320T-8*	1.75	NE565N*	1.75	75491CN	79
LM320T-12*	1.75	NE566CN*	1.25	75492CN	89
LM320T-15	1.75	NE567H*	1.95	75494CN	89
LM320T-18*	1.75	NE567V*	1.50	**RCA LINEAR**	
LM320T-24	1.75	LM703CN	45	CA3013	2.15
LM323K-5*	9.95	LM709H	29	CA3032	2.56
LM324N	1.80	LM709N	29	CA3035	2.48
LM339N	1.70	LM710N	79	CA3039	1.35
LM340K-5	1.95	LM711N	39	CA3046	1.30
LM340K-6	1.95	LM723H	55	CA3059	3.25
LM340K-8	1.95	LM723H	55	CA3060	3.25
LM340K-12	1.95	LM733N	1.00	CA3080	85
LM340K-15	1.95	LM739N	1.00	CA3081	2.00
LM340K-18	1.95	LM741CH	35	CA3082	2.00
LM340K-24	1.95	LM741CN	35	CA3083	1.60
LM340T-5	1.75	LM74114N	39	CA3086	85
LM340T-6	1.75	LM747H	79	CA3089	3.75
LM340T-8*	1.75	LM747N	79	CA3091	10.20
LM340T-12	1.75	LM748H	39	CA3123	2.15
LM340T-15	1.75	LM748N	39	CA3130	1.39
LM340T-18*	1.75	LM1303N	90	CA3140	1.25
LM340T-24	1.75	LM1304N	1.19	CA3600	1.75
LM350N	1.00	LM1305N	1.40	RC4194	5.95
LM351CN	65	LM1307N	85	RC4195	3.25

74LS00 TTL

74LS00	39	74LS55	.39	74LS151	1.55
74LS02	39	74LS73	65	74LS153	1.89
74LS03	39	74LS74	65	74LS157	1.55
74LS04	45	74LS75	79	74LS162	2.25
74LS05	45	74LS76	65	74LS163	2.25
74LS08	39	74LS83	2.19	74LS164	2.25
74LS10	39	74LS86	65	74LS181	3.69
74LS13	79	74LS90	1.25	74LS190	2.85
74LS14	2.19	74LS92	1.25	74LS191	2.85
74LS20	39	74LS93	1.25	74LS192	2.85
74LS26	49	74LS95	2.19	74LS193	2.85
74LS27	45	74LS96	1.89	74LS194	2.25
74LS28	49	74LS107	65	74LS195	2.25
74LS30	39	74LS112	65	74LS257	1.89
74LS32	45	74LS132	1.55	74LS260	55
74LS40	49	74LS136	65	74LS279	79
74LS51	39	74LS138	1.89	74LS670	5.95

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XC22Orange 4/$1
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.185" dia.
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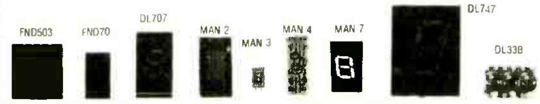
XC526Green 7/$1
XC526Yellow 4/$1
XC526Orange 4/$1
XC526Clear 7/$1

.200" dia.
XC556Red 10/$1
XC556Green 7/$1
XC556Yellow 7/$1
XC556Orange 7/$1
XC556Clear 7/$1

.085" dia.
MV50
.085" dia. Micro red LED
6/$1

DISPLAY LEDS SUPER SAVINGS!

MAN 7 $.99 — DL33B $.99



TYPE	POLARITY	HT		TYPE	POLARITY	HT	
MAN 1	Common Anode	.270	2.49	MAN 3620	Common Anode-orange	.300	.99
MAN 2	5 × 7 Dot Matrix	.300	4.95	MAN 3640	Common Cathode-orange	.300	.99
MAN 3	Common Cathode	.125	3/1	MAN 4710	Common Anode-Red	.400	99
MAN 4	Common Cathode	.187	1.95	DL701	Common Anode red	.300	99
MAN 7	Common Anode	.300	.99	DL707	Common Anode	.300	1.60
MAN 7G	Common Anode green	.300	1.95	DL 728	Common Cathode	.500	1.99
MAN 7Y	Common Anode-yellow	.300	1.95	DL 747	Common Anode	.600	2.25
MAN 52	Common Anode-green	.300	.99	DL 750	Common Cathode	.600	2.49
MAN 64	Common Anode-red	.400	.99	DL 33B	Common Cathode	110	.99
MAN 72	Common Anode	.300	.99	FND70	Common Cathode	.250	.50
MAN 74	Common Cathode	.300	1.15	FND503	Common Cathode	500	1.29
MAN 82	Common Anode yellow	300	.99	FND507	Common Anode	.500	1.29
MAN 84	Common Cathode-yellow	.300	.99				

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.17	16	15	24 pin	$.38	37	36
14 pin	20	19	18	28 pin	45	44	43
16 pin	22	21	20	36 pin	60	59	58
18 pin	29	28	27	40 pin	.63	.62	61
22 pin	37	.36	35				

SOLDERTAIL STANDARD (TIN)

	1-24	25-49	50-100		1-24	25-49	50-100
14 pin	$.27	25	24	28 pin	$.99	.90	.81
16 pin	30	27	25	36 pin	1.39	1.26	1.15
18 pin	35	32	30	40 pin	1.59	1.45	1.30
24 pin	49	45	42				

SOLDERTAIL STANDARD (GOLD)

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.30	27	24	24 pin	$.70	63	57
14 pin	35	.32	29	28 pin	1.10	1.00	.90
16 pin	38	35	32	36 pin	1.75	1.40	1.26
18 pin	52	47	43	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

	1-24	25-49	50-100		1-24	25-49	50-100
10 pin	$.45	41	37	24 pin	$1.05	95	85
14 pin	39	38	37	28 pin	1.40	1.25	1.10
16 pin	43	42	41	36 pin	1.59	1.45	1.30
18 pin	.75	68	62	40 pin	1.75	1.55	1.40

50 PCS. RESISTOR ASSORTMENTS $1.75 PER ASST.

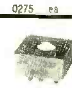
ASST. 1	5 ea.	10 OHM / 27 OHM	12 OHM / 33 OHM	15 OHM / 39 OHM	18 OHM / 47 OHM	22 OHM / 56 OHM	1/4 WATT 5%	50 PCS.
ASST. 2	5 ea.	68 OHM / 180 OHM	82 OHM / 220 OHM	100 OHM / 270 OHM	120 OHM / 330 OHM	150 OHM / 390 OHM	1/4 WATT 5%	50 PCS.
ASST. 3	5 ea.	470 OHM / 1.2K	560 OHM / 1.5K	680 OHM / 1.8K	820 OHM / 2.2K	1K / 2.7K	1/4 WATT 5%	50 PCS.
ASST. 4	5 ea.	3.3K / 8.2K	3.9K / 10K	4.7K / 12K	5.6K / 15K	6.8K / 18K	1/4 WATT 5%	50 PCS.
ASST. 5	5 ea.	22K / 56K	27K / 68K	33K / 82K	39K / 100K	47K / 120K	1/4 WATT 5%	50 PCS.
ASST. 6	5 ea.	150K / 390K	180K / 470K	220K / 560K	270K / 680K	330K / 820K	1/4 WATT 5%	50 PCS.
ASST. 7	5 ea.	1M / 2.7M	1.2M / 3.3M	1.5M / 3.9M	1.8M / 4.7M	2.2M / 5.6M	1/4 WATT 5%	50 PCS.

5 EACH MINIMUM PER VALUE ON ANY RESISTORS FROM 2.2 OHM TO 5.6M
5-25 PCS .05 ea 30-95 PCS .04 ea 100-495 PCS .03 ea 500-995 .0275 ea

SINGLE TURN 3/8" CERMET POTENTIOMETER

- Resistance Tolerance ± 20%
- High Power — 0.5 Watt at 70°C
- Wide Operating Temp. Range −55°C to +125°C

$.89



STANDARD RESISTANCE VALUES
50Ω 100Ω 500Ω 1K 2K 5K 10K 20K 50K 100K 200K 500K 1 MEG

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MINIATURE TOGGLE

OPDT				JMT	1	2-9	10-29	30-99
	ON	OFF	ON	221	2.95	2.55	1.87	1.70
	ON	NONE	ON	223	2.95	2.15	1.58	1.43
	ON	OFF	ON	121	2.35	1.95	1.43	1.30
	ON	NONE	ON	123	2.05	1.65	1.21	1.10

PUSH BUTTON

SPDT — SERIES PB, PB1
Maintained Action Switch — Push To Make Contact And Push Again To Reverse Action
Momentary Action Switch — Normally Open or Normally Closed (For N.C. circuit use terminals 2 & 1, for N.O. 2 & 3; for N.C. and N.O. 1, 2 & 3)

PB-123 $1.75
PB-126 $1.75

5 AMP RATINGS

THUMBWHEEL SWITCHES

THUMBWHEEL SWITCH ONLY
SF — Front Mount SR — Rear Mount

Part No	Description	Price
SF 12	Single Pole 10 Position	$2.50
SR 12	Decimal	3.00
SF 21	10 Position BCD only	2.50
SR 21	" "	3.00

Ordering: Order desired switch or switches and add necessary accessories for your particular application.

ACCESSORIES

Part No	Description	Price
SF EP	End Plate (Pair)	$.50
SF DP	Divider Plate (each)	40
SF BB	Blank Body (each)	40
SF HB	Half Body (each)	40

ACCESSORIES

Part No	Description	Price
SR EP	End Plates (pair)	$.50
SR DP	Divider Plate (each)	40
SR BB	Blank Body (each)	40
SR HB	Half Body (each)	40

CLIPLITE !! NEW LED MOUNTING SYSTEM — 4/$1.00

- CLIPLITE mounts from the front of the Panel in a .250 hole on 3/8" centers. Panel thickness from 1/16" to 1/8".
- CLIPLITE equalizes and increases the brightness of commonly used wide beam LEDS.
- CLIPLITE is to be used with XC556 LEDS only. Specify red, green, amber or yellow CLIPLITES when ordering.

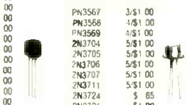
ZENERS—DIODES—RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400m	4/1.00	1N4005*	600 PIV	1 AMP	10/1.00
1N751A	5.1	400m	4/1.00	1N4006*	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007*	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	8/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4734	5.6	1w	28
1N5232	5.6	500m	28	1N4735	6.2	1w	28
1N5234	6.2	500m	28	1N4736	6.8	1w	28
1N5235	6.8	500m	28	1N4738	8.2	1w	28
1N5236	7.5	500m	28	1N4742	12	1w	28
1N456	25	40m	6/1.00	1N4744	15	1w	28
1N458	150	7m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N485A	180	10m	5/1.00	1N1184	100 PIV	35 AMP	1.70
1N4001	50 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4003	200 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00
1N4004	400 PIV	1 AMP	12/1.00				

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR	$1.95
C38M	35A @ 200V	SCR	1.95
2N2328	1.6A @ 200V	SCR	.50
MDA 980-1	25A @ 50V	FW BRIDGE REC.	1.95
MDA 980-3	25A @ 200V	FW BRIDGE REC.	1.95

TRANSISTORS



MPS A05	5/$1.00			PN4249	4/$1.00
MPS A06	5/$1.00	PN3567	3/$1.00	PN4250	4/$1.00
2N2219A	3/$1.00	PN3568	4/$1.00	2N4400	4/$1.00
2N2221	4/$1.00	PN3569	4/$1.00	2N4401	4/$1.00
2N2222A	5/$1.00	2N3704	5/$1.00	2N4402	4/$1.00
2N2369	5/$1.00	2N3705	5/$1.00	2N4403	4/$1.00
2N2369A	4/$1.00	2N3706	5/$1.00	2N4409	5/$1.00
FN2415	5/$1.00	2N3707	5/$1.00	2N5086	4/$1.00
2N2484	4/$1.00	2N3711	5/$1.00	2N5087	4/$1.00
2N2906A	4/$1.00	2N3724	$.65	2N5088	4/$1.00
2N2907A	5/$1.00	2N3725	$1.00	2N5089	4/$1.00
2N2925	5/$1.00	2N3903	5/$1.00	2N5129	5/$1.00
2N3053	2/$1.00	2N3904	4/$1.00	2N5138	5/$1.00
2N3055	$.89	2N3905	4/$1.00	2N5139	5/$1.00
MJE3055	$1.00	2N3906	4/$1.00	2N5209	5/$1.00
MJE2955	$1.25	2N4013	3/$1.00	2N5951	5/$1.00
2N3392	5/$1.00	2N4014	3/$1.00	C106B1SCR	2/$1.00
2N3398	5/$1.00	2N4123	10/$1.00	2N5432	$2.00

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
10 pf	.05	.04	.03	.001µF	.05	.04	.035
22 pf	.05	.04	.03	.0047µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	.1µF	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead	1-9	10-49	50-100	Radial Lead	1-9	10-49	50-100
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.15	.13	.10	1.0/16V	.15	.13	.10
4.7/25V	.16	.14	.12	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

CIRCLE NO. 15 ON FREE INFORMATION CARD

BY MARSHALL LINCOLN

Build a Versatile Nickel-Cadmium Battery Charger

Provides variety of charging rates and operates from ac line or 12-V dc source

IN THESE DAYS of portable devices powered by nickel-cadmium batteries, recharging devices are becoming increasingly important. Unfortunately, most chargers are designed for a specific application. For example, a charger for a calculator may not satisfactorily charge the batteries in a portable tape recorder. Similarly, you can't expect to charge the batteries in a walkie-talkie with a charger designed for a photographic speedlight. Here's a general-purpose battery charger you can build for under $15 that will accommodate popular AA-, C-, and D-size nickel-cadmium cells. With this unit, you won't need a separate charger for each piece of equipment containing batteries.

The battery charger, shown schematically in Fig. 1, overcomes the single-application design by providing a variety of charging rates. To make it as versatile as possible, the power source for the charger can be the ac line through *PL1* or any 12-volt dc source (including a car battery) through *PL2*. It can charge from 1 to 4 C cells at once with the cells either installed in battery clips on the charger or connected to the charger through an external cord.

Values of current-limiting resistors *R1* through *R4* were selected to keep the charging current through the cells low enough so that damaging overcharging would not occur. Switch selection, via *S2*, automatically switches in the proper series resistance to match the number of cells connected to the charger circuit. Meter *M1* provides a means of monitoring the charging current so that you always know the charge current is within cell ratings.

A 12-volt filament transformer, *T1*, and diode, *D1*, permit the charger to operate from a 117-volt ac line source. To operate the charger from a 12-volt dc source, *S1* must be in its alternate position, placing the *R6/PL2* circuit in the system and removing the *PL1/T1/D1* circuit. Resistor *R6* is in the circuit to insure that the same charging current is delivered in the dc mode as in the ac mode.

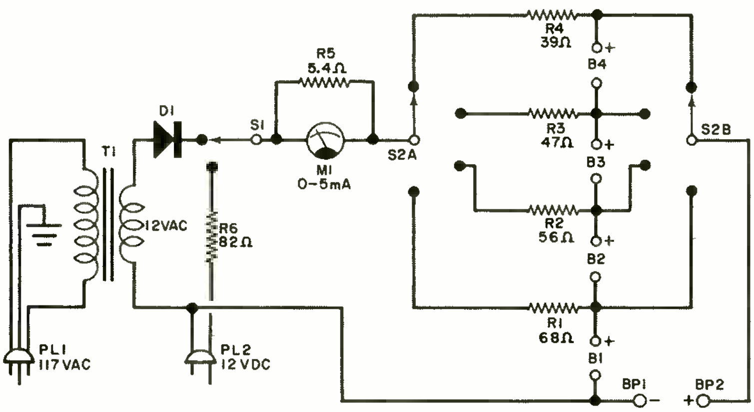


Fig. 1. Charger can be used for one to four C cells with cells in clips or connected to binding posts.

PARTS LIST

B1-B4—D-cell battery holders
BP1, BP2—Five-way binding post (one black, one red)
D1—200-PIV, 200 mA silicon diode
M1—0-5-mA meter movement
PL1—Ac plug with line cord, or use chassis-mounting plug
PL2—Polarized dc plug (automotive or other), or use chassis-mounting plug
R1—68-ohm, 1-watt resistor
R2—56-ohm, 1-watt resistor
R3—47-ohm, ½-watt resistor
R4—39-ohm, ½-watt resistor
R5—5.4-ohm, ½-watt resistor
R6—82-ohm, 1-watt resistor
S1—Dpst switch
S2—2-pole, 4-position rotary switch
T1—12-volt, ½-ampere filament transformer
Misc.—Chassis box; hookup wire; hardware; rubber grommet or plastic strain reliefs (2) for line and dc power cords; solder; etc.

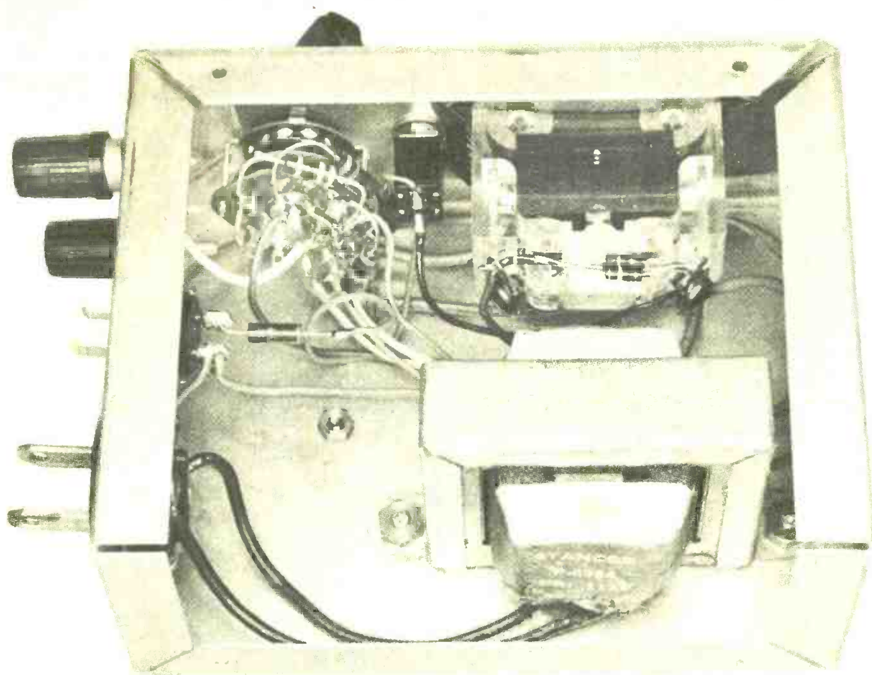


Fig. 2. Photo shows inner assembly of the prototype. All parts are installed by point-to-point wiring so it is not necessary to use circuit board.

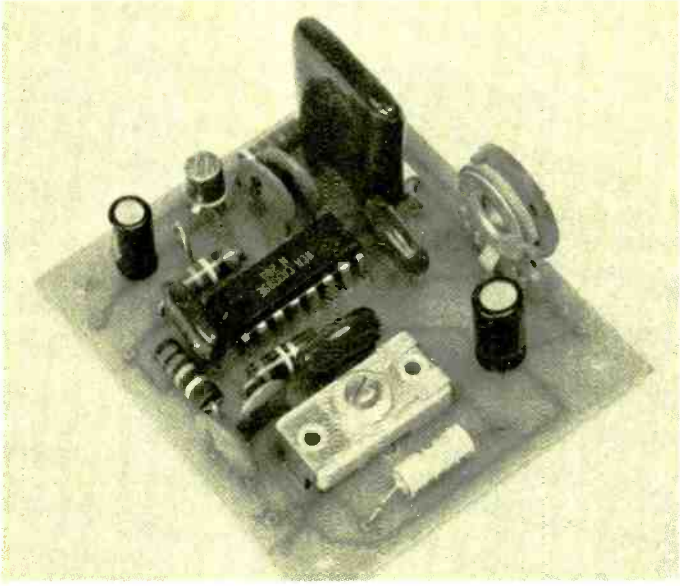
The values of *R1* through *R4* were selected to yield slightly less than 100 mA of charging current. When *S2* puts *R1* in the circuit, charging current is delivered to only the *B1* battery contacts. Switching through *R2*, *R3*, and *R4* successively adds the remaining battery contacts so that up to four batteries can be recharged simultaneously. Note, however, that the circuit is "live" only if the proper number of batteries are installed for any given switch position. For example, if *S2* were in the *R4* position, four batteries must be in the charger; any lesser number would leave an open circuit.

If you examine the schematic, you will note binding posts *BP1* and *BP2*. These connectors are a convenience feature that allows batteries of different physical configurations to be recharged with the aid of test leads. Select black and red binding posts for *BP1* and *BP2*, respectively.

The only other component in the circuit is *R5*. This resistor serves as a current shunt for *M1*. It permits the meter, a 0-5-mA movement, to accommodate a 0-120-mA current range.

Building the battery charger is a simple and straightforward project. As shown in Fig. 2 and the lead photo, no printed circuit or perforated phenolic board is required during assembly. All parts are installed by point-to-point wiring.

In use, the battery charger, operating at a 1/10 C charging rate, will fully charge a depleted nickel-cadmium battery in about 14 to 16 hours. For only partially discharged cells, the recharging time will be shorter. ◈



BY FRANK P. KARKOTA, JR.

SCA ADAPTER REVEALS HIDDEN MUSIC AND NEWS ON YOUR FM RECEIVERS

IN AN EFFORT to utilize more fully the radio spectrum, the Federal Communications Commission some time ago authorized FM radio stations to use special subcarriers to broadcast additional program material. This was covered in the FCC's Subsidiary Communications Authorization—hence the letters SCA, applied to the process in general. The most common use of SCA is in the transmission of background music; but other broadcasts may include detailed weather forecasting, special time signals, and other material designed and intended for special-interest groups, such as religious and ethnic groups and handicapped listeners, doctor's offices, stores, factories, and other public places.

Broadcasters who use SCA generally make their profits by leasing the special receivers required to detect the subcarriers. However, the SCA

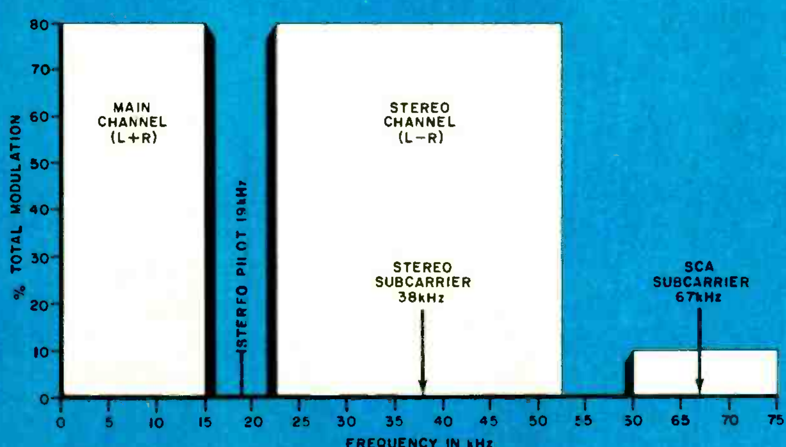


Fig. 1. Makeup of the frequency spectrum of an FM transmitter carrying both stereo and SCA signals. Main channel is at left, stereo at center, and SCA subcarrier at right.

adapter described here will enable the owner of almost any conventional FM receiver to listen to these broadcasts. (*A word of caution:* it is illegal to use SCA broadcasts for commercial purposes without written permission from the broadcaster.) Using a single IC, this low-cost SCA adapter can derive its operating power from the receiver with which it is used. In many cases, the adapter can be built directly into the cabinet with the receiver. A small pc board and simple alignment procedures make the project easy to construct and use with most home FM receivers.

How SCA Is Handled. In mono FM broadcasting, the main channel transmits only audio frequencies up to 15 kHz, and the transmitter/modulator is designed for this range only. For all stereo FM broadcasting, the transmitter/modulator is designed to pass not only the 15-kHz main (L + R) channel, but also a 19-kHz stereo pilot carrier and an amplitude-modulated 38-kHz subcarrier that contains the stereo (L − R) information. For an FM station to transmit also the SCA information, it must be able to accommodate the SCA channel as a narrow-band (7-kHz deviation) subcarrier centered at 67 kHz. The audio-modulation frequency spectrum for an FM transmitter carrying both stereo and SCA is shown in Fig. 1.

To extract the SCA material from this composite signal requires the equivalent of two receivers—one to demodulate the composite from the FM transmission and the other to recover only the SCA from the detected composite signal. A conventional FM receiver performs the first operation, and the output of its detector forms the input signal for the second "receiver." Essentially, the latter is in the form of a narrow-band FM receiver tuned to 67 kHz. The audio output of this SCA adapter is used to drive an external amplifier and speaker.

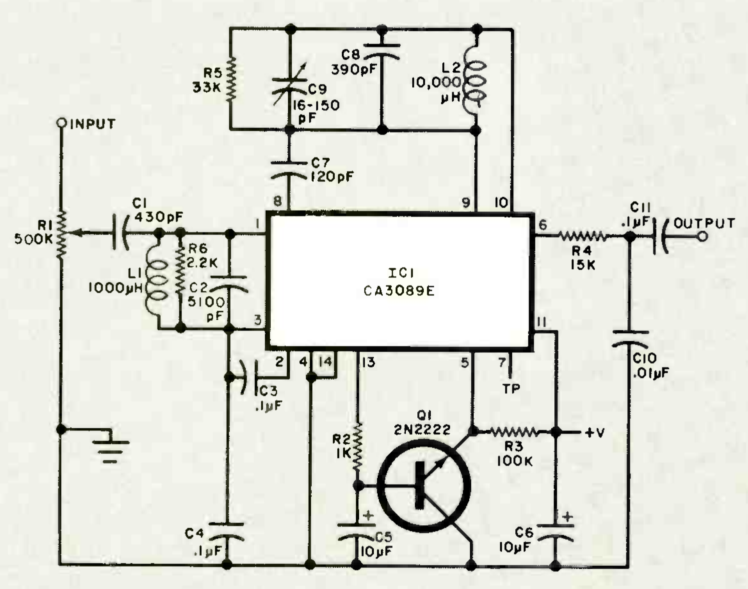


Fig. 2. Single IC contains a complete i-f system, a quadrature FM detector and an audio amplifier.

PARTS LIST

C1—430-pF, 5%, silver-mica capacitor
C2—5100-pF, 5% silver-mica capacitor
C3, C4, C11—0.1-µF, 10-volt disc capacitor
C5,C6—10-µF electrolytic capacitor
C7—120-pF, 5% silver-mica capacitor
C8—390 pF, 5% silver-mica capacitor
C9—16-150-pF trimmer capacitor (Arco 424 or similar)
C10—0.01-µF disc capacitor
IC1—CA3089E
L1—1000-µH, 5% inductor (Nytronic WEE 1000 or similar)
L2—10,000-µH, 10% inductor (Nytronic WEE-10,000 or similar)
Q1—2N2222
R1—500,000-ohm trimmer potentiometer (CTS X-201 or similar)
R2—1000-ohm, ½-watt resistor
R3—100,000-ohm, ½-watt resistor
R4—15,000-ohm, ½-watt resistor
R5—33,000-ohm, ½-watt resistor
R6—2200-ohm, ½-watt resistor
Misc.—Power supply, interconnecting shielded cables, pc board, optional mounting hardware, etc.
Note—The following are available from Communications Poly Services, 46 Groton Rd., Westford, MA 01886: etched and drilled pc board at $2.25; complete kit of parts including pc board at $13.50, both postpaid. Massachusetts residents, please add 5% state sales tax.

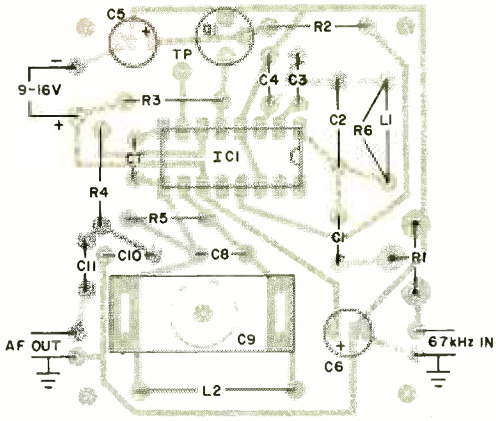
How It Works. The schematic of the adapter is shown in Fig. 2. The IC is a new unit which contains a complete FM strip on a single chip. Although designed to work at the conventional 10.7-MHz i-f, this IC works well at 67 kHz for SCA.

The demodulated composite signal is applied to control potentiometer *R1*, which acts as a squelch (to be explained later). The relatively low value of *C1* provides a high-pass filter to reject the main channel and most of the stereo subcarrier. Capacitor *C2* and inductor *L1* form a tuned circuit that helps to reject noise above and below 67 kHz and *R6* determines the bandwidth. Capacitors *C3* and *C4* are used as bypasses to allow one side of the tuned circuit (*C2 − L1*) to remain at signal ground while current from pin 3 biases the i-f amplifiers connected to pin 1.

The internal i-f amplifiers also provide the limiting that eliminates any amplitude variations that might be present on the input signal. This also improves the rejection of the stereo subcarrier since the stereo information appears as amplitude noise.

The limited and amplified signal then enters the internal quadrature detector where capacitor *C7* and the tuned circuit formed by *L2, C8,* and *C9* form the required phase-shift network for tuning the detector. Resistor *R5* connected across the tuned circuit determines the bandwidth of the detector. The detected signal then drives a squelch-controlled audio preamplifier (also on the chip). A set of level detectors in each i-f amplifier provides a dc output proportional to the log of the input signal. This dc voltage is applied through *R2* to the base of *Q1*, while *C5* removes any 67-kHz component that might be included. When a predetermined signal level appears at the input to the i-f amplifiers, the base current of *Q1* causes it to saturate. Resistor *R3* forms the load for *Q1*. When *Q1* saturates, the low emitter-to-collector voltage cannot squelch the internal audio system. When the signal level drops below the predetermined level, *Q1* is cut off; and its output signal (at pin 5) is sufficient to operate the internal audio squelch.

The recovered audio output (pin 6) is de-emphasized by *R4* and *C10* while



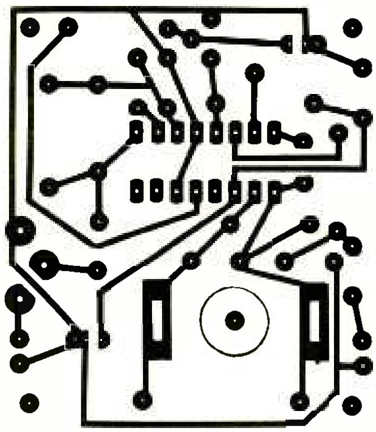


Fig. 3. Actual-size foil pattern and (far left) component installation. Observe polarities on electrolytics.

C11 blocks the dc component from the audio output.

Construction. Although there are no r-f signals present, the high gain of the IC makes parts placement in the circuit somewhat critical. A pc board is therefore recommended (Fig. 3). When tuning the capacitor, *C9*, is installed, the side of the capacitor having the top plate should be closest to capacitor *C6*. Observe the notch code on *IC1* and the polarities of the two electrolytic capacitors.

The test point is simply a small loop of bare wire, soldered into the board at the point (TP) shown in Fig. 3.

The demultiplexer requires between 9 and 16 volts dc at 20 to 30 mA. If it is not available from the conventional receiver, a small supply can be built using the circuit shown in Fig. 4.

Alignment. Use a shielded cable to connect the adapter input to the FM receiver. If you are lucky, the FM receiver will have a phono jack marked "detector out," "composite out," "output to MPX adapter," "output to stereo adapter," or some variation of these. If the receiver does not have this jack, a connection must be made to the FM detector *before* the de-emphasis network. Make the connection as shown in Fig. 5. Connect the output of the SCA adapter to the external audio amplifier and speaker.

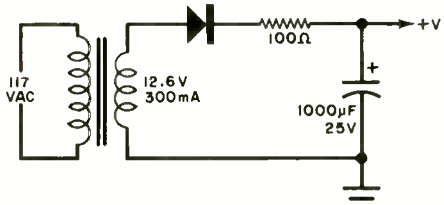


Fig. 4. This power supply can be built if not available elsewhere.

Before applying power, temporarily connect a short circuit between the emitter and collector of *Q1*. Adjust variable capacitor *C9* for half mesh, and set potentiometer *R1* fully counterclockwise (rotor at input end).

Connect a dc voltmeter from the test point to the side of *C9* closest to *C6*. Turn on the FM receiver and apply power to the SCA adapter. When the FM receiver is tuned across the band, noise and distorted main-channel programming will be heard on those stations not carrying SCA. When a station carrying SCA is tuned, this material will be heard. Adjust *C9* for zero volts on the dc voltmeter. If a dc voltmeter is not available, adjust *C9* for best results.

Remove the temporary short across *Q1*. If the audio output drops away when this is done, the SCA adapter is receiving too little signal. Check the connection to the FM receiver to make sure it is properly made.

The internal squelch circuit is used to quiet the SCA adapter between music selections in the event that the station making the SCA broadcasts turns off the subcarrier between selections. In this case, adjust potentiometer *R1* to silence the noise between selections.

The ultimate quality of the demultiplexed SCA signal is largely a function of the FM receiver. It is important to have a strong signal, as free of multipath as possible. It should be noted that the signal level required for noise quieting increases as the bandwidth of the received signal increases. It is for this reason that a stronger signal (compared to a mono transmission) is required for adequate reception of stereo broadcasts; and an even stronger signal is required when an SCA subcarrier is added. Note, also, that any distortion (such as phase) present in the FM receiver will appear in the demultiplexed signal as crosstalk.

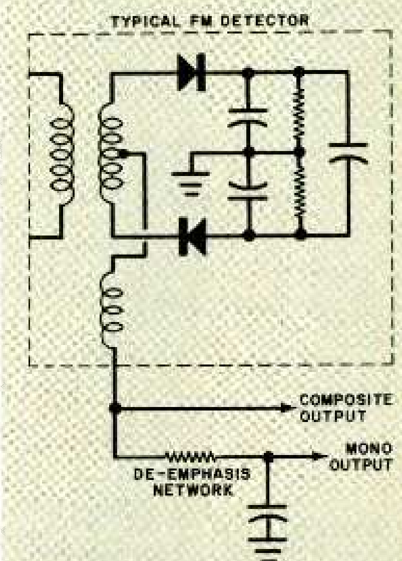
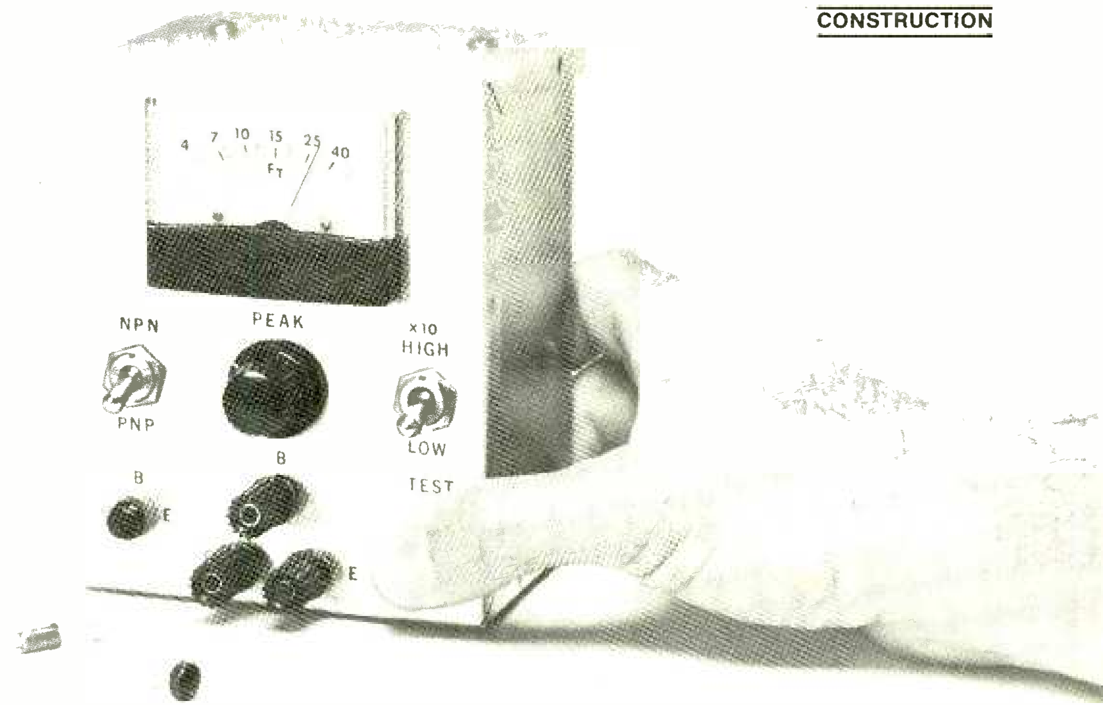


Fig. 5. Typical FM detector showing where the composite output can be taken out.

Modifications. There have been rumors of a proposal to reallocate the FM subcarriers to accommodate four-channel sound. If this comes about, or if you hear of any frequency other than 67 kHz being used for the SCA subcarrier, the SCA adapter described here can easily be modified for the new frequency by changing the value of two capacitors. For *C2*, the value is $10^9(4\pi^2f^2)$; and for *C8*, use $10^8/(4\pi^2f^2)$—70; where C is in picofarads and f is in kilohertz. ◈



R-F TRANSISTOR TESTER

Checks upper frequency limit of bipolar transistors

BY DANIEL METZGER

CHECKING out an r-f transistor on a "standard" tester is as tricky as testing a high-voltage TV tube on the corner-drugstore machine. When the indicator reads "good," the device can still be bad.

Unfortunately, most transistor testers perform dc checks only. They indicate the device's beta (amplification) and, in some cases, leakage current. Few check performance at radio frequencies, however, which is an essential parameter if you're troubleshooting a transistorized front end.

The important characteristic here is the transistor's cutoff frequency, f_T. As the frequency increases, a transistor's amplifying capability drops rapidly. Above f_T, there is no gain at all, and the transistor just doesn't work. You can check your transistors' f_T to determine if they will operate satisfactorily at r-f by building the circuit shown in Fig. 1. (For more about the importance of f_T, see the box on page 59.)

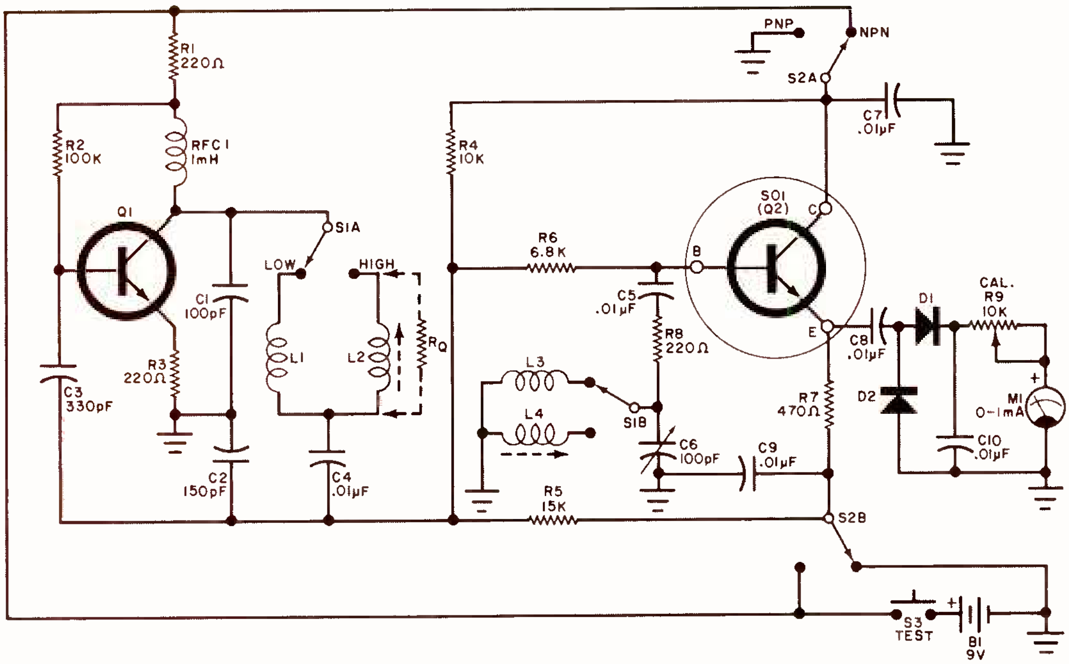
How It Works. The circuit is essentially an emitter-follower amplifier whose input impedance varies with the f_T of the transistor. The input impedance is then used as one leg of a voltage divider, and the output voltage, as indicated on the meter, is a function of f_T.

The *Q1* circuit is a conventional Colpitts oscillator running at 1 MHz on the LOW range and 10 MHz on the HIGH range of *S1*. A signal of approximately 6 volts p-p is applied to the left end of resistor *R6*. Resistors *R4* and *R5* provide base bias for *Q2*, the transistor being tested. Either *L3* or *L4* forms a tuned circuit with *C6* and the input capacitance of the transistor being tested. With *C6* tuned to resonance, the reactance of the transistor's C_{in}, which would otherwise load the signal, is cancelled.

The input impedance of the base of *Q2* is essentially beta times the emitter resistance. This emitter resistance is *R7* in parallel with the effective resistance of the metering circuit. Emitter resistance varies with the setting of the calibrate control, but should be near 400 ohms. If a transistor having an f_T of 17 MHz is checked on the 1-MHz range, it will have a beta of $f_T/f = 17/1 = 17$. The base input resistance of the transistor will then be:

$$r_b = \beta\, r_e = 17(400) = 6800 \text{ ohms}$$

The 6-volt p-p input signal is the voltage divided by *R6* and r_b to produce a 3-volt p-p signal at the base (and also at the emitter) of *Q2*. Diodes *D1* and *D2* rectify this signal, but since each diode requires about 0.6 volt before it begins to conduct, only about 1.8 volts dc appears across *C10*.



PARTS LIST

B1—9-volt battery
C1—100-pF disc capacitor
C2—150-pF disc capacitor
C3—330-pF disc capacitor
C4,C5,C7-C10—0.01-µF disc capacitor
C6—100-pF variable capacitor
D1,D2—Silicon signal diode (1N914 or similar)
L1,L3—400-µH inductor
L2,L4—25 turns No. 26 enamel wire, close-wound on ¼-in. slug-tuned form
M1—0-1-mA dc meter movement
Q1—Transistor (2N4124 or similar)
Q2—Transistor under test
R1,R3,R8—220-ohm, ½-watt resistor
R2—100,000-ohm, ½-watt resistor
R4—10,000-ohm, ½-watt resistor
R5—15,000-ohm, ½-watt resistor
R6—6800-ohm, ½-watt resistor
R7—470-ohm, ½-watt resistor
R9—10,000-ohm trimmer potentiometer
RQ—3300-to-33,000-ohm resistor (see text)
SO1—Transistor socket
S1,S2—Dpdt toggle switch
S3—Spst normally open pushbutton switch

Fig. 1. The transistor being tested (Q2) is connected to socket SO1. Transistor Q1 is an r-f oscillator which supplies a signal to Q2. Frequency is changed by switching reactances.

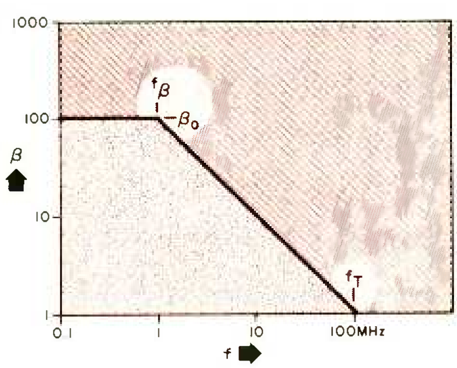
Construction. Almost any type of construction can be used. The prototype was built up on a small piece of perforated board. However, keep in mind that the tester operates in the r-f range, so all leads must be as short as possible.

The test socket (*SO1*) and all controls and switches (except for *R9*) are mounted on the front panel. The battery is supported by a mounting clip. Coils *L2* and *L4* are mounted on a small metal bracket so that their screwdriver adjustments can be easily reached.

On the prototype, three five-way binding posts were connected to *SO1* and mounted on the front panel to facilitate testing using clip leads to connect to the transistor.

Calibration. Calculations such as those given above and in the box can be extended to apply to a range of f_T values and a calibration chart for the low range of the meter can be constructed as shown in Fig. 2. Other values of *R6*, *R7*, and signal frequency can be used to alter the range of the instrument, but care should be taken to ensure that betas higher than 50 will

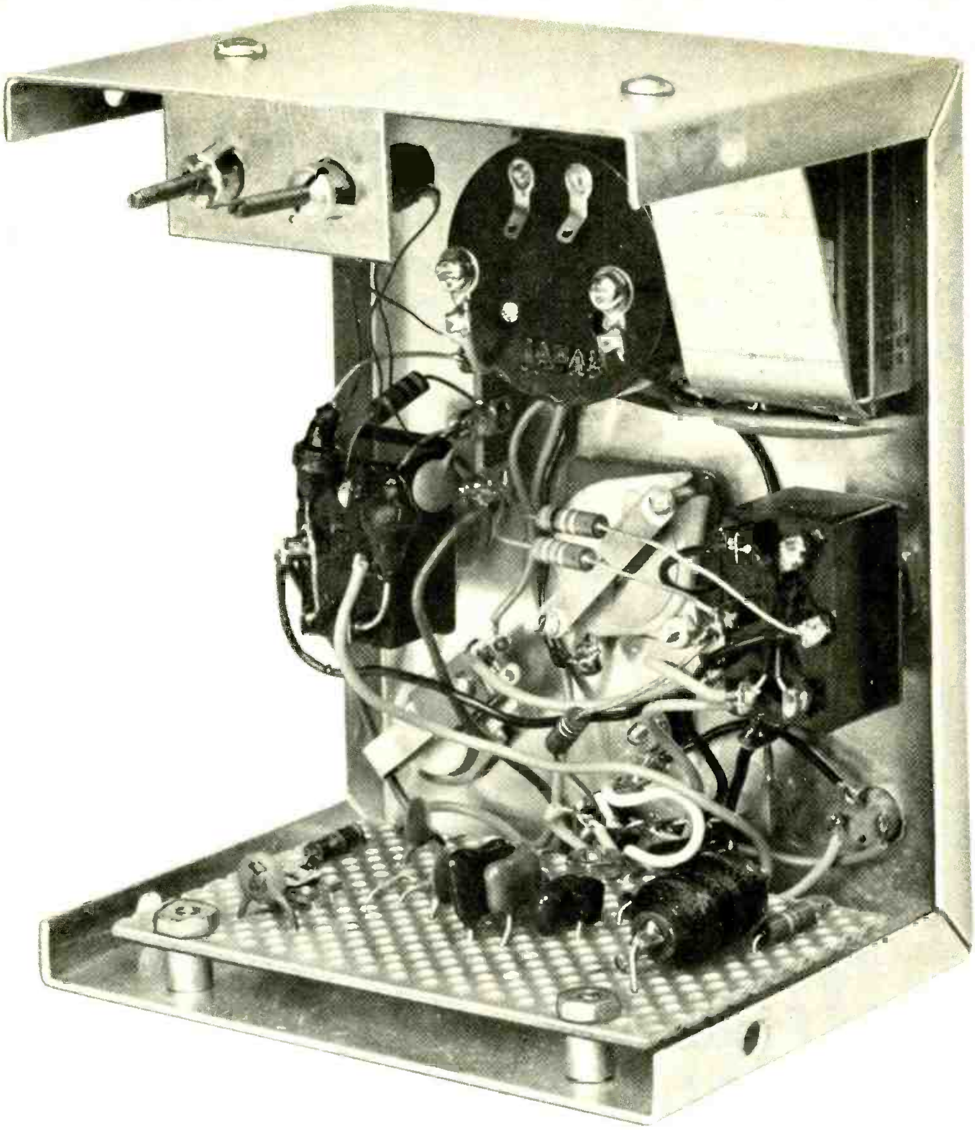
WHAT IS f_T?



The cutoff frequency (sometimes also called gain-bandwidth product) is the frequency at which the current gain (h_{fe}) drops to unity. For frequencies lower than f_T, h_{fe} increases linearly at a rate of 6 dB per octave. (The beta doubles as the frequency is halved.) The rise in beta continues until the low-frequency beta (β_0) is reached at the beta cutoff frequency (f_β) as shown in the diagram. Notice that, for any frequency above f_β, the product of current gain and operating frequency is constant and equal to f_T. Hence, the name gain-bandwidth product for f_T.

Calculating h_{fe} at any frequency when f_T is known is a simple matter if this relationship is kept in mind. For example, if a transistor having an f_T of 200 MHz is to be used in a 27-MHz amplifier, its effective beta is f_T divided by f or 200/27 = 7.4.

To find the frequency at which beta will begin to drop below its full low-frequency value, the procedure is reversed. Thus, in the example above, if the transistor has a low-frequency beta of 150, it will begin to drop at 200/150 = 1.33 MHz.



This photograph shows how prototype was assembled. Be sure to use short lead lengths to avoid r-f interference.

always drive the meter above full scale. This is because many transistors have a low-frequency beta not much higher than 50 and they would otherwise read low on the f_T scale.

To calibrate the instrument, a high-beta transistor with an f_T specification above 250 MHz is inserted in test socket *SO1* with range switch *S1* on LOW. The author used a 2N4124 with a measured low-frequency beta of 200. The beta of the transistor is known to be 200 at 1 MHz, giving an I_m of 1.3 mA as shown in the last line of Fig. 2. A 3-mA meter is then inserted in series with the instrument's meter, and *R9* is adjusted for 1.3 mA. The low range of *S1* is now calibrated. Use *C6* to set the meter pointer at maximum.

To calibrate the high range, it is necessary to insure that *Q1* is really oscillating at 10 times the low frequency (10 MHz in this case). This can be determined by using a grid-dip meter, a high-frequency oscilloscope, or a frequency counter.

Finally, the output of the oscillator (junction of *R4* and *R6*) must be checked with an r-f voltmeter and trimmed if necessary to keep the r-f output constant in both the high and low ranges. The trimming is accomplished by placing a resistor (*RQ*) across *L1* or *L2* and choosing its value so that the r-f voltmeter reads the same on both ranges. The resistor effectively lowers the Q of the coil and reduces the oscillator output on the range for which it is inserted. The value of *RQ* may be from 3300 to 33,000 ohms, depending on the difference in Q between the two coils. The calibration for the high range is simply 10 times the low range. ◈

FIG. 2. SAMPLE CALIBRATION CHART

f_T MHz	β	r_b Ohms	v_e Volts (p-p)	V_{C10} Volts	I_m mA
4.2	4.2	1.67 K	1.2	0	0
7.0	7	2.8 K	1.7	0.5	0.15
10	10	4.0 K	2.2	1.0	0.30
17	17	6.8 K	3.0	1.8	0.55
30	30	12 K	3.8	2.6	0.79
50	50	20 K	4.5	3.3	1.00
>250	200	80 K	5.5	4.3	1.30

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BUILD A Shirt-Pocket METRONOME

BY A.A. MANGIERI

Provides precision audible count of 40 to 220 beats per minute.

THE ubiquitous 555 IC is proving to be the answer to many timing problems. Here, for example, it is used as the heart of a precision shirt-pocket electronic metronome having an adjustable range from 40 to 220 beats per minute. It costs less than $5 to build.

About the Circuit. The timer (*IC1*) is operated as an astable oscillator whose period is determined by capacitor *C1* and timing resistors *R1* through *R3*. When the voltage across *C1* reaches ⅔ of V_{cc}, *C1* discharges rapidly through *R1* and the internal circuit of the IC to ⅓ of V_{cc}, and then the cycle repeats. With the IC trigger terminal (pin 2) connected as shown, the IC re-triggers itself to initiate the next cycle.

The output of *IC1* (pin 3) is a pulse which drives a small speaker voice coil through coupling capacitor *C2*. Using small resistance values for *R1* and large values for *R2* and *R3* produces brief pulses at moderate time intervals, with potentiometer *R3* determining the repetition rate.

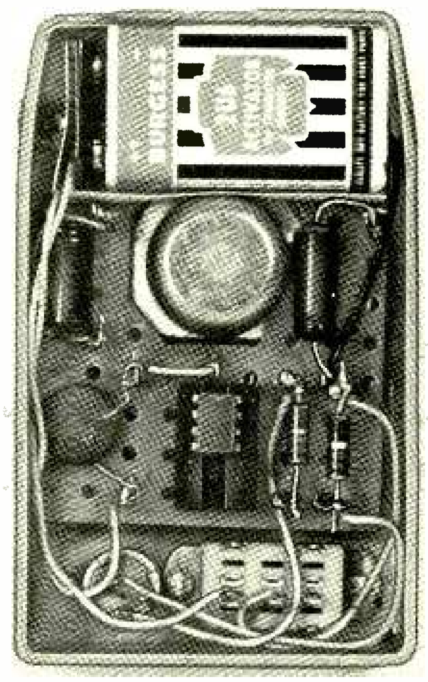
Since the trigger levels of the IC depend on the ratio of some "on-the-chip" resistors, timing is not affected by changes in the supply voltage. Also, because the 555 delivers sufficient current, a much higher audio volume will result than in the conventional UJT approach.

Construction. Using a socket for *IC1*, the complete circuit can be assembled on a small piece of perf board and installed in almost any type of chassis. The prototype, as shown in the photos, was built in a plastic transistor radio case.

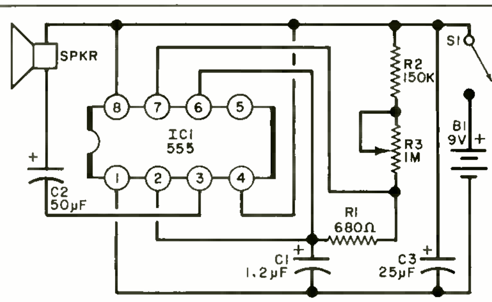
The metronome should deliver 40 to 200 beats per minute, so set *R3* at maximum resistance and pick a capacitance for *C1* that will provide slightly less than 40 beats per minute. This is done by using five 0.22-μF disc capacitors and padding them until the desired 40 beats are obtained. Then set *R3* to minimum resistance and pick a resistance for *R2* that will provide slightly more than 220 beats. You can count the beats over a 5- or 10-second interval.

The impedance of the speaker limits the peak current surges through the output stage transistors. The prototype has been used with six-inch speakers having only several ohms of resistance and also with a 16-ohm speaker. So pick a speaker that will fit the selected enclosure.

Use a dial scale on *R3*, and calibrate it at the most frequently used rates. For photographic work, make the one-per-second beat calibration the most accurate.



The author's prototype, using perf board, fits in transistor radio case.

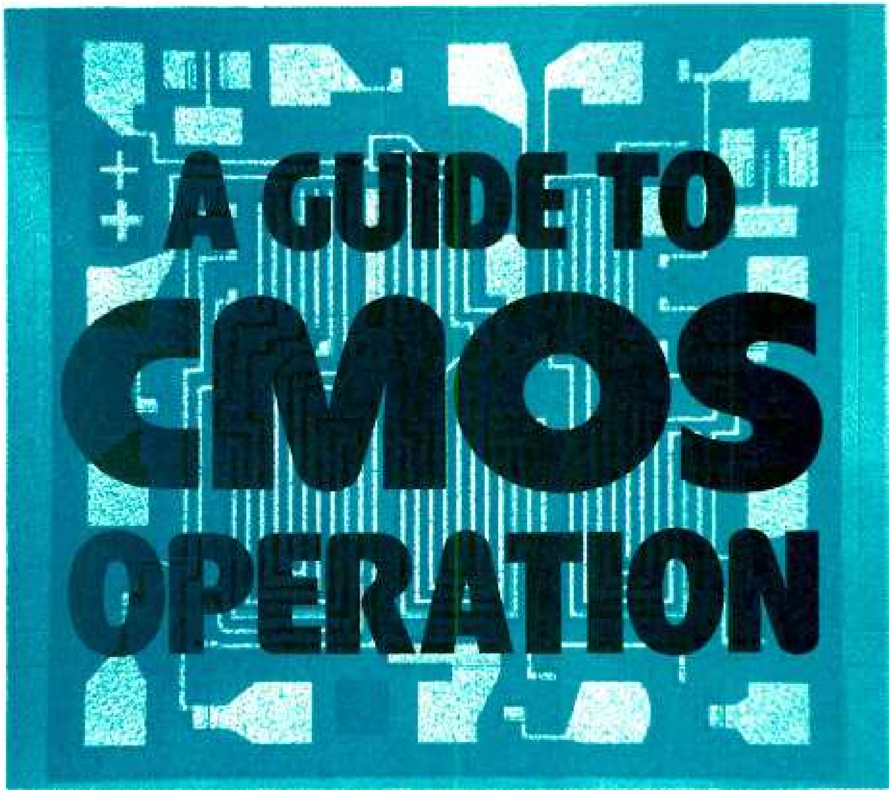


The clock rate, generated by IC1, is determined by C1 and the associated resistors. A small speaker converts current pulses to audible clicks.

PARTS LIST

B1—9-volt transistor battery
C1—1.2-μF, 12-volt disc capacitor (see text)
C2—50-μF, 15-volt electrolytic capacitor
C3—25-μF, 15-volt electrolytic capacitor
IC1—555 IC timer
R1—680-ohm, ½-watt resistor
R2—150,000-ohm, ½-watt resistor (see text)
R3—1-megohm miniature linear-taper potentiometer
S1—Spst slide switch
SPKR—Miniature speaker
Misc.—Case, perf board, IC socket, push-in terminals, battery clip, knob, etc.

Application. Turn on the metronome and adjust *R3* for the desired beat rate. After *S1* is first turned on, a few moments will elapse before the first click is heard while the dc voltage levels become established. Replace the battery when the audio output drops below a satisfactory level. The average current drain is about four milliamperes, so battery life should be long. ◈



Photomicrograph of COS/MOS chip courtesy RCA Corp.

Complementary-Symmetry Metal-Oxide Semiconductor IC's are revolutionizing circuit design concepts. Here's how and why they are fast replacing TTL in applications from electronic timepieces to frequency synthesizers.

BY WALTER G. JUNG

ARE YOU confused by CMOS IC's? For instance—what do they do? How do they do it? How are they different from other types? And, how are they the same (if at all)? Well, chances are we've all wondered at one time or another about some aspect of the CMOS puzzle. Maybe now is the time to sort out the pieces, one at a time.

The CMOS is not like any other form of IC, even if we were to restrict the discussion to the digital form of CMOS. Don't try to make comparisons or analogies to DTL, TTL, or, for that matter, any other logic. Not only is CMOS a unique type of IC logic; it is also usable in linear applications.

The Basic CMOS Structure. Any kind of IC, no matter whether it is digital or linear, must contain some type of amplifier because it is the amplification that does the useful work. When you get right down to it, the type of amplifier used in CMOS really provides its uniqueness.

There are a few things that most circuit designers want in an ideal amplifier: high input impedance (so as not to load down the input signal); low output impedance (to drive many other stages); and high voltage swings (about 100% of the power supply for CMOS). Then, why should we waste voltage drops in biasing? In fact, why not eliminate biasing? Also, why not have an amplifier that does not consume any standby power? The only power used should be in the load. Finally, the amplifier should be as simple as possible (with only one or two components, for instance).

By now, you are probably saying all this sounds ridiculous; but hang on for a moment, and see how closely we can come to this ideal amplifier.

Most of us know that a MOSFET (metal oxide semiconductor field effect transistor) has an extremely high input resistance, usually a million megohms or more. MOSFET's are voltage-operated devices, responding to an input voltage rather than current. The voltage applied to the gate controls the drain-to-source resistance. Therefore, a MOSFET can be looked upon as a voltage-controlled resistor. The range of control varies from a few hundred ohms when on, to several thousand megohms when off. MOSFET's come in two types: p channel and n channel. A p-channel MOSFET conducts when its gate goes negative and an n-channel unit conducts when its gate is positive. Thus it can be seen that p- and n-channel MOSFET's complement one another; and, in fact, using matched p- and n-channel MOSFET's gives complementary MOS or CMOS.

A CMOS amplifier stage is shown in Fig. 1. This is the most basic form of CMOS circuit and is functional as shown. Using just two transistors as an amplifier seems unusual; but, in fact, this circuit will serve in a variety of digital and linear applications, as we shall see later.

In Fig. 1, *P1* is the p-channel device, and *N1* is the n-channel part. This is an inverting amplifier with both units operating in the common-source mode so *P1's* source goes to the supply, while *N1's* source goes to ground. In MOS language, V_{DD} is the positive supply and V_{SS} the negative supply voltage. These are simply new terms—one for what we have previously known as V+ and the other for the normal ground.

In spite of all its simplicity, there is a key to what enables the circuit to work, and this is the matched and complementary characteristics of the p and n units. If, for instance, a voltage of exactly half of V_{DD} is applied to the input, both the p and n units will have an equal amount of voltage from gate to source; and both will conduct equally. If both are conducting equally, they may be likened to a matched pair of equal-value resistors, so that the output is $\frac{1}{2}V_{DD}$, precisely balanced. Surely, a stage couldn't be biased more simply than this.

The stage also has an appreciable voltage gain, since a common-source amplifier is, in this regard, similar to a common-emitter stage, noted for its high gain. Gain will vary with supply voltage, but we will have more to say on that later, also.

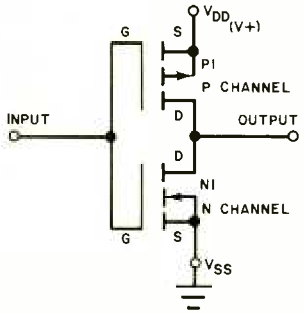


Fig. 1. Basic CMOS stage consists of n-channel and p-channel MOSFET. Input impedance is high, output impedance is low.

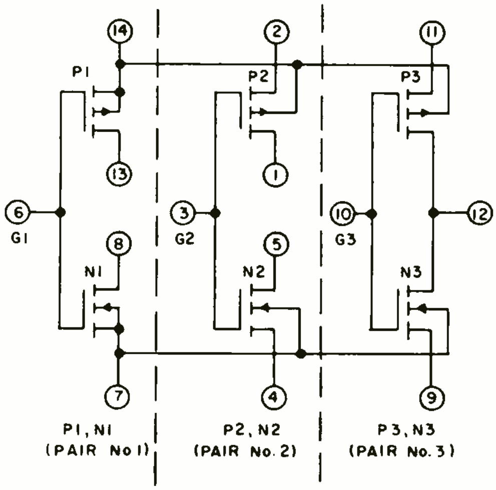


Fig. 2. RCA's COS/MOS CD4007AE and CA3600E three-section arrays.

Suppose there is an increase in the input voltage—approaching V_{DD}. This produces less bias on *P1* and more on *N1*. Consequently, *N1* is turned on more (lower resistance) and *P1* less (more resistance). More resistance in *P1* and less in *N1* changes the balance of this "voltage divider" and the output goes lower, approaching ground. As you can see, a negative-going input reverses the order, sending the output to a higher level. The complementary units, *P1* and *N1*, act as an electronic "see saw" adjusting their respective resistances in response to the change in relative input voltage. They can, in fact, be viewed as an electronic voltage divider whose common point can be moved from ground to V_{DD}, controlled by the input voltage.

Typical CMOS stages achieve input resistances of 10^{12} ohms and an input current of only 10 pA, and that is high Z. Output impedance is a few hundred ohms, varying slightly from one type to another; but the point is that one of these stages can certainly drive a great number of similar ones. In addition, they can be operated over a wide power-supply range since the p and n units are designed to match over a range of 3 to 15 volts. Since either the p or n transistor can be turned on while its mate is completely off, the output swing is high in either direction.

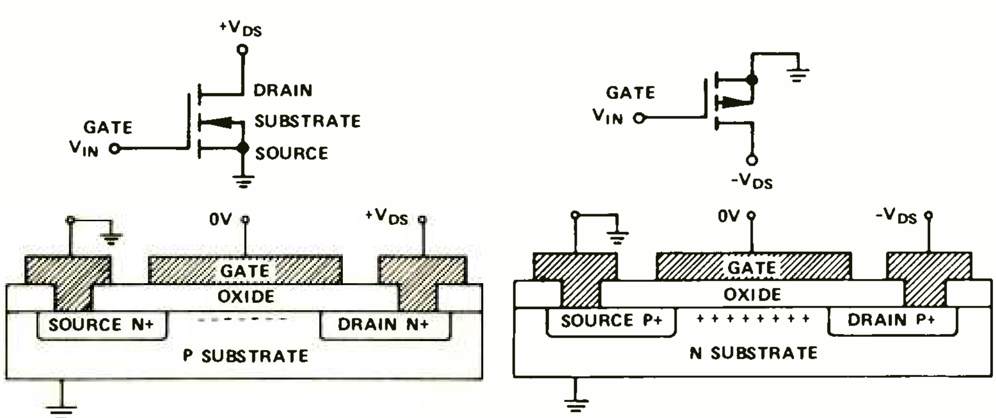
Moving from generalities to hardware, consider some representative CMOS units. The CD4007AE and CA3600E (Fig. 2) are both made by RCA, which first introduced CMOS in its COS/MOS series. These two units are chosen as examples because they can be used to set up a wide variety of different experiments and are readily available. They also illustrate both the digital and linear aspects of CMOS.

The CD4007AE and CA3600E are identical with regard to pin arrangement and they are interchangeable in many circuits. The main difference between the two is that the CA3600E has characteristics controlled for linear service, which (in general) is tighter.

CMOS in Digital Applications. Digital use of an amplifier implies operation in a switching mode, an ideal application for CMOS. In the inverter of Fig. 1 for example, if the input is low or near ground, *N1* will be completely off and *P1* completely on. So *P1*'s resistance is at its lowest point of about 500 ohms, and *N1* is effectively an open circuit. Under these conditions, the output pulls up to V_{DD}, since it simply looks like a 500-ohm resistor to V_{DD}. So the high logic level of CMOS is essentially equal to V_{DD}. By essentially, we mean within a few millivolts. If the state of the input is reversed and a high level is applied, the output state reverses, and *N1*'s low resistance pulls the output to ground. Since, in this state, the output looks like 500 ohms to ground, a CMOS logic low looks essentially like ground (also within a few millivolts). If no current is flowing from the output, which is usually the case when driving other CMOS stages, there will really be no measurable difference between the high and low output levels compared to V_{DD} and ground, respectively. This is logical, because if no current flows through the 500-ohm resistance, there is no voltage drop.

This brings up another interesting point—in either the digital high or low state, one of the two transistors is always off. This means that there is no static power drain in a CMOS digital stage because one of the two switched devices is always in a high-resistance state. The only current that flows is due to leakage and is far down in the sub-microampere range—about 5 nanoamperes for the CD4007AE. That is why CMOS provides low-power logic: one of the two series switches is always off.

Logic Threshold. So far, we have discussed the effects of a high- or low-level digital input voltage. But this is hardly the whole story. There are the "in-betweens" but they present no problem. A CMOS stage's output is balanced when the input is $\frac{1}{2}V_{DD}$ and for digital use, this means that above or below the balance point, the output will go toward its low or high state.



Operation of n-channel (left) and p-channel MOSFET's as depicted by Solid-State Scientific.

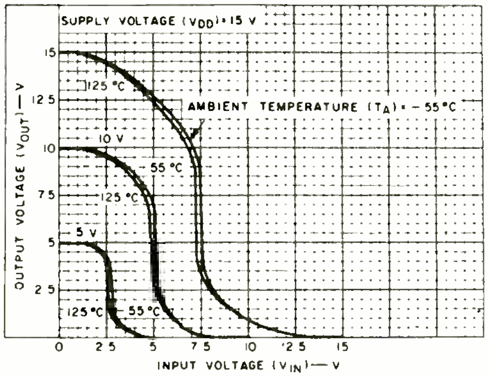


Fig. 3. Transfer characteristics of typical COS/MOS stage show input threshold stability for variations in supply or temperature.

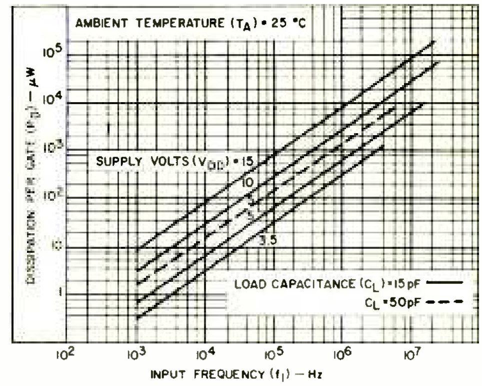


Fig. 4. Curves show how dissipation of RCA COS/MOS logic stage increases according to frequency, supply, and load capacitance

Since the stage has a fairly high gain, it is not necessary to go very far from the input voltage's center point to flip the output completely high or low. To simplify matters even more, this $\frac{1}{2}V_{DD}$ switching threshold very nicely stays constant over wide temperature ranges—even over the operating range of supply voltage.

A graph of this effect is called a "transfer characteristic" and a family of these is shown in Fig. 3. What these curves show is how the output responds as the input changes. The important thing to note is that, for any supply voltage (5, 10, or 15 V), the output changes (dropping in this case) at a point where the input equals $\frac{1}{2}V_{DD}$ (2.5, 5 or 7.5 V). A more subtle point is that each set of curves also shows variations of the thresholds for temperatures from −55° to 125°C. This means that temperature effects at room temperature operations are negligible.

The important thing to remember about CMOS logic is that its input switching threshold is ½ the supply voltage for any value of supply (within rating of course). This is not true of any other form of logic.

Power Dissipation and Frequency Effects. As long as one of the series n or p units of a CMOS amplifier is off, there is no great power drain (with dc operation). However, because of the duration of time that they are both on, they look like a pair of resistors in series across the power supply. And, they draw a pulse of current for the time they are on. The level of this current pulse increases with the supply voltage, reaching about 10 mA at V_{DD} = 15 V. What this means is that CMOS power drain increases with frequency since every time the stage switches, it draws current.

This effect is summarized in Fig. 4, a graph of power versus speed. Although this curve is from a CD4007A data sheet, there is similar information for other CMOS units. The curves show the power dissipated in a single gate as the operating frequency is increased.

As an example, note that, at V_{DD} = 15 V and with a frequency of 1 MHz, the dissipation of an individual gate is 10^4 microwatts or 10 mW, which is not really very low. On the other hand, at frequencies of 100 Hz or lower, the power drops to 10 microwatts or less per gate, depending on supply voltage. In practical terms, this means that, if a CMOS system has a timing cycle of seconds, the ac power dissipation effects can be disregarded. For a CD4007A, the dissipation is typically 0.05 microwatt per gate with a 10-volt supply. This means that, for battery operation, the power drain will hardly affect the battery more than if it were sitting on the shelf.

Load capacitance also affects power dissipation since it takes higher average current to charge a high capacitance. This effect is shown in Fig. 4 (dashed line). To summarize, lowest power results from lowest supply voltage, lowest load capacitance, and lowest clock frequency.

Speed Capability. While it is true that the biggest advantage of CMOS is at low-speed operation, the devices can be used at speeds up to several MHz and propagation times in the 50-to-100-ns range. Of course, that is not "super" fast, so if speed is a main consideration, other devices should be used. There are, however, some general rules that can be used to improve the speed obtainable in CMOS circuits.

First, speed capability increases with supply voltage. This is because, as supply voltage increases, the resistances of the n and p units drop during the conducting state. This allows shorter RC time constants. The time constant is determined essentially by the output impedance of the CMOS and the load capacitance. If either is lowered, the speed is increased. The CD4007AE propagation time at 5 volts (for instance) is about 35 ns; but at 10 volts, it is 20 ns. Looking at it from the capacitance angle, increasing the load capacitance to 80 pF from 15 pF, while operating at 10 volts will increase the propagation time from 20 to 50 ns.

Gates, inverters, buffers, and simple

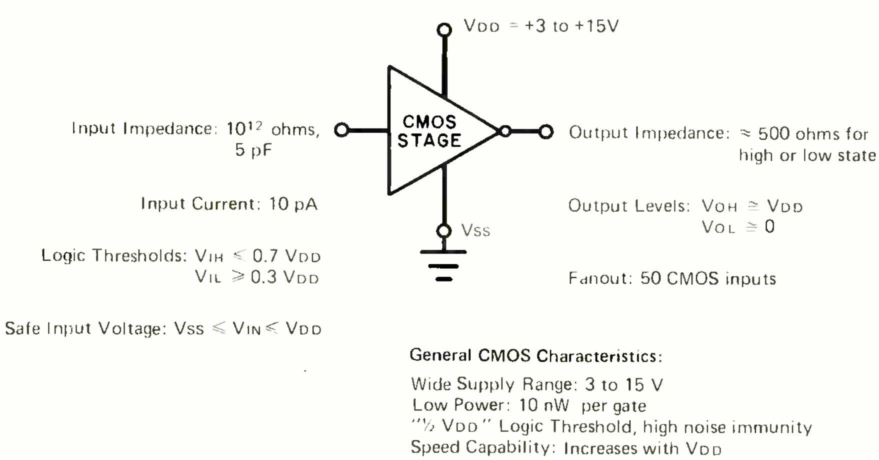


Fig. 5. Capsule summary of CMOS logic stage.

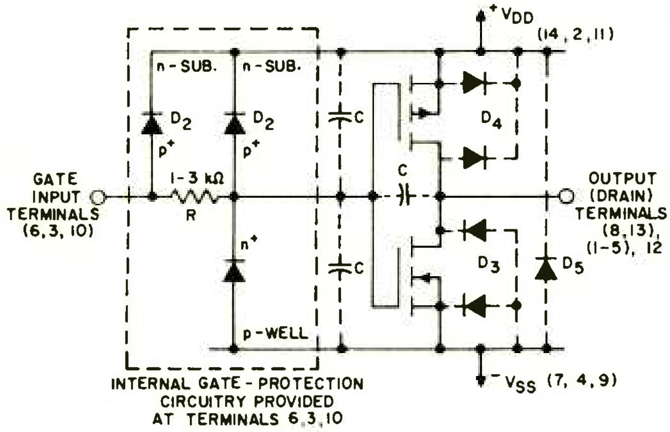


Fig. 6. Internal voltage clamping diodes protect terminals of RCA COSMOS

logic elements are measured in terms of propagation delay. Flip-flops and registers are rated in terms of toggle speed; and the lower the propagation delay, the faster the toggle speed. Some typical numbers for CMOS flip-flops are 4 MHz at 5 V, 10 MHz at 10 V, and 13 MHz at 15 V.

The important thing to remember is that CMOS is not really fast, and operation at even a few MHz means a sacrifice in power. However, if appreciably higher speeds are necessary, CMOS units can be mixed with a faster type of logic (such as TTL) which can handle higher speeds. Interfacing the two types will be discussed later. Higher speeds can of course be obtained by reducing the load capacitance and using additional drive. This can be accomplished by using a high-power CMOS buffer stage, and paralleling stages.

CMOS Fanout. Problems of limited current drive in a CMOS system are not likely to be encountered since a single output can drive virtually any number of inputs. Remember the gate input current is only 10 picoamperes. However, it must also be remembered that each gate represents about 5 pF and enough 5-pF capacitances in parallel (with some stray capacitance) increase the propagation time as we mentioned before. So the ac effects are the real limiting factor in CMOS fanout. To be conservative and minimize speed degradation, most CMOS manufacturers say the fanout is 50 CMOS inputs for one CMOS output.

Summary of Characteristics. Before getting into other logic functions and the CMOS family, it is a good idea to note again the characteristic highlights. This is done in Fig. 5.

CMOS Handling—The Facts of Life. Like many MOS devices, CMOS transistors are subject to damage when abused. This means they can be easily destroyed if not properly handled. This should not prevent them from being used, however, if some simple do's and don't's are observed:

(1) Keep unused devices in conductive foam (in which most of them are packed) or somehow short the leads until ready for use to prevent static build-up. Never put them in styrofoam or "snow."

(2) Use grounded soldering tips and grounded test fixtures.

(3) Never insert or remove a CMOS device with the power on. In breadboarding, use sockets; and make circuit changes with the chip out.

(4) Observe the input voltage limits faithfully. This means that the input voltage must be less than or equal to V_{DD} and greater than or equal to V_{SS} (normally ground). If either limit is exceeded, internal diodes will conduct and, if the current is not limited, the chip will be destroyed. These diodes are shown in Fig. 6. They are used at each gate terminal of CMOS IC's. There are also diodes between the output pins and each supply line. These should never be forward biased unless the current is limited to about 100 microamperes or less. All of this means that an input signal can be applied only with the power on, unless some series input resistance is used to limit current flow.

(5) Don't allow unused inputs to float. Tie them high and low according to their function (AND high, OR low), or tie them in parallel with a like input from the same gate. Input leads which go off the board should not be left hanging since, when the board is removed, they will be floating. A simple 1-megohm resistor to ground will solve this problem. In the CD4007AE and CA3600E units, connect unused p and n sources to V_{DD} and V_{SS}, respectively (for example, 2 and 11 to 14 or 4 and 9 to 7).

CMOS MANUFACTURERS

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Motorola Semiconductor Products **Box 20912** **Phoenix, AZ 85036**	**14500, 14000 (A&B)**
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Applications for CMOS. Now that we have considered the basics, we can move on to the use of CMOS in circuits that provide the various logic functions. These run the gamut from simple gates and flip-flops to registers, arithmetic units, and even memories. Space does not permit our going into detail on all of the circuits, but we will be able to get an idea of how the low-order functions operate. Most of them can actually be assembled using either the CD4007AE or CA3600E for experimentation.

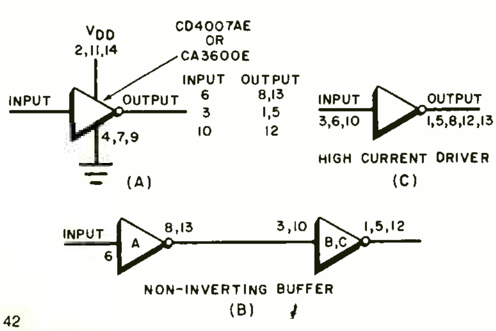

Fig. 7. Using the CMOS as a triple inverter (A), a non-inverting buffer (B), and (C) as high-current driver with units in parallel.

Inverters and Buffers. The basic inverting function is a natural for CMOS. In fact, the CD4007AE and CA3600E contain three inverters in one package with pin connections as shown in Fig. 7A. Note that there are three pins for V_{DD} and three for the ground.

A noninverting buffer can be made by cascading two inverters as shown in Fig. 7B. However, note that in the second stage of this circuit, sections B and C are connected in parallel. This allows them to function as a single stage with twice the output drive—a neat trick to remember. This paralleling of like stages can be done with as many CMOS sections as necessary, as long as they are in the same package. With the CD4007AE or CA3600E, up to 3 sections can be connected in parallel as shown in Fig. 7C.

Paralleling can be used in digital or linear applications. A single CD4007AE section can handle up to 2.5 mA of output current with a 10-volt supply; 3 sections boost the output to 7.5 mA. This is valuable in driving TTL with CMOS; for example, three CD4007AE sections with a 5-volt supply will drive four low-power TTL stages. When driving into CMOS from TTL, however, be sure to add a pull-up resistor (about 4700 ohms) to the 5-volt supply.

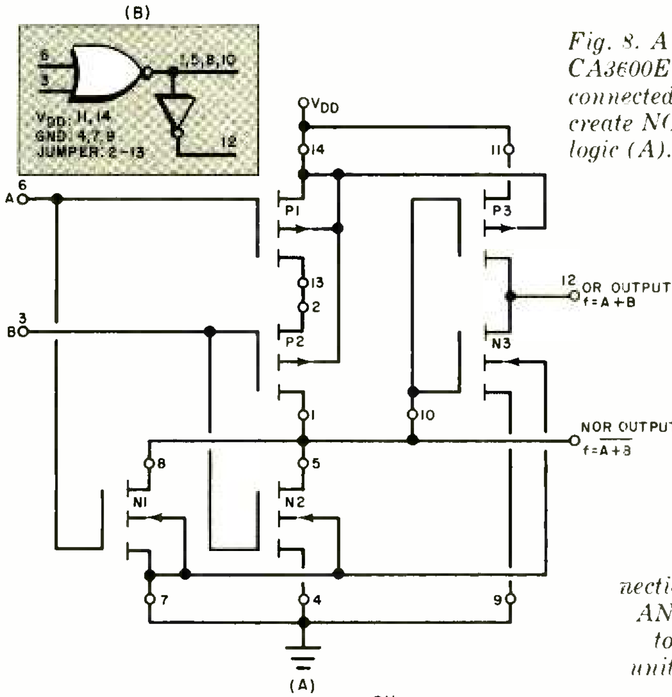

Fig. 8. A CD4007AE or CA3600E can be interconnected as shown to create NOR or OR logic (A). Symbol is at (B).

NOR and OR Functions. The gate structure of CMOS logic is as interesting as the basic amplifier and is almost as uniquely simple. It involves interconnections of p and n transistors to perform the required logic. Figure 8A shows how simple it is to construct a NOR (or OR) gate. In the NOR gate, if either input is high, the output will be low. If both inputs are low, the output is high. The NOR logic is performed by *P1, P2, N1, N2*. If either the A or B input is high, *N1* or *N2* is held low by the low resistance of *N1* (or *N2*). Also, during a high input, either *P1* or *P2* is off, so there is no series path to V_{DD}. But suppose both inputs are low. Then, both *P1* and *P2* are on and *N1* and *N2* are off. The output is pulled high to V_{DD} by the low on resistances of *P1* and *P2* in series. With only 4 transistors, this circuit performs the NOR function; and it can be wired up easily using the pin connections shown.

By adding a third stage as shown in Fig. 8A, a 2-input OR/NOR gate is obtained. The logic symbol for the complete gate is shown in Fig. 8B.

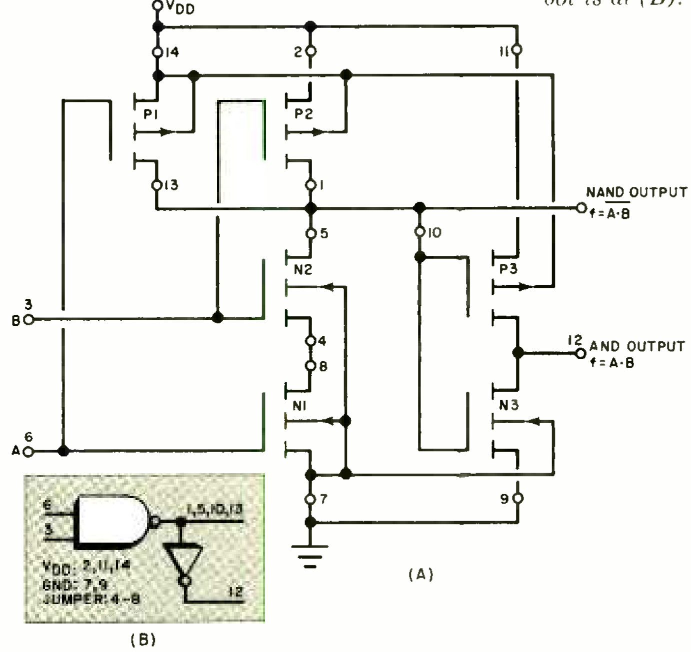

Fig. 9. The interconnections for a NAND and AND circuit are similar to those in Fig. 8, with units upside down. Symbol is at (B).

Two-input gates are by no means the limit. NOR gates with three, four, or more inputs, can be built by stacking more p units in series and adding more complementary n units in parallel. In fact, the CD4007A data sheet shows an example of a 3-input NOR. However, beyond 3 inputs, or for a number of gates, it is better to use units already manufactured—of which there are several. The CD4001AE, for example, is a quad, two-input NOR; the CD4002AE is a dual, four-input NOR; and the CD4025AE is a triple, three-input plus inverter. By examining the schematics of these devices, it can be seen that more inputs are added by building on the basic gate of Fig. 8A.

NAND and AND Functions. NAND logic is also very simply created by interconnecting p- and n-channel transistors. The NAND function means that, if both inputs are high, the gate output is low. If either input is low, the output is high. This is shown in Fig. 9A.

Note that this circuit is somewhat similar to the NOR gate with the series and parallel devices "turned upside down." The series-connected units, *N1* and *N2*, are both on when A and B are high. Consequently, the output is low only when this is true. If either A or B is low, the series *N1-N2* path is broken. Also, a low on either A or B means that *P1* or *P2* is on, so the output is high. With the pin numbers shown, either a CD4007AE or CA3600E can be used for this gate. To get an AND func-

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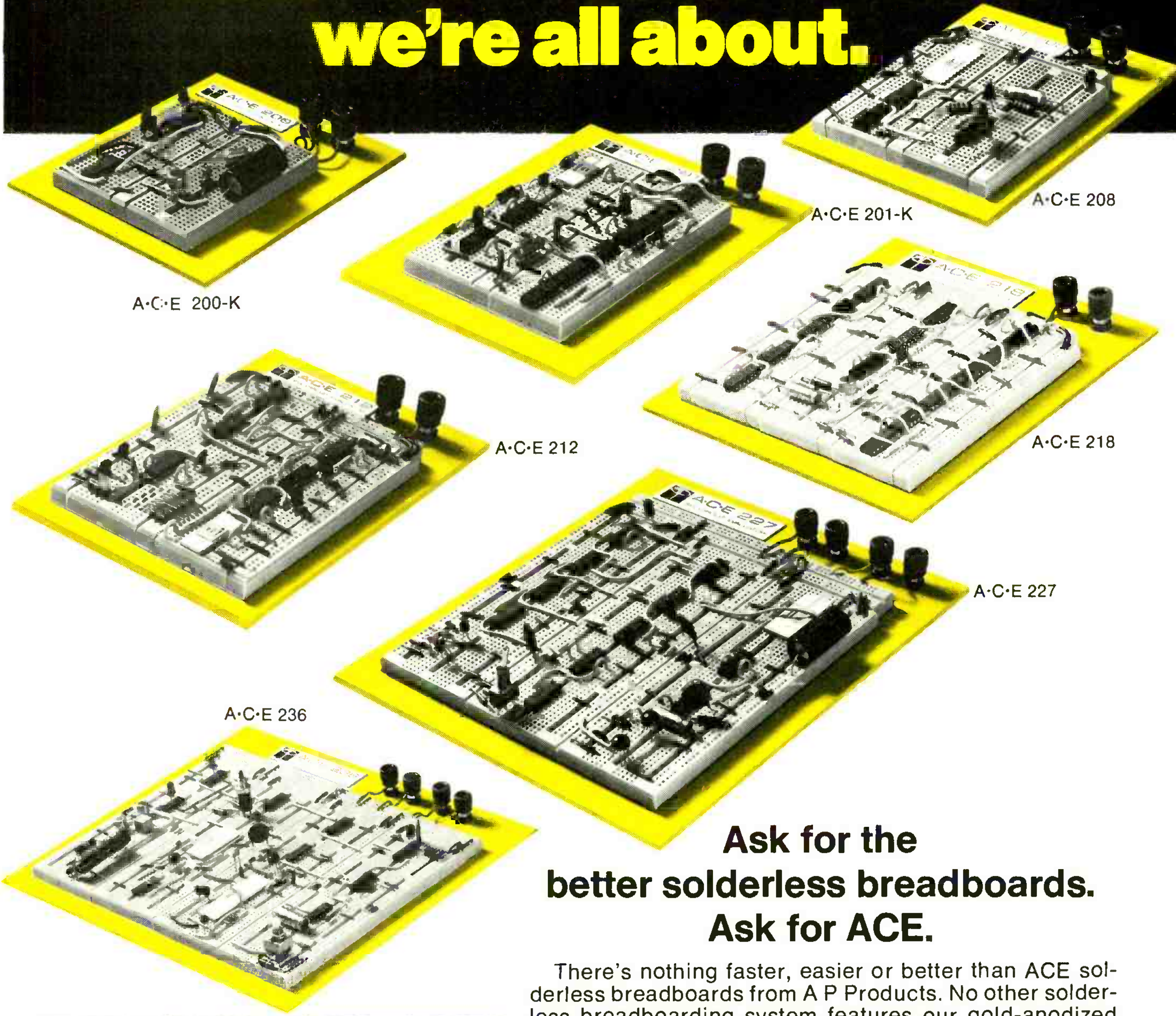

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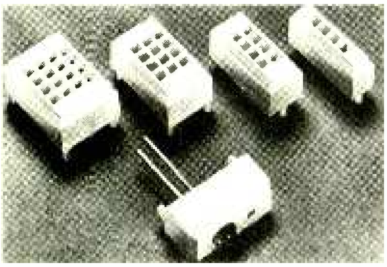

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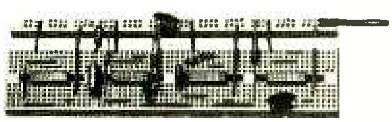

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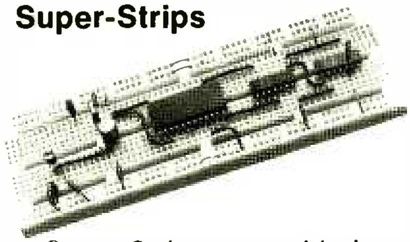

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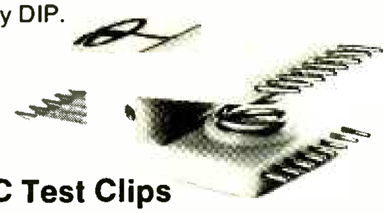

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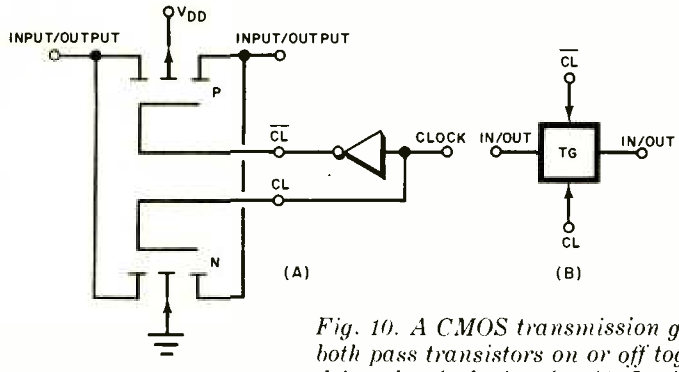


Fig. 10. A CMOS transmission gate (TG) has both pass transistors on or off together when driven by clock signals (A). Logic diagram is at (B).

tion, add the *P3/N3* inverter. The logic is in Fig. 9B.

As with the NOR gate, more inputs can be added by stacking more series n units and more shunt p units. For example, the CD4007A data sheet also shows a 3-input NAND. For multiple circuits, however, there are devices that will serve the purpose without stacking. The CD4011AE is a quad, two-input NAND; CD4012AE is a dual four; and CD4023AE has triple, three-input capability.

While these basic multiple gates offer either NAND or NOR logic as they stand, AND/OR functions can be obtained by using inverters. Having both NAND and NOR logic readily available greatly simplifies logic designs since it isn't necessary to invert to use only one type of gating (often necessary with TTL or DTL, which use NAND logic).

Transmission Gates. The logic functions we have discussed so far are really just variations on the basic inverter. For counting and storage elements, a new type of CMOS is used—one which has no counterpart in other types of logic. This is the transmission gate, a basic building block which is used in flip-flops, counters, shift registers, and memories.

As its name implies, a transmission gate is used to transmit or block a signal. Its circuit is quite simple, as shown in Fig. 10A.

To form a transmission gate p- and n-channel transistors are connected in parallel and placed in series with the signal to be controlled. Since a CMOS transistor is really a voltage-controlled resistor, a transmission gate uses this property to switch both devices to a low-resistance state when on and a high-resistance state when off. This is effectively an electronic switch whose state is controlled by the drive to the gates of the transistors. Transmission gates are bilateral switches, which means they can pass signals in either direction, so either signal terminal can be used for an input or output.

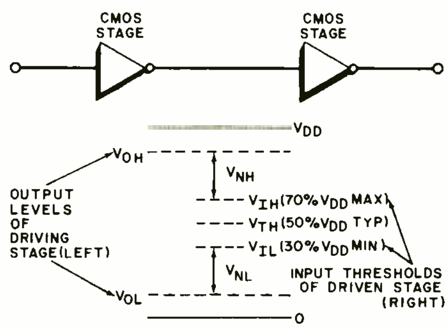
Since p and n units require opposite polarities on the gates to be on or off simultaneously, a transmission gate requires a two-phase (push-pull) gate drive. This is usually obtained from a single clock (control) line with an inverter. In both the actual circuit (Fig. 10A) and the symbolic equivalent (10B), the gate is on when the clock is high and off when the clock is low. Examples are the CD4016AE and CD4066AE.

Latching (RS) Flip-Flop. The simplest form of flip-flop is the latch or RS (set/reset) device; and it can be made by cross-connecting a pair of gates—either NOR or NAND depending on the input triggering requirements. The general function of a latching flip-flop is to store the information commanded by the last active input pulse. NOR gates respond to positive input pulses. Thus, the circuit shown in Fig. 11A changes state when the set and reset lines alternately go high. This flip-flop can be made by cross-coupling any two CMOS NOR gates. Since there are two gates, the outputs are complementary.

Sometimes, negative-going inputs are available to store input timing information with a latch flip-flop. Rather than invert these negative inputs to drive a NOR latch, it is simpler to use a NAND latch as shown in Fig. 11B. The function of this circuit is exactly the same except that its inputs are sensitive to negative-going transitions. This latch can be made up of any two CMOS NAND gates, and it also has complementary outputs. For both the NOR and NAND latch-input flip-flop functions, there are also standard devices which offer multiple circuits. The CD4043AE is a quad NOR latch, and the CD4044AE is a quad NAND latch. Both of these units have built-in transmission gates which can be used to enable the output.

Type D Flip-Flops. Using latching flip-flops and transmission gates in a master/slave arrangement, the type D flip-flop is clocked, meaning that its outputs do not respond to input data until the clock line goes from low to high. A typical CMOS type D flip-flop is the CD4013AE as shown in Fig. 12.

CMOS NOISE IMMUNITY



At the beginning of this article we mentioned the fact that CMOS stages switch at approximately half of the supply voltage. This transfer characteristic and the fact that the high and low logic levels approach the values of the supplies provide the very high noise immunity that is typical of CMOS. Typically the noise immunity is specified as 45% of V_{DD}.

Noise immunity is basically the difference between the high and low states of the output voltages and the high and low states of the input thresholds. This is shown graphically in the accompanying sketch. In general, an output voltage (V_{OH}) greater than the next stage's high input threshold (V_{IH}) guarantees that the driven stage will recognize the input level as a valid high level and switch properly. Similarly, an output low voltage (V_{OL}) lower than the stage's low input threshold (V_{IL}) guarantees recognition of a valid low level. The difference between the actual V_{OH} and necessary V_{IH} is the high-state noise margin (V_{NH}) since a noise pulse of this amplitude can exist without disturbing the validity of a one logic state. In like manner, the difference between V_{OL} and V_{IL} is the low-state noise margin (V_{NL}).

The highest noise margins (V_{NH} and V_{NL} maximum) occur when V_{OH} approaches V_{DD}, V_{OL} approaches 0, and V_{IH} and V_{IL} are nearly centered between V_{DD} and 0. These factors are all characteristic of CMOS stages. V_{OH} and V_{OL} are typically within 10 mV of V_{DD} and 0, and the input thresholds are centered around ½V_{DD}. CMOS noise margins at room temperature are typically 45% of V_{DD}—at a minimum, 30%. This makes the worst-case upper and lower input thresholds 30% and 70% of the supply.

The key to the operation of this flip-flop is the transmission gates, which are controlled by the clock input. There are two sets of gates, driven in opposition. In the master section, data is entered and held, then transferred into the slave section when the clock line goes from low to high. The slave (output) section has separate set and reset inputs which can be used to latch it upon application of a high input, regardless of the state of the clock.

JK Flip-Flop. The standard CMOS JK flip-flop is the CD4027AE, a dual device with set and reset capability. This flip-flop circuit is similar to the type D, with additional gating for the J and K inputs. Like the CD4013, the CD4027 changes states synchronously with the positive transition of the clock pulse. It also has set and reset inputs, which override the clock and respond to high-level inputs. The CD4027AE is useful in counters, registers, and control circuits and will typically clock at 8 MHz with a 10-volt supply.

Counters and Registers. There are many CMOS high-order devices. They are multiple stages of the basic CMOS functions and many of them are MSI or LSI. Circuits with large component density are ideally suited to CMOS because its all-transistor circuit allows high packing densities.

There are a number of multiple-stage counters available. The CD4024AE is a 7-stage unit, allowing counts up to 128, with buffered taps at each of the seven stages. A common line resets all stages together. The CD4040AE is similar, but has twelve stages (counts up to 4096). Fourteen stages are available in the CD4020AE, which counts up to 16,384.

A watch can be made with the CD4045AE, a 21-stage counter, which can count to 2,097,152. It also has output pulse shaping for motor drive and a stage for an oscillator. With this one device, it is possible to have a crystal-controlled source with 1-second outputs.

There are a number of CMOS registers with various input/output formats. The CD4015AE is a 4-stage device; CD4014AE has 8 stages; and CD4006AE 18 stages. The versatile CD4034AD is an 8-stage register which can be used serial in and parallel out, parallel in and out, bidirectionally, and either synchronously or asynchronously.

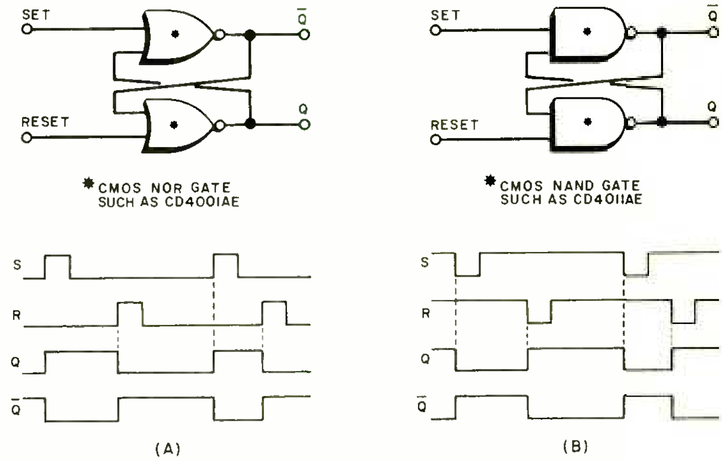


Fig. 11. Cross-coupled NOR gates respond to positive-going input signals (A) while cross-coupled NAND gates respond to negative signals.

Display Decoders and Drivers. To use with the counters and registers, a number of display drivers and decoders are available. The most basic are the CD4026A and CD4033A, decade counters with seven-segment decoders. Outputs can be interfaced to LED and other popular 7-segment displays with a high-current buffer.

The low-power display to go with low-power CMOS is the liquid-crystal type, and there are several decoder/driver combinations which can drive liquid-crystal displays directly. The CD4054AE is the basic unit, a 4-line input (with latches) and display drivers. The CD4055AE is a BCD input unit with 7-segment decoder and drivers. The CD4056AE is basically the same, but it has a latch with strobe on each input line.

Other CMOS Variations. What has been described so far are the basic elements of the RCA 4000A COS/MOS line. RCA was a pioneer in the field and the 4000A series is now manufactured by many other companies. However, in addition to the 4000A devices, several manufacturers offer their own highly useful versions of CMOS logic elements.

Motorola Semiconductor has a very broad line of CMOS devices—both 4000B types and its own variety. Motorola's CMOS line (which it calls McMOS) is similar in concept to those we have discussed but they have a greater power supply range. Military devices (denoted by an AL suffix) operate from 3 to 18 V and the CL or CP types operate from 3 to 16 V at −40 to +85°C. The numbering of the 4000A devices is slightly different—the 4007A, for instance, is Motorola's type MC14007AP.

In addition to the MC14000 series, Motorola has an MC14500 series, with many special features. The most interesting devices are in the MSI category. For instance the MC14517CP is a dual, 64-stage shift register, with taps at 16, 32, 48, and 64 bits. The Mc14511CP is a BCD-to-7-segment latch/decoder/driver which can supply up to 25 mA or output current. The MC14514CL and MC14515CL are combination 4-bit latches and 4-line to 16-line decoders.

An interesting counter set is the

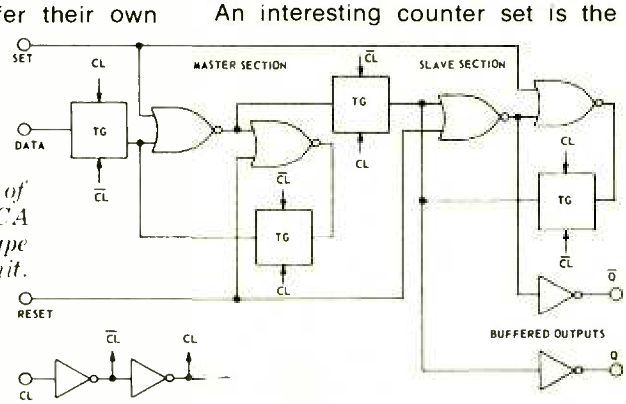


Fig. 12. Block diagram of one section on an RCA CD4013AE COS/MOS type D flip-flop unit.

MC14522CP and MC14526CP, BCD and binary (respectively) programmable "divide-by-N" counters. The BCD unit can divide by 1 to 999 at up to 5 MHz.

The standard monostable is also available in the MC14528CP, a dual one-shot. Its two sections can be triggered with either pulse edge, and pulse width is set by external resistance and capacitance.

National Semiconductor has two CMOS lines—one a 4000A series and the other a series with "74-type" pin configurations. The latter, the much broader of the two lines, are pin-for-pin functional equivalents of 7400 TTL. In this, a 74C00 is a quad 2-input NAND gate just as is a 7400. The rest of the series is the same, including gates, inverters, flip-flops, counters, registers, decoders, and so on. The line is still being expanded. All 74C outputs are designed to drive two 74L loads, making interfacing easy.

National's CD4000 series is equivalent to the 4000A CMOS lines. The National part number for a CD4007AE is CD4007C.

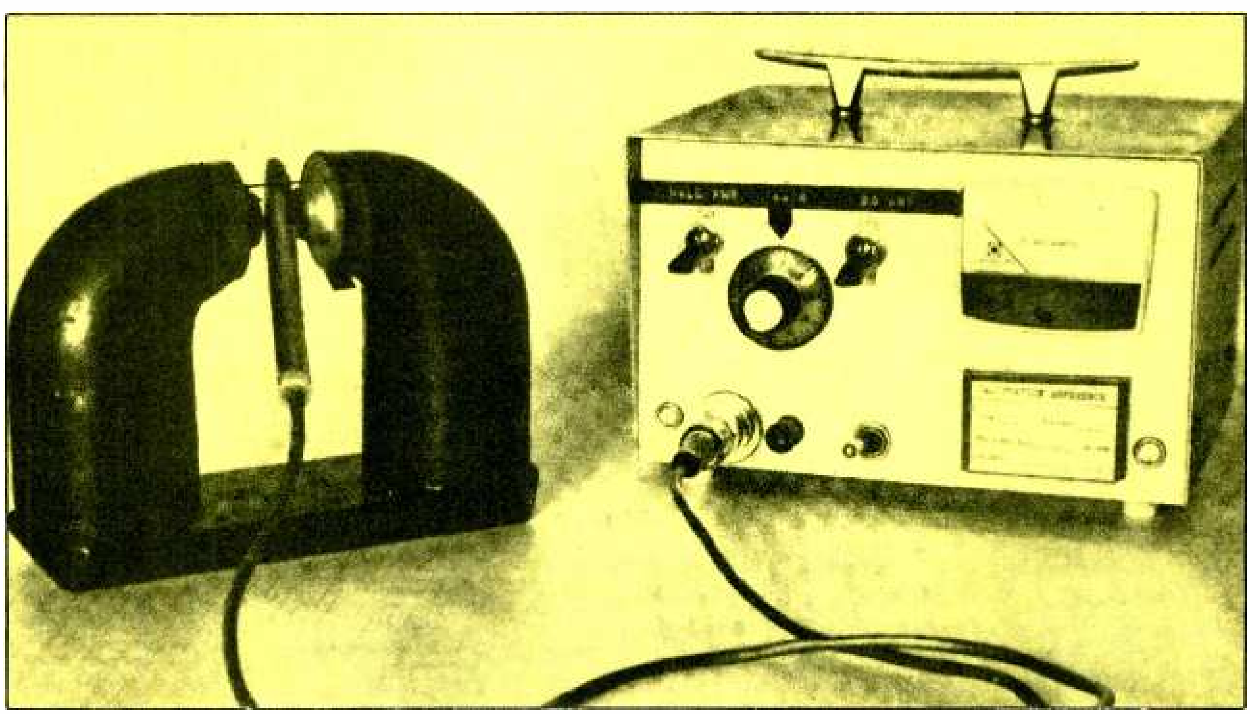
Harris Semiconductor has made a unique contribution to CMOS technology with its process of "dielectric isolation" which yields both higher speed and even lower power than regular CMOS. Harris has 4000A types as well as 54/74C devices. The 4000A devices are designated simply as HD-4000 types. For instance, an HD-4007-9 is a 4007A in a ceramic package. 54/74C numbering follows similarly; i.e., HD-74C00, for instance.

Summary. We have covered the important aspects of the operation and application of CMOS IC's. The important thing now is for the reader to try them in his own circuits and come up with new ideas. ◈

BY L. GEORGE LAWRENCE

Probe magnetic fields with this home-built instrument.

HALL • EFFECT



MAGNETOMETER

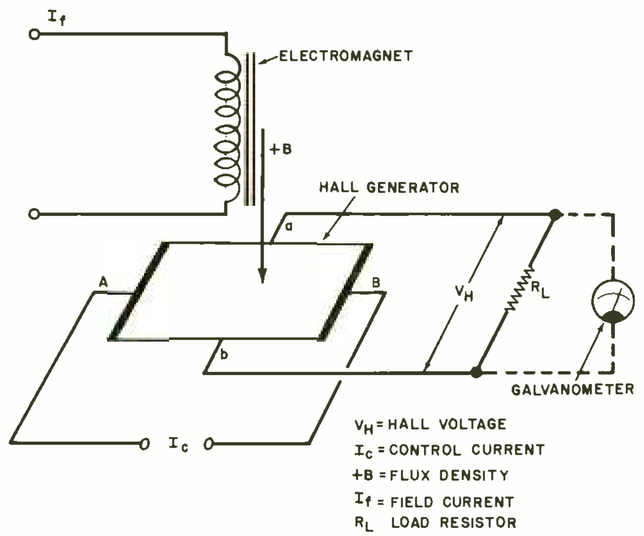


Fig. 1. Hall generator is a thin strip of conductor with current flowing through it. With magnetic field applied at right angles to the current, a potential difference occurs.

IN 1879, E.H. Hall published a paper in which he described how a magnetic field, when passing through a current flowing in a thin piece of metal, produced a voltage between the edges of the metal. The same effect was also observed to greater degree in semiconductor materials such as germanium, silicon, and various indium compounds.

Hall-effect devices can sense magnetic forces without making physical contact. Such devices made from semiconductors are used to measure magnetic forces in almost every phase of applied electronics and power generation, including such diverse applications as the manufacture of razor blades, satellites, and large tractor tires.

In this article, we will tell how to construct a versatile Hall-effect magnetometer. It will not only demonstrate the principles of the Hall-effect operation, but will also make an educational Science Fair project. A commonly available IC, a transistor and conventional components are used in the project.

How a Magnetometer Works. The Hall generator can be a very thin strip of conductor through which a current is passed from *A* to *B* as shown in Fig. 1. If a galvanometer is connected to directly opposite points at the sides of the strip (*a* and *b*), the potential between the points will be the same, and the galvanometer will not register a deflection. However, Hall discovered that if a very strong magnetic field (+B) is then applied at right angles to the strip's plane, the state of electrical balance is disturbed. The meter then indicates a potential difference between points *a* and *b*.

By holding control current I_C constant, Hall voltage V_H depends directly on +B (the magnetic flux density). If both I_C and +B are variable, the output (V_H) is proportional to the product of the two terms. Also, with the magnetic flux and control current held constant, V_H becomes a function of the angle between +B and the Hall generator's active area.

Today, Hall-effect devices are widely used in measuring current, usually by magnetic-field induction. Since the magnitude of a magnetic field at a given point is proportional to the current creating the field, the Hall voltage is proportional to the current level. Amplification is needed to make the small Hall voltage readable on a meter.

In Fig. 2 are shown various types of Hall-effect sensor applications. The simplest configuration (Fig. 2A) involves nothing more than a Hall generator mounted near a current-carrying conductor. This application works exceptionally well where very high direct currents—such as those required by automobile starters—must be measured without making

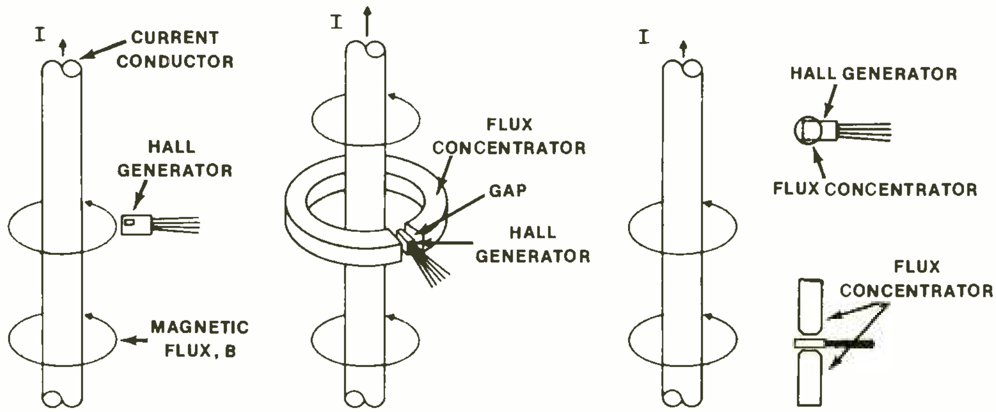


Fig. 2. A simple current sensor is shown at (A). In (B) the Hall generator has a flux concentrator ring. A Moly permalloy strip concentraotr is at (C).

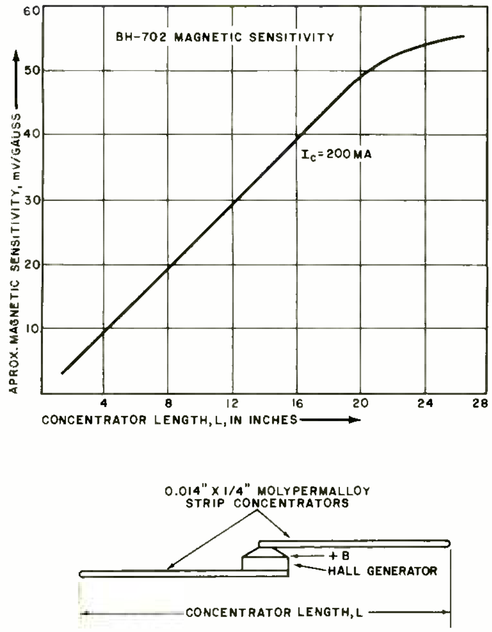


Fig. 3. Graph at left shows how length of concentrator improves magnetic sensitivity.

contact. The magnetometer of which the Hall generator is a part is calibrated against a high-current source of known value.

Hall generators with flux-ring concentrators (Fig. 2B) provide increased sensitivity. The smaller the width of the gap in the concentrator (such as in an Arnold Engineering "Silectron" core), the higher the system's sensitivity.

Another flux-field concentrator arrangement is shown in Fig. 2C. Here a ¼-in. diameter rod of ferrite or high-permeability steel, such as molypermalloy, makes a good concentrator. About 500 ampere-turns of field strength is the bottom measurable limit with this arrangement.

In Fig. 3 is shown another concentrator. Note how concentrator length L improves the magnetic sensitivity of the Hall generator (such as the F.W. Bell Type BH-702). Molypermalloy strip concentrators measuring 0.014 in. by 0.25 in. are simply bonded to the Hall generator's main body and suitably secured in epoxy to avoid mechanical damage to the Hall device due to accidental bending.

A Home-Built Magnetometer. The magnetometer shown schematically in Fig. 4 can be built in a home workshop. Its highly flexible design can accommodate different types of Hall generators and their excitation currents. It has special provisions for use with the 741 IC amplifier, and the meter is easily calibrated.

The Hall generator specified is a Bell Type BH-702 that requires a control current of 200 mA so that, when suspended in a 100-gauss magnetic field, the open-circuit Hall voltage is about 10 mV. The generator has an operating temperature range of −40°C to +100°C (boiling point of water), which is typical of many similar Hall-effect devices.

The generator's control current is regulated by *Q1*, whose operating bias is set by *B1* and *R8*. A simple adjustment of *R8* will permit the system to accommodate other Hall generators that require different control currents. (You simply connect a dc ammeter in the collector circuit of *Q1* and adjust *R8* to set the required current.)

The Hall generator's output is fed into a high-gain operational amplifier (*IC1*) whose gain is set by *R3*. Null adjustment *R5* is vital for zeroing the amplifier under quiescent conditions (Hall generator energized but without a magnetic field applied). Calibration control *R7* permits proper full-scale settings of the meter.

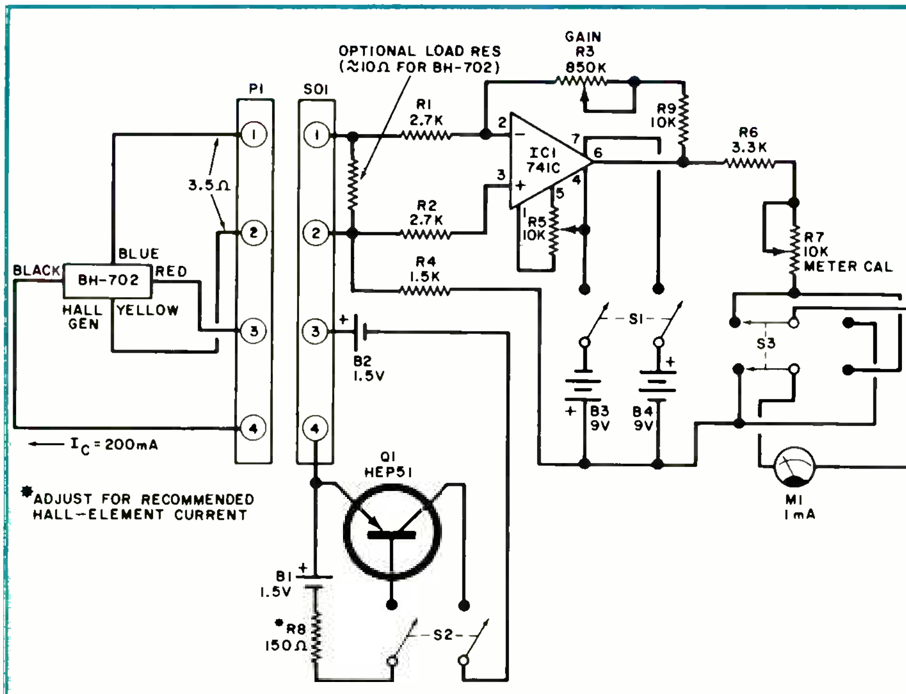


Fig. 4. Schematic of magnetometer. Transistor Q1 supplies plate current, and op amp IC1 is amplifier.

PARTS LIST

B1,B2—1.5-volt D cell
B3,B4—9-volt battery
Hall Generator—BH-702 (F.W. Bell)*
IC1—741C op amp
M1—1-mA meter (Calectro D1-912 or similar)
P1—4-pin plug with attached color-coded leads (see text)
Q1—HEP-51 transistor
R1,R2—2700-ohm, ½-watt resistor
R3—850,000-ohm linear potentiometer
R4—1500-ohm, 1-watt resistor
R5,R7—10,000-ohm linear potentiometer
R6—3300-ohm, ½-watt resistor
R8—150-ohm, 1-watt resistor (adjusted for recommended Hall-element current)
R9—10,000-ohm, ½-watt resistor
S1,S2—Dpst switch
S3—Dpdt switch
SO1—4-pin socket to match P1
Misc.—D-cell holder (2), pipe clamps (2) for 9-volt battery, battery connectors (2), suitable chassis, calibrated dial for R3, probe holder, cement, wire, mounting hardware, etc.
*Hall generators of different sensitivity ranges and prices are available from (among others) F.W. Bell, Inc., 4949 Freeway Drive East, Columbus, Ohio 43229; and Ohio Semitronics, Inc., 1205 Chesapeake Ave., Columbus, Ohio, 43212.

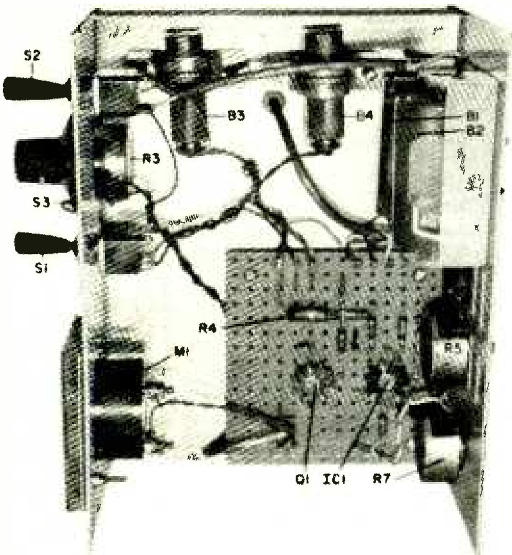


Fig. 5. Photo shows the interior of the author's prototype Hall-Effect generator.

Construction. The electronic components can be easily mounted on perforated phenolic board as shown in Fig. 5. The four batteries should be held in place with pipe clamps and holders for 1.5-volt D-size cells.

The three switches, meter, connector, and potentiometer *R3* mount on the front panel of the chassis case. Use a 0-to-10 dial scale for *R3*, and make up a "Calibration Reference" card. Affix the latter to the case's front panel.

Constructing the main unit is not critical. However, special consideration must be taken when assembling the probe for the Hall generator (see Fig. 6). First, remember that Hall generators are very fragile and cannot be handled like most miniature electronic components. Their aluminum-oxide substrates are brittle. So, use *only the leads* to move and locate the generator. Avoid putting tension on the leads and bending them close to the substrate. Bends must be at least ⅛ in. away from the substrate.

The Hall generator can be housed in a small plastic tube containing a paper filler to provide mechanical support. The Hall plate, being small, can be bonded to a glass or non-magnetic mount with epoxy cement to form a fillet and protect the leads from breakage. Position the Hall plate inside the tube so that the "active" (+B) side faces the tube's wall. Mark this position with red paint or some other means of identification; it is the Hall generator's most sensitive area. Typically, the ceramic substrate—onto which the actual Hall plate is bonded—will face away from the probe's wall. Watch for special markings, since different manufacturers use different indicators.

Final assembly of the probe involves cutting the generator's four leads to a suitable length and connecting them to the magnetometer's 4-conductor, color-coded feeder cable. In the prototype, a 4-contact Amphenol No. 91-MC4M-385 plug and No. 91-PC4F-385 receptacle were used to make the connection. A 5- or 4-ft-long cable will suffice for most applications. Be sure to insulate the solder connections.

Calibration. Prior to calibrating the magnetometer, remember that most Hall generators are high-current devices that heat up very rapidly unless some form of heat sinking is provided. Therefore, activate the probe for only a few seconds at a time, turning it off immediately after measurements are completed.

Precise calibration depends on whether the Hall generator is of the high- or low-sensitivity type. Calibrations can be made by using either magnets of known field strength or a conductor through which a known magnitude of current is passed.

With the Hall probe connected to the input, start the nulling procedure by turning on *S1* and *S2*. Set *R3* for maximum gain. If the meter's pointer deflects with no external field present, adjust the setting of *R5* until the pointer drops to zero.

To calibrate the magnetometer in given values of direct current, use a high-current battery charger or a fully charged battery as the current source. Connect the current source, with a rheostat, switch, and ammeter, in series with a length of cable. With the magnetometer activated, hold the Hall probe adjacent to the energized cable and set the *R3* gain control for a given indication on the meter (say a scalar value of 0.5 for a current of 10 amperes). Touch up calibration control *R7* to assure pointer deflection above and below that range.

The value on the dial of *R3*, together with the meter indication, provide your calibration reference. Enter this on the card on the front of the magnetometer. Calibration with reference magnets is accomplished in a similar manner, but the meter indications are referred to magnetic field strength (gauss) instead of current.

Applications for the Hall-effect magnetometer are limited only by your imagination. It is very useful, for example, in servicing automotive or marine electrical systems. The electrical system of the vehicle can be "mapped" (while energized); and then when trouble occurs, you can use the map to locate areas where abnormal conditions indicate the trouble.

Excellent frequency response and high speed make Hall-effect generators most valuable for physics experiments. If, for example, an oscilloscope is connected across the meter in the magnetometer, high-energy discharge of capacitors can be observed. It is also possible to duplicate Hall's original discovery by using strip conductors.

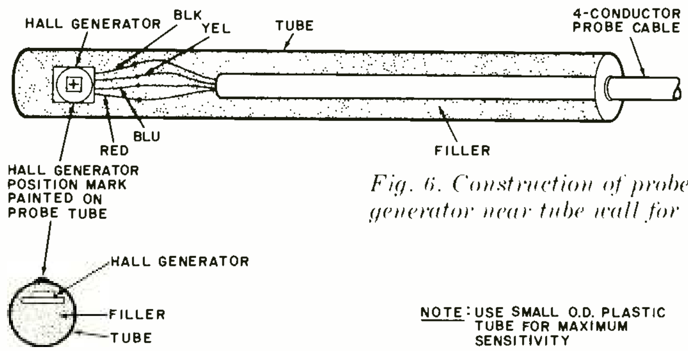


Fig. 6. Construction of probe. Position Hall generator near tube wall for best sensitivity.

MULTIPLIER

Add this low-cost accessory to your shortwave receiver and enjoy more stations with greater clarity.

BOOSTS SW SELECTIVITY & GAIN

BY JOE A. ROLF

IF YOU are using a typical medium-priced shortwave receiver, chances are you need more gain and better selectivity to separate the stations on the crowded SW bands. Before you make the decision to trade in your receiver for a newer, "hotter" one, consider adding a Q multiplier, it is relatively inexpensive and just might save you a lot of money.

The reason most medium-priced SW receivers are far from ideal for serious SW listening is that they are designed with i-f bandwidths of between 5 kHz and 10 kHz. This is okay for good performance on the relatively uncluttered AM broadcast band, but on shortwave, where stations operate almost on top of each other, such a broad i-f bandwidth is often less than satisfactory. So, for a receiver that lacks a narrow i-f bandwidth, the Q multiplier can prove a valuable accessory for shortwave tuning.

The Q multiplier described here is designed around a single field-effect transistor to provide the equivalent gain of an extra i-f stage. Additionally, it doubles as a bfo. Best of all, it can be built for less than $20.

Theory of Operation. The schematic diagram of the Q multiplier is shown in Fig. 1. The circuit consists of a simple 455-kHz Colpitts oscillator that can be adjusted in and out of oscillation by *R3* and *R4*. A field-effect transistor is used for *Q1* to provide a high impedance to the tuned circuit consisting of *L1* and *C3* through *C6*.

When the circuit oscillates, the Q (selectivity) of the tuned circuit is determined primarily by the components used. However, when the oscillator is adjusted to a regenerative point just below oscillation, component losses are offset by feedback, and the selectivity rises to many times the normal value. If the oscillator (Q multiplier) were connected in parallel with a 455-kHz i-f transformer in a receiver, the selectivity of the transformer would also be greatly increased.

In Fig. 2 is shown a typical i-f response curve for a medium-priced SW receiver and the effect a Q multiplier has on selectivity. The i-f bandpass of the receiver is reduced to a fraction of the original by the Q multiplier. Since the multiplier is tunable, it can be used to peak any signal in the original bandwidth.

By connecting the Q multiplier in a slightly different manner, the i-f response can be left unaltered except for a very sharp adjustable notch. Used in this manner, the circuit can tune out or null unwanted signals.

Since both the peak and the null functions are desirable, the Q multiplier has been designed to operate in either mode, simply by flipping selector switch *S1*. A small 365-pF tuning capacitor (*C4*), trimmed by *C3*, tunes the circuit across the receiver's i-f bandpass. When neither the peaking nor nulling function is needed, the Q multiplier can also be switched out of

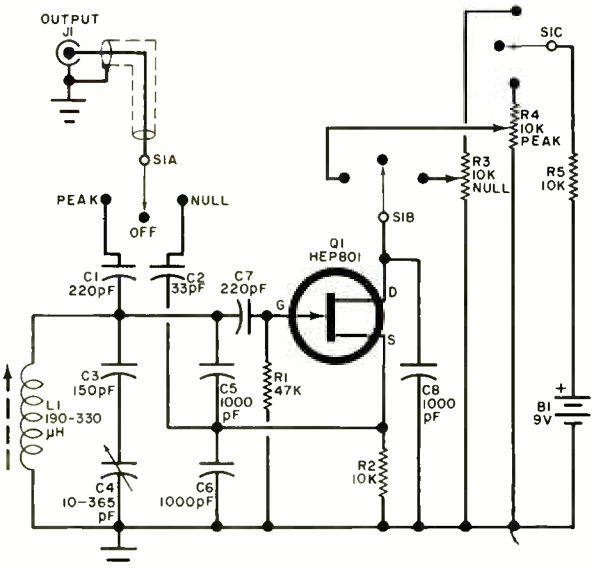


Fig. 1. The circuit is essentially a Colpitts oscillator which is adjusted by R3, R4.

PARTS LIST

B1—9-volt battery
C1,C7—220-pF polystyrene capacitor
C2—33-pF polystyrene capacitor
C3—150-pF polystyrene capacitor
C4—10-365-pF tuning capacitor (Archer No. 272-1341, or equivalent)
C5,C6—1000-pF polystyrene capacitor
C8—1000-pF ceramic disc capacitor
J1—Phono jack
L1—190-330-µH miniature adjustable choke (J.W. Miller No. 4565, or equivalent)
Q1—HEP801 (Motorola) field-effect transistor
R1—47,000-ohm, ¼-watt resistor
R2,R5—10,000-ohm, ¼-watt resistor
R3,R4—10,000-ohm miniature potentiometer (Mallory No. MLC14L or similar)
S1—Three-pole, three-position, non-shorting rotary switch (Calectro No. E2-168 or similar)
Misc.—Metal chassis box; printed circuit or perf board with solder clips; battery connector; phono jack (for receiver); phono plugs (2); shielded cable; etc.

the circuit and the receiver is on its own.

Construction. The Q multiplier can be assembled in any metal chassis box large enough to accommodate it. A box with a front-panel area measuring roughly 2¼" high by 3¼" wide and a depth of about 4", such as the Archer No. 270-251 from Radio Shack, will be suitable.

Since the circuit of the Q multiplier is very simple, perforated phenolic board and solder clips can be used for mounting most of the parts. Alternatively, you can design and make your own printed circuit board.

Mount *B1* on the bottom of the chassis, close to the rear wall. On the rear wall itself goes *J1*. The front panel should have mounted on it NULL and PEAK controls *R3* and *R4*, MODE switch *S1* (with appropriate position legends), and TUNE capacitor *C4*. Coil *L1* should be mounted on the board assembly in such a manner that its slug adjustment is readily accessible.

To simplify hookup to your receiver, it is a good idea to mount a phono jack on its rear apron and use a length of shielded cable to interconnect the jack and first i-f transformer as shown in Fig. 3. (Note: ground this cable only at the jack.)

Finally, solder phono plug to the ends of a length of Belden No. 8421, or equivalent, low-capacitance shielded cable. This cable should be as short as possible, preferably less than 24 inches.

In Use. To put the Q multiplier into operation, connect it to the receiver with the shielded cable. Turn on your receiver and tune to a quiet spot on the AM broadcast dial. Set the Q multiplier to PEAK. With *C4* (TUNE) set to mid-position and PEAK control *R4* fully clockwise, tune *L1* until you hear a signal. If the Q multiplier is tuned to the receiver's i-f, the signal will be heard continuously across the AM band, with a beat note when you tune across a broadcast station. In this mode, the Q multiplier can be used as a bfo.

Switch to NULL and rotate the TUNE knob until a signal is again heard with the NULL control fully clockwise. (The setting of *C4* in the NULL and PEAK positions of the MODE switch will be slightly different, in which case it may be necessary to make a compromise adjustment of *L1* to get both to fall as near the center of the TUNE capacitor's setting as possible.) Finally, set the Q multiplier to a point below oscillation and peak the i-f transformer to which it is connected as needed.

It takes a little practice to learn how to use a Q multiplier efficiently if this is the first time you have used one. Adjusting the PEAK control clockwise increases selectivity and decreases i-f bandwidth. Greatest selectivity occurs just before oscillation, indicated by a ringing sound when the receiver is tuned across a signal.

When in NULL, the notch is made sharper as the NULL control is turned clockwise, and a very noticeable drop in signal will be heard when the Q multiplier is tuned to an unwanted signal. A little practice at the controls will enable you to peak or null any signal you hear for best reception. ◈

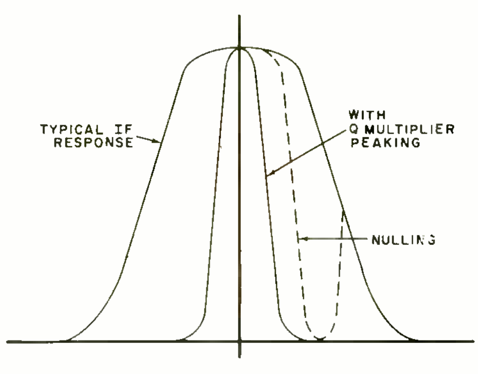


Fig. 2. Waveforms show effect of Q multiplier on i-f response of medium-priced receiver.

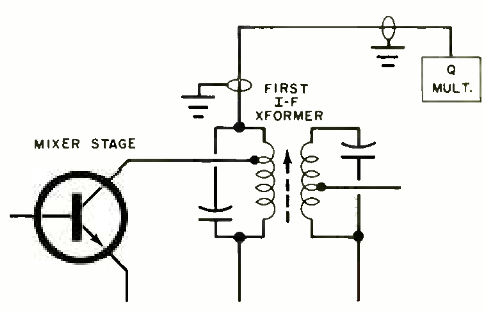


Fig. 3. How to connect the Q multiplier into your receiver using coax.

UNDERSTANDING YOUR TRIGGERED SWEEP SCOPE

A brief explanation of those puzzling trigger controls.

BY VIRGIL A. THOMASON

MOST technicians and electronics enthusiasts are familiar with the theory behind a triggered sweep scope. Others, however, still seem to be troubled by the special triggering controls used in this type of scope. Let's see if we can't clarify the uses of these sometimes baffling controls.

First, just what is a "trigger"? Remember that there are two different types of scope sweeps: recurrent and triggered. The recurrent sweep is always present on the CRT face and can be synchronized by a front-panel control appropriately marked. A triggered sweep is not recurring and usually is invisible until a trigger pulse comes along to start the sweep. In normal operation (before triggering), the invisible spot is at the left side of the CRT. The incoming trigger not only starts the trace, but also triggers an internal circuit that "unblanks" the beam for the duration of that sweep. Once the sweep has been initiated, a special "lockout" circuit keeps any other trigger from affecting the sweep until that particular sweep is completed and the beam has returned to the left side of the CRT and is ready to accept another trigger. Therefore, any signal applied to the trigger circuit (usually from the vertical amplifier) will have no effect during the sweep time. This is what contributes so much to triggered sweep stability.

The controls for a typical scope triggering section are shown in Fig. 1. Your particular scope may have different names for these controls, but the principles are the same. Follow the signal flow shown in Fig. 2.

When the scope is to be used to view a signal, the first step is to estimate the input signal level and set the vertical amplifier attenuator controls accordingly. Although a scope, unlike a VOM, cannot normally be damaged by excessive off-scale operation, it is good practice to make this signal level estimate—keeping in mind that the ac signal may have a dc component. If the latter is the case, set the vertical amplifier input selector to AC to begin with. If the scope is left in the DC mode, the desired ac signal may be riding on enough dc to cause the display to be so far off scale that it can't be seen. If you know that only an ac signal will be present, then you can use the DC mode of the vertical input selector.

The first trigger control encountered is the SOURCE selector. If you want to trigger the sweep at some point on the displayed waveform, use the INT (internal) position. This automatically picks up the signal from the vertical amplifier. The EXT (external) position allows the use of a trigger signal from outside the scope. If the displayed signal is related to the commercial power line frequency, then the LINE position will pick up a trigger signal from the power supply within the scope.

The next control is the trigger COUPLING selector. If you want to trigger at a particular dc level on the applied signal, use the DC position. To trigger from an ac signal use either AC position. If your scope has two AC positions, the one marked AC FAST uses a network that passes only the higher frequencies and is usually used to block any 60-Hz component that might be present on the triggering signal.

The SLOPE switch is used to pick a triggering point on either the positive or negative portion of the triggering waveform. The TRIGGERING LEVEL control is used to pick the actual point on either the positive- or negative-going portions at which you want the trigger to occur.

The TRIGGERING MODE switch usually has three positions. In FREE RUN, the sweep oscillator is made free-running, thus starting another sweep directly after the first is completed. This is similar to a conventional recurrent sweep scope. If your triggered sweep scope does not have this position, then the AUTO position may provide this feature, usually at some low frequency (in many cases, about 50 Hz). The selected trigger signal will override the 50 Hz to synchronize the sweep properly. In other words, the AUTO mode is the same as ac coupling, your choice of slope, and the exact center of the triggering level—provided the applied trigger is faster than 50 Hz. The NORMAL mode is used with the triggered sweep.

As a further aid to understanding these controls, try this little experiment. Use a filament transformer as the vertical input source to the scope. As a triggering source, you can use either the LINE position of the SOURCE switch or you can feed the secondary of the transformer to the horizontal input also and use the external input as the trigger source. Use AC coupling and place the SLOPE switch on the positive position. The level potentiometer can now be adjusted to start the sweep on any portion of the positive-going sine wave being displayed. Changing the SLOPE switch to the negative position will now enable you to pick almost any point on the negative half cycle as the starting point. ◈

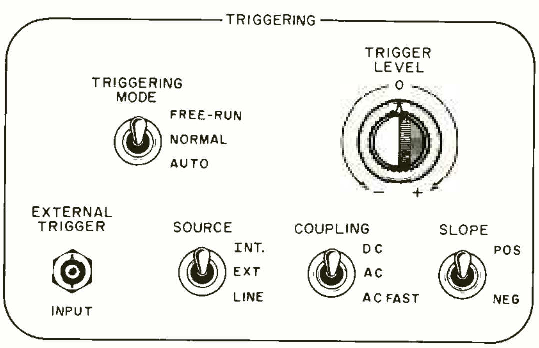


Fig. 1. Basic trigger controls for typical scope. Particular markings may differ from one scope to another but the principle is the same.

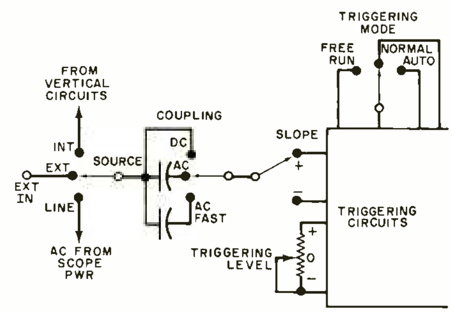
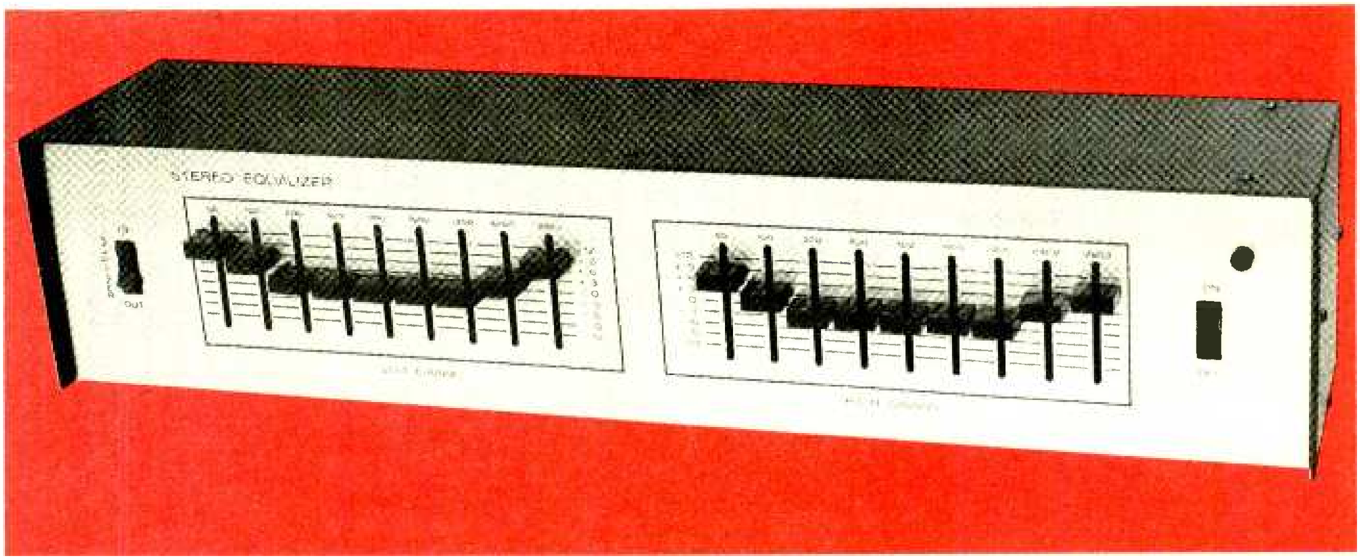


Fig. 2. Diagram shows usual signal flow through triggered oscilloscope.



BULD THIS

NINE-CHANNEL STEREO EQUALIZER

Active op-amp filters produce very low distortion, no ringing. Eighteen independent control positions offer full flexibility.

BY GARY KAY

AN INCREASING number of audiophiles are adding equalizers to their hi-fi/stereo equipment. These auxiliary devices permit adjusting the response of the system in relatively small frequency increments to achieve a desired effect—whether it be to compensate for room acoustics or speaker deficiencies, or just to please their own personal tastes.

If you are contemplating adding an equalizer to your system, but are concerned about the cost of a commercial unit with enough flexibility, you will want to consider building the unit described here. Designed for a stereo system, it has nine 1-octave adjustments in each channel. Using integrated circuit (op amp) active filters, the equalizer has an internal ac power supply. Boost and cut limits are ±12 dB; voltage handling limit is 2 V rms; and the total harmonic distortion is a low 0.05 percent.

The frequency response of the equalizer is from 20 to 20,000 Hz (3 dB), hum and noise is 65 dB below 1 volt rms, input impedance is 100,000 ohms, and output impedance is less than 10,000 ohms. Connection to an operating audio system can be made between the preamp-out/power-amp-input jacks or between the tape-out/tape-monitor input jacks.

The nine gain controls are centered at 50, 100, 200, 400, 800, 1600, 3200, 6400 and 12,800 Hz. Although the lowest and highest frequency filters are bandpass types, their use in a feedback loop gives them a low-pass/high-pass response. The enclosure of the entire array of active bandpass filters in a feedback loop also provides low noise and distortion.

The arrangement of the potentiometer knobs for both channels on the front of the equalizer provides a true graphic representation of the tonal compensation. The equalizer can also be used in an electronic musical instrument system by connecting it between the preamp and the power amplifier.

How It Works. The schematics for one channel and the power supply are shown in Fig. 1. The input to the channel is coupled through capacitor *C1* to voltage divider *R1-R2*. One of the two op amps in *IC1* buffers the input from the voltage divider and provides a low-impedance source for the nine active filters. Each of the latter is composed of an operational amplifier (½ of *IC1* and both halves of *IC2-IC5*) with the related resistors and capacitors. The outputs of the bandpass networks are then summed in one half of *IC6*, whose output is fed back through *R3-R11*. Slide potentiometers *R12* through *R20* vary the overall gain of the feedback loop at the operating frequency of each filter.

Since the filter circuit has unity gain at 0-dB equalization settings, it is necessary to follow the summer with an amplifier made up of the second half of *IC6*. The amplifier also provides the signal inversion that is necessary to keep the input and output signals in phase.

An EQUALIZER IN-OUT switch (*S1*) is provided so that the unit can be bypassed if desired.

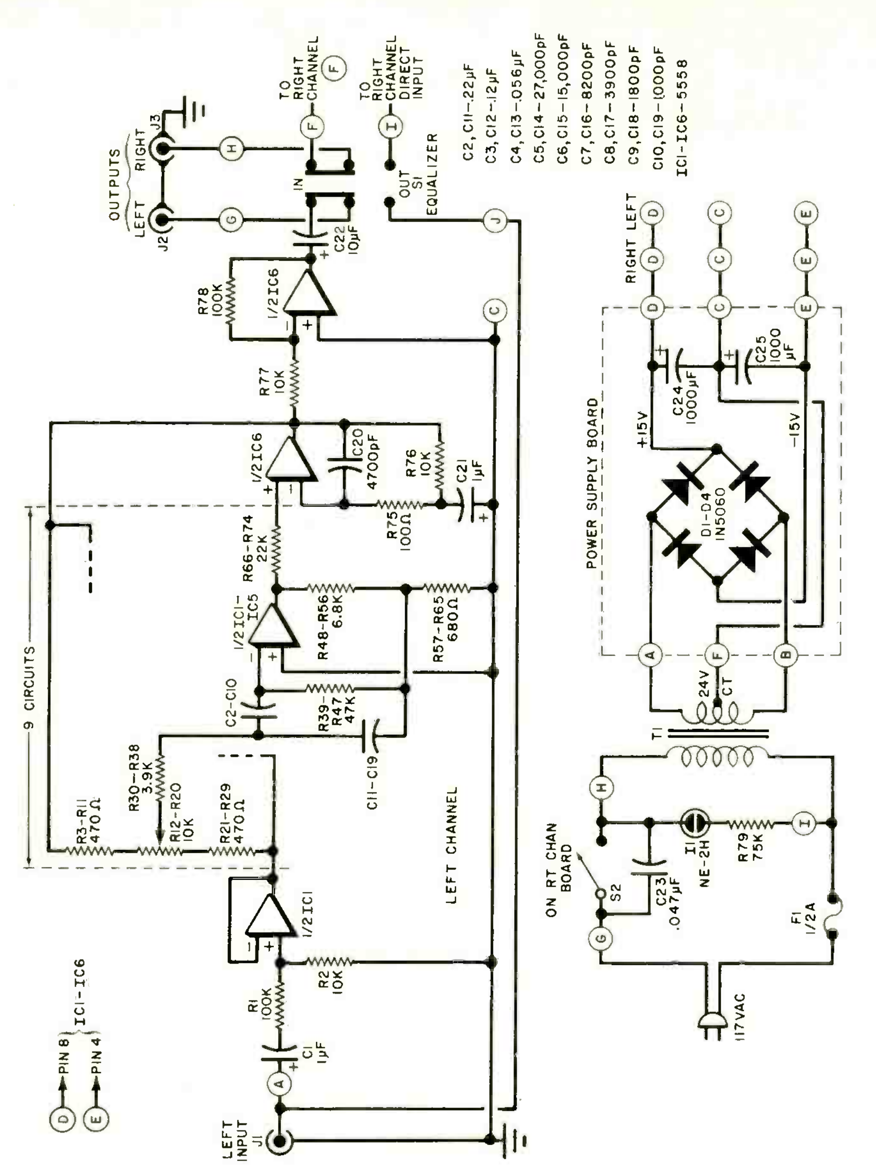


Fig. 1. Schematic for left pc board and power-supply section.

PARTS LIST

For equalizer boards (1 of each for each board):
C1,C21—1-µF, 50-volt electrolytic capacitor
C2,C11—0.22-µF capacitor
C3,C12—0.12-µF capacitor
C4,C13—0.056-µF capacitor
C5,C14—27,000-pF capacitor
C6,C15—15,000-pF capacitor
C7,C16—8200-pF capacitor
C8,C17—3900-pF capacitor
C9,C18—1800-pF capacitor
C10,C19—1000-pF capacitor
C20—4700-pF capacitor
C22—10-µF, 60-volt electrolytic capacitor
IC1-IC6—5558 op amp IC
J1,J2—Audio connector
Unless otherwise noted, resistors are ¼-watt.
R1,R78—100,000-ohm
R2,R76,R77—10,000-ohm
R3,R11,R21-R29—470-ohm
R12-R20—10,000-ohm slide potentiometer
R30-R38—3900-ohm
R39-R47—47,000-ohm
R48-R56—6800-ohm
R57-R65—680-ohm
R66-R74—22,000-ohm
R75—100-ohm
Following components on right board only:
C23—0.047-µF capacitor
I1—Neon lamp (NE-2H) and holder
R79—75,000-ohm resistor
S2—Dpdt switch
Following component on left board only:
S1—Dpdt switch
Following on power supply:
C24,C25—1000-µF, 25-volt electrolytic capacitor
D1-D4—1N5060 rectifier diode
F1—0.5-A fuse and holder
T1—Transformer: secondary: 24 VCT, 80 mA
Misc.—Suitable enclosure, knobs for slide potentiometers (18), rubber feet (4), line cord, mounting hardware, etc.
Note—The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, TX 78216: Circuit boards (#216-3B) at $11.75; complete kit with case (#216) at $99.50; ppd in U.S.

PROJECT EVALUATION
(A Hirsch-Houck Labs Report)

The equalizer lives up to its specifications very easily—usually with a good margin of safety. All of the octave controls have ranges of at least 12 dB and most are about 14 dB. The frequency response is "dead flat" with the equalizer switched out (±0.5 dB, 20 Hz to 20,000 Hz) and has a few bumps when it is switched in with the controls set to indicated center points. Even so, it is within ±0.75 dB, which is not bad at all.

The center points of the equalizer controls are a little off, usually by 10 to 20%, which, of course, is of no practical importance. Needless to say, almost any sort of curve can be generated, depending only on the user's talent and patience. The frequency response with controls centered rises outside the audio band at both ends, but is within 3 dB of the 1000-Hz level (unity gain) from 20 Hz to 190 kHz.

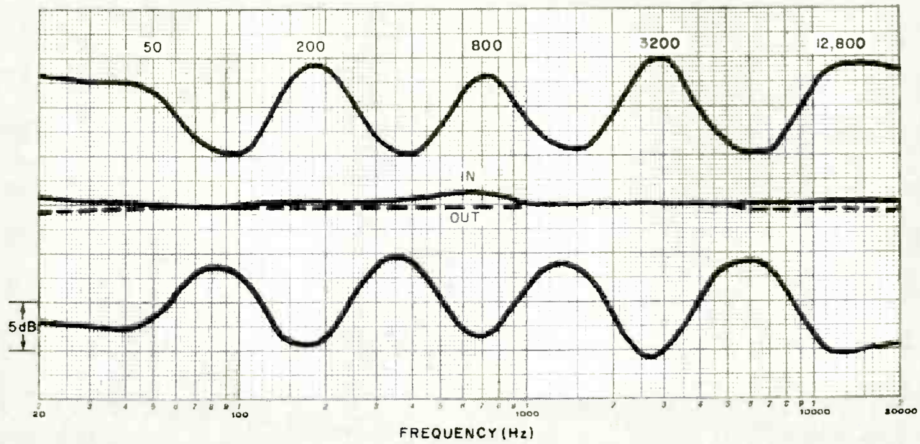
The 2-volt signal limit is evidently based on the input level, allowing for all or many of the octave controls to be at full boost. This is ultra-conservative, but it seems to be the only explanation for a 2-volt rating on a unit which has virtually no distortion up to the 10-volt maximum of our audio signal generator. Up to an output of about 4 volts (1000 Hz, all controls centered), the THD is entirely noise and hum, as indicated by the 6-dB/octave negative slope of the distortion-vs-level curve. At an output of about 7 volts, we begin to have distortion overcoming noise, with a reading of 0.0075%. At the maximum test limit of 10 volts, the total harmonic distortion was all of 0.0095%!

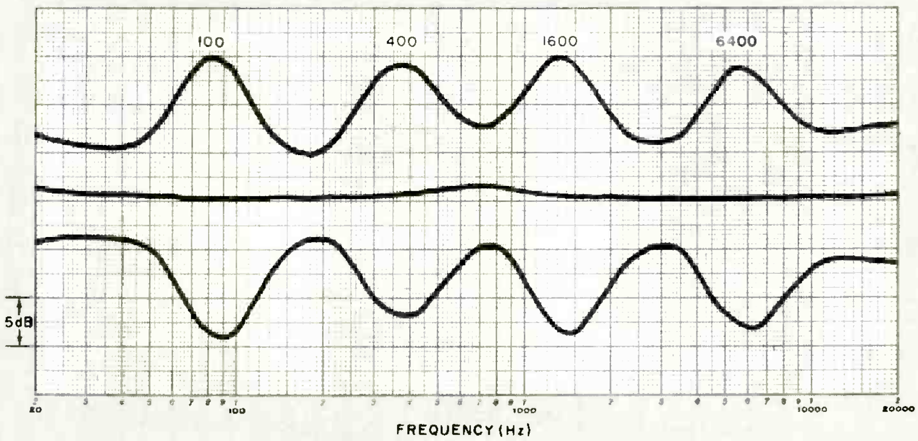
The unweighted noise level in the output was 66 dB below 1 volt (just a little below the specified rating). When the measurement bandwidth was restricted to 250 to 20,000 Hz, to exclude hum and ultrasonic random noise, the measurement was 74 dB below 1 volt.

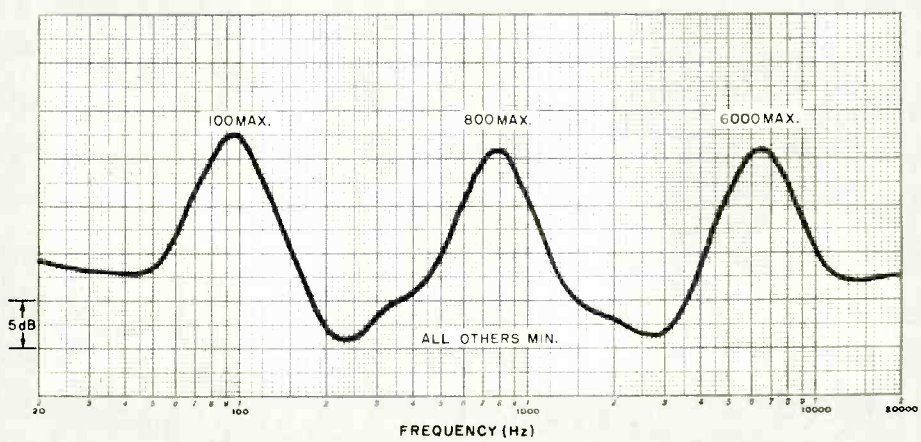
The physical packaging of the equalizer is unconventional, since it is too wide to sit on top of a receiver or any other component. The controls operate very smoothly, and have a nice "feel." On the assumption that it will be connected into a tape monitoring circuit, it would have been nice to have included tape input and output jacks and a monitor switch, to replace those used on the amplifier or receiver (standard practice on most such accessories). On the other hand, the equalizer can just as well be placed between preamp and power amplifier, since it can handle any signal levels there and will not add to audible noise.

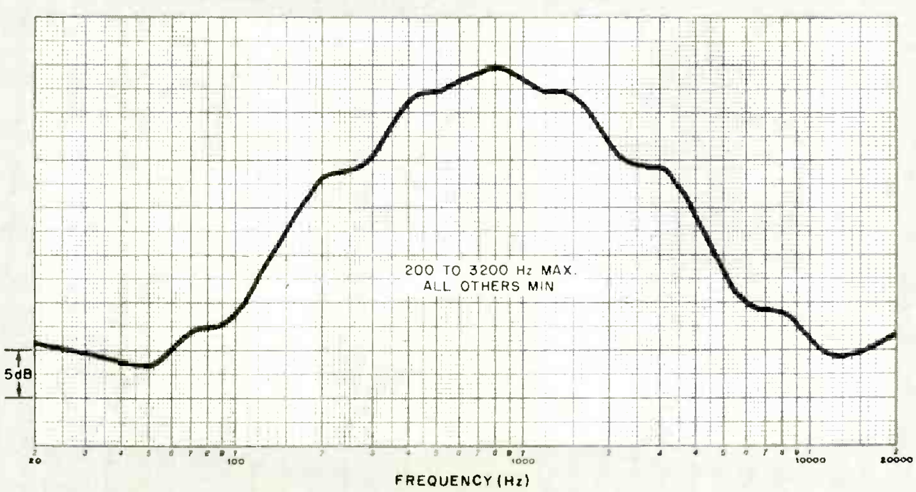
Square-wave tests showed virtually no distortion other than that introduced by the frequency shaping. No ringing was visible with the controls centered.

In quality of performance, this equalizer is comparable to commercial units costing twice as much. This one boasts separate adjustments for the two channels and nine bands per channel instead of five.


50
200
800
3200
12,800
IN
OUT
5dB
FREQUENCY (Hz)


100
400
1600
6400
5dB
FREQUENCY (Hz)


100 MAX.
800 MAX.
6000 MAX.
5dB
ALL OTHERS MIN.
FREQUENCY (Hz)


200 TO 3200 Hz MAX.
ALL OTHERS MIN
5dB
FREQUENCY (Hz)

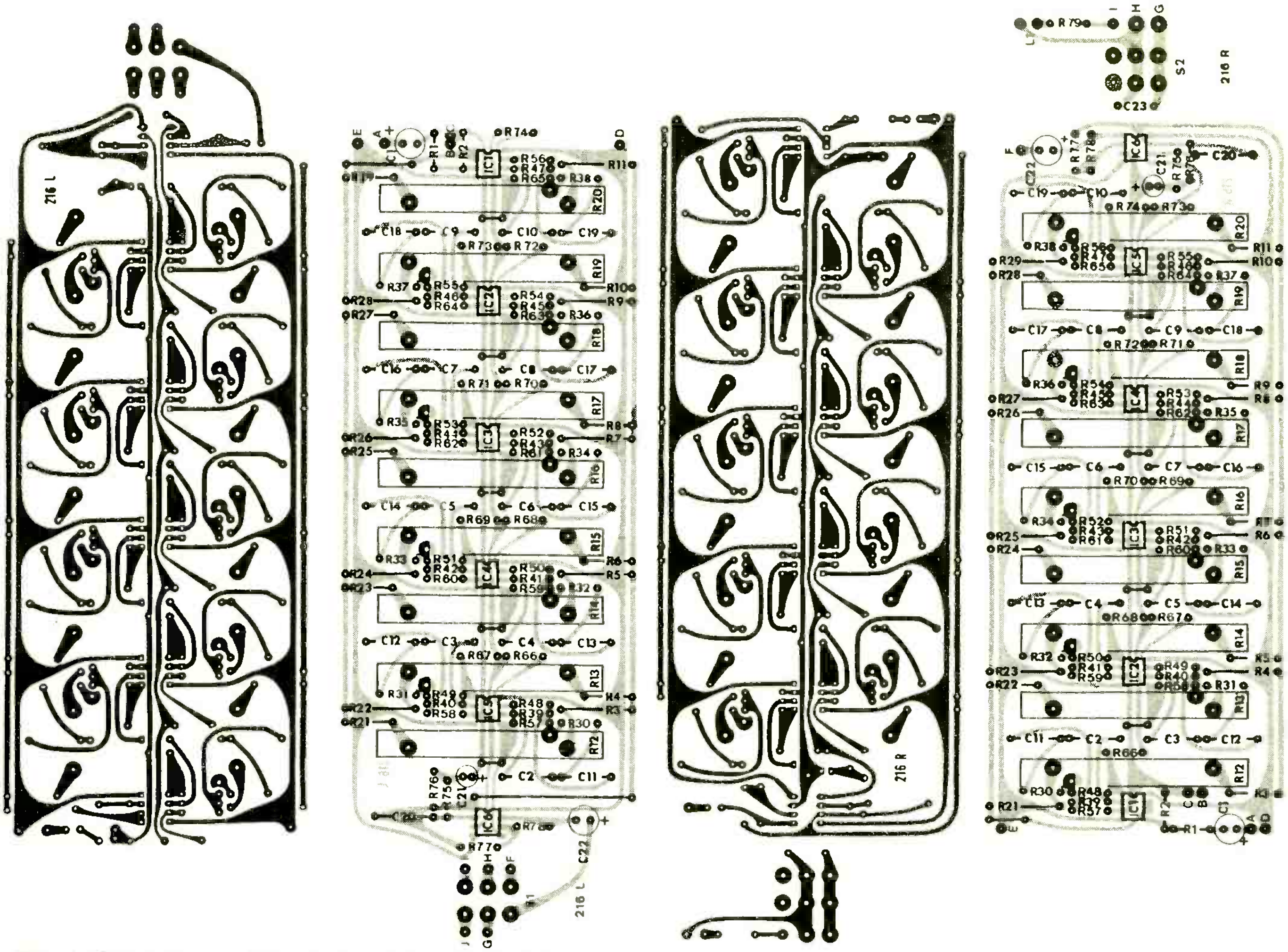


Fig. 2. Foil patterns and component layouts for left and right channels are shown half-size. Foil pattern for power supply is not shown, but can be made easily.

Construction. Three printed circuit boards are used: one each for left channel, right channel, and power supply (see Fig. 2). By mounting all the switches and controls on the circuit boards, wiring is kept to a minimum.

When mounting the components on the boards, be sure to orient the diodes, integrated circuits, and electrolytic capacitors properly. See the component layout diagrams in Fig. 2.

Several jumpers are used on the two equalizer boards, as indicated by the solid lines on the component layout diagrams. The jumpers can be made by stripping the insulation from the ends of short lengths of #24 hook-up wire.

The pc boards with the slider potentiometers attached can be mounted in the chassis in one of a number of ways. They can be mounted one above the other, or, as shown in the photo of the prototype, they can be side-by-side. In either case, be sure that sufficient room is left in the slots for the potentiometer arms so that they slide smoothly without binding.

The slides should be identified on the front panel as to center frequency and the amount of boost (+12 at the top) and attenuation (−12 at bottom).

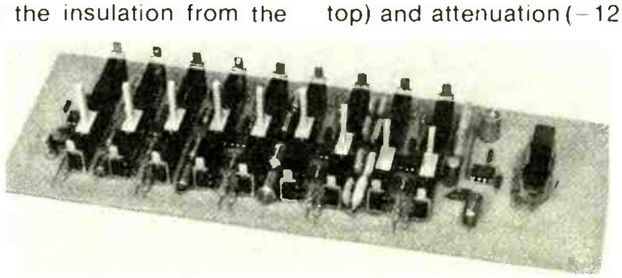


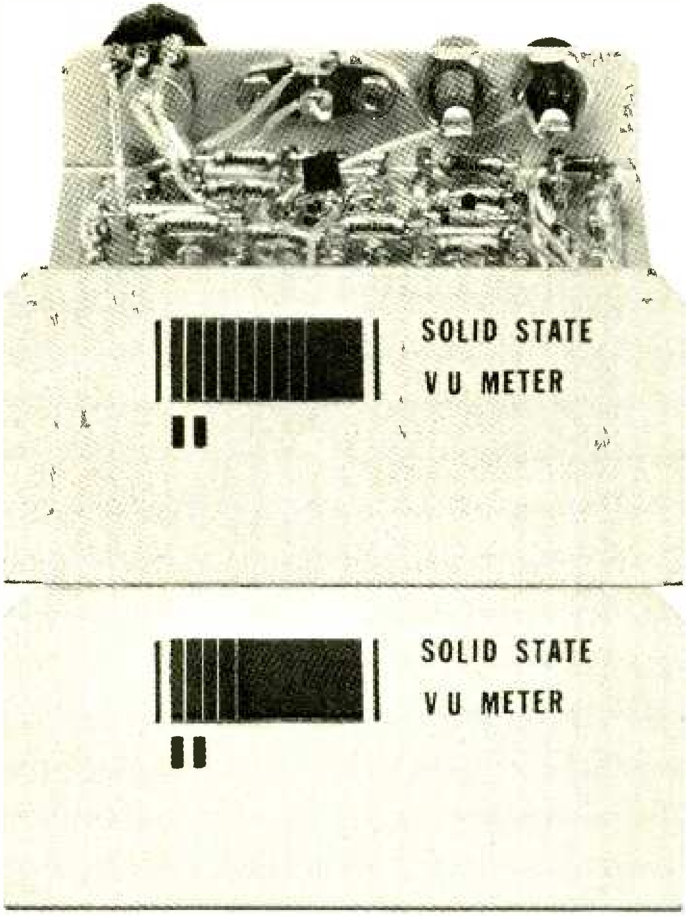
Photo of left-channel board including S1.

The power supply can be mounted in any convenient spot in the chassis, but be careful to keep leads carrying audio signals far from the supply.

Operation. If the stereo system has separate components, attach the equalizer between the preamp and the power amplifier. Alternatively, it can be connected to the tape-out and the tape-monitor input jacks. If neither of these is possible, it will be necessary to find the spot in the equipment where the preamp feeds the power amplifier. In any case, the input level to the equalizer should not exceed 2 volts rms.

After installation, set the audio system tone control for flat response. Using just the equalizer's controls for tone compensation will provide a better graphic representation of the equalization preferred.

Compensating for room acoustics is a bit tricky, but it can be accomplished by using a sound pressure level meter and test record. ◈



A VU METER WITH NO MOVING PARTS

New bar-graph device provides signal-strength readouts, accurate peak signals

BY TERRY L. MAYHUGH

VU METERS cannot accurately read out momentary peaks due to meter-movement inertia. For example, the ballistics of a professional VU meter is standardized so that about 0.30 second is required before a steady-state reading is reached. Obviously, this is too slow to register the fast peaks that occur in music. A peak-responding LED is sometimes used to indicate the presence of such transients.

Here is a "VU" meter that combines the features of a standard VU and the peak indicator. It is a meter with no moving elements. The all-solid-state circuit is designed around a new incandescent bar indicator that instantaneously shows relative signal strength, including sharp peaks, over a wide dynamic range.

The readout element resembles a conventional DIP IC (in shape) and displays up to ten discrete signal levels on parallel filaments. In this case, it has a dynamic range of 30 dB, with each sequential filament illuminating fully at 3 dB over the preceding one. The tenth filament (the final 3 dB) is the peak signal indicator.

Circuit Operation. As shown in Fig. 1, potentiometer *R1* sets the level of the audio input to a precision full-wave rectifier that uses both halves of *IC1*. The rectified output is coupled to 10 parallel voltage comparators in *IC2*, *IC3*, and *IC4*.

Each of the 10 filaments in the display operates at 5 volts and 10 mA. The first nine are driven directly by the comparators. The tenth is controlled by a one-shot multivibrator (*IC5*) to indicate the peaks.

Two other comparators in *IC2* are used as voltage regulators to supply a reference voltage. A third regulator made up of *D3* and *Q1* supplies the higher current required for the display filaments.

The resistor network made up of *R24* through *R42* is arranged as an R-2R ladder that allows a precision voltage divider to be constructed using only two different values of precision resistors. The consecutive reference voltages for the noninverting inputs of the comparators are selected to increase in 3-dB steps from the low end to the high end of the range. As the rectified audio voltage to each comparator's inverting (−) input reaches that of the associated noninverting (+) input, the comparator switches to turn on its associated display filament. Thus, the number of filaments turned on (illuminated) at any instant is determined by the level of the audio input.

Construction. The circuit can be assembled on a pc board or a perforated board. All of the components except for the power supply and the display can be on the board. Sockets should be used for the IC's.

When laying out the board, be sure that wires carrying the comparator outputs and inputs are not too close to each other to avoid oscillation. Since the output pins of the comparators are at one end of the package, there should be no problem in getting a satisfactory layout. The $+V_{cc}$ pin of each IC should be bypassed to ground by a 0.1-μF disc capacitor mounted as close to the pin as possible.

Output indicator *DIS1* and its socket are cemented in a suitable rectangular cutout on the front panel. Since the incandescent filaments emit a white light, a filter of almost any color can be used in front of the display. In the prototype, a green filter was used.

Any power supply delivering 12 volts at 200 mA can be used.

Diode *D3* must be selected by trial and error. First, tack-solder a standard 1N914 into the circuit. Apply an input audio signal of about 1 or 2 volts rms to *J1* and adjust *R1* until all 10 segments are lit. All 10 segments should be bright, but there is a possibility that the first nine may not have equal brightness due to different current-sinking capabilities of the com-

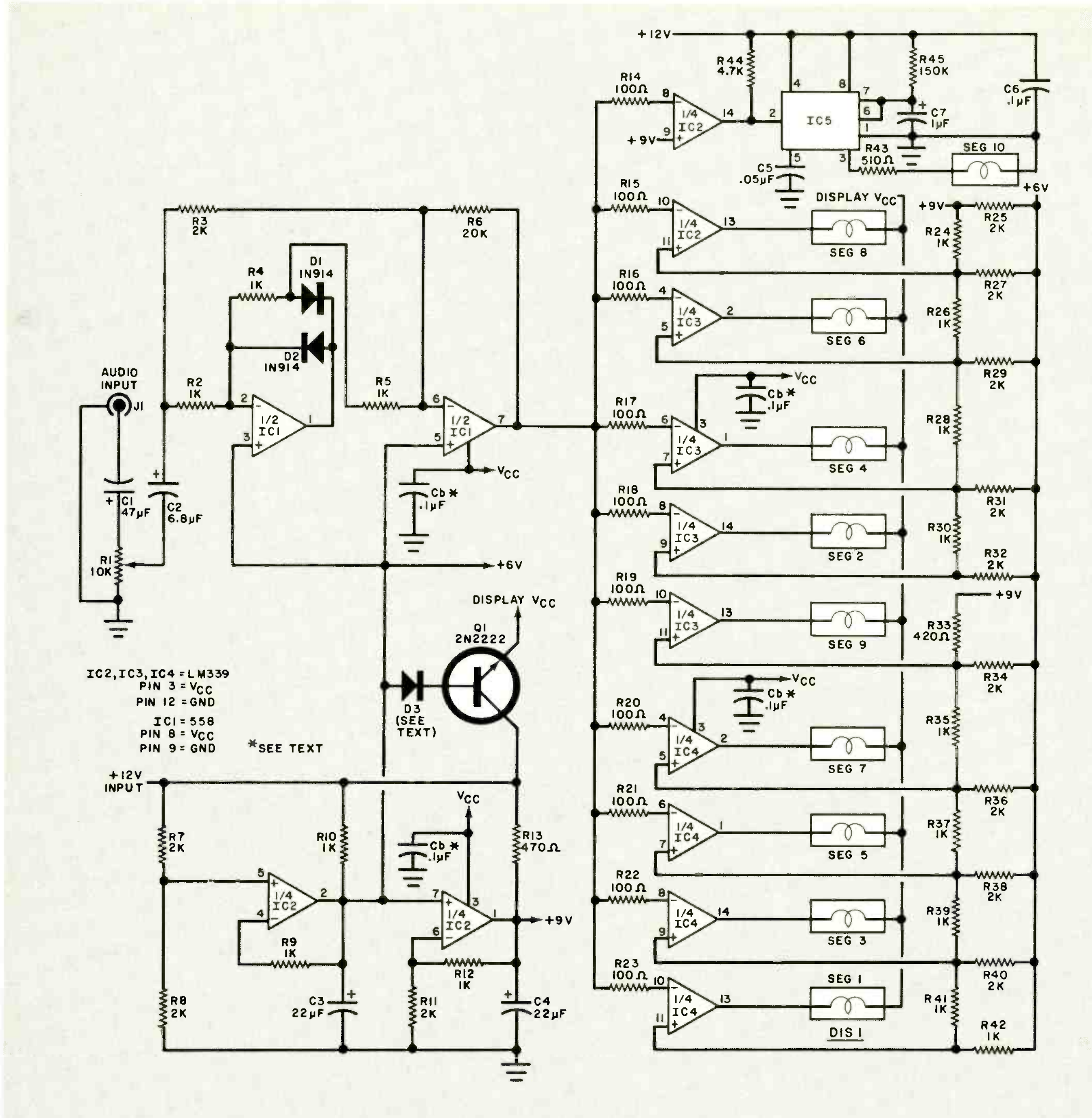


Fig. 1. The audio signal is rectified and applied to sequential comparators, which turn on filaments in display.

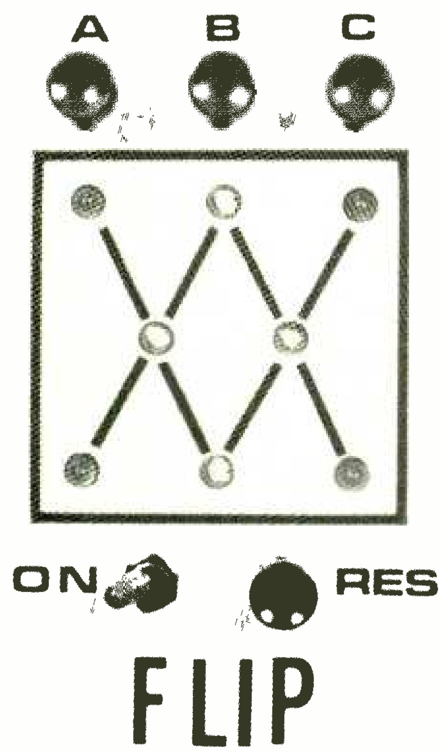
PARTS LIST

(Two of each needed for stereo)
C1—47-µF tantalum capacitor
C2—6.8-µF tantalum capacitor
C3,C4—22-µF tantalum capacitor
C5—0.05-µF ceramic capacitor
C6—0.1-µF ceramic capacitor
C7—1-µF tantalum capacitor
D1,D2—1N914 diode
D3—See text
DIS1—Bar indicator light (see note)
IC1—558 dual op amp
IC2,IC3,IC4—LM339 quadruple comparator (National)
IC5—555 timer
J1—Phono connector
Q1—2N2222 transistor (or similar)
R1—10,000-ohm potentiometer
R2,R4,R5,R9,R12,R26,R28,R30,R32, R35,R37,R39,R41,R42—1000-ohm, 1% resistor
R3,R7,R8,R11,R25,R27,R29,R31,R34, R36,R38,R40—2000-ohm, 1% resistor
R6—20,000-ohm, 5% resistor
R10—1000-ohm,5% resistor
R13—470-ohm, 5% resistor
R14 to R23—100-ohm, 5% resistor
R33—420-ohm, 1% resistor
R43—510-ohm, 5% resistor
R44—4700-ohm, 5% resistor
R45—150,000-ohm, 5% resistor
Misc.—IC sockets (6), transparent filter, cement, mounting hardware, power supply.
Note—Bar indicator (3015Q) is available from Readouts, Inc., Box 149, Del Mar, CA 92014, for $4.25, plus postage.

parators. If there is a noticeable difference in segment brightness, use two diodes in series for *D3*. Recheck the brightness. At least one diode must be used for *D3*; but as many as three (connected in series) may be used to get the desired brightness.

Use. Since the meter has a relatively high input impedance, it can be connected directly across the speaker terminals of any audio amplifier. In fact, two meters can be used for stereo balance tests.

Adjust potentiometer *R1* so that the last segment flickers on the required audio peaks. ◈



FLIP

A CMOS GAME COMPUTER

Do you dare challenge a handful of CMOS chips to a game of logic?

BY JOSEPH A. WEISBECKER

HERE IS a fascinating new electronic game based on digital logic. Called "Flip," it will introduce you to some basic computer concepts, pose a number of interesting mathematical questions, and provide a set of challenging puzzles. The puzzles are easily solved, however, when the proper logic sequence is understood.* Using low-cost CMOS logic and LED readouts, construction of Flip is simplified.

Circuit Operation. There are 8 flip-flops (*A* through *H*) connected as shown in Fig. 1. Eight LED indicators on the front panel show the state of each flip-flop (Fig. 2). A trigger pulse applied to a flip-flop reverses its state. Momentary-contact switches *S1*, *S2*, and *S3* provide trigger pulses for flip-flops *A*, *B*, and *C*. For example, pressing switch *S1* will trigger flip-flop *A* so that, if *LED1* was on, it will go off, and vice versa. The transition from off to on also supplies a pulse to trigger flip-flop *D*. The reversal of *D* then supplies a trigger pulse to *F* or *G*.

The circuits in Fig. 1 actually form a number of 2- and 3-bit interacting counters. For example, flip-flops *C*, *E*, and *G* form a 3-bit binary counter that is triggered each time *S3* is pressed. Fig. 3 shows how this counter works. Pressing the reset switch, *S4*, sets the *C*, *E*, and *G* lights as shown in the top row. Now, repeated pressing of *S3* causes the lights to go on and off in the 3-bit binary sequence shown in Fig. 3. The combinations of flip-flops *BEH*, *BDF*, *ADF*, etc. also form 3-bit binary counters.

The circuit in Fig. 1 also contains 8 "memory" cells which remember an 8-bit pattern. This pattern (or state) can be modified by the input switches and is displayed by the LED's. A wired-in "program" controls the change-in-state of the device as a function of the previous state and an input switch. Pressing a single input switch 8 times always returns the device to its initial state, thereby demonstrating its ability to count input switch depressions.

In Fig. 1, *IC5* and *IC6* are quad 2-input NAND gates connected to form three set/reset flip-flops for debounce of the switches. Eight D-type flip-flops are provided by *IC1* through *IC4*, which are triggered by a positive-going edge. Flip-flops *A*, *B*, and *C* are triggered directly by the three debounce flip-flops. Flip-flops *D*, *E*, *F*, *G*, and *H* are each triggered by transitions of other flip-flops. The capacitance-resistance combinations differentiate the outputs of these flip-flops to form positive pulses. For example, *C1-R1* and *C7-R7* differentiate the positive-going not-Q outputs of *A* and *D* to feed an OR gate formed by *D1* and *D7* and trigger flip-flop *F*. Trigger pulses for *D*, *E*, *G*, and *H* are derived in a similar manner.

Integrated circuits *IC7* and *IC8* are hex-inverting buffers used to drive the displays. Resistors *R22* through *R29* were chosen to limit the LED current to about 7 mA. Any LED that provides reasonable brightness for this current can be substituted — possibly reducing the cost. Resistors *R22-R29* can also be reduced in value to increase the brightness of the LED's; but this loads *IC7* and *IC8* above rated values and will also decrease battery life.

Construction. The Flip circuit uses CMOS logic circuits since they require low power, have good noise immunity and can be operated with unregulated voltage between 3 and 15 V. However, in using CMOS, some precautions must be kept in mind. All unused gates must have their inputs tied to the plus or minus supply voltage to prevent potential chip burn-out. Care must also be taken in installing the devices. Avoid any possibility of static charges on the inputs Keep them in the insulation in which they are shipped until

*Flip is an electronic version of a plastic computer game called "Think-A-Dot" made by Edu-Cards Corp. An article entitled "Mathematical Theory of Think-A-Dot" in the Sept.-Oct. 1967, issue of Mathematics Magazine provided a detailed analysis of the game. The original Think-A-Dot instruction book also provided an extensive discussion of the device, with methods for demonstrating counting, adding, and subtracting of 8-bit binary numbers.

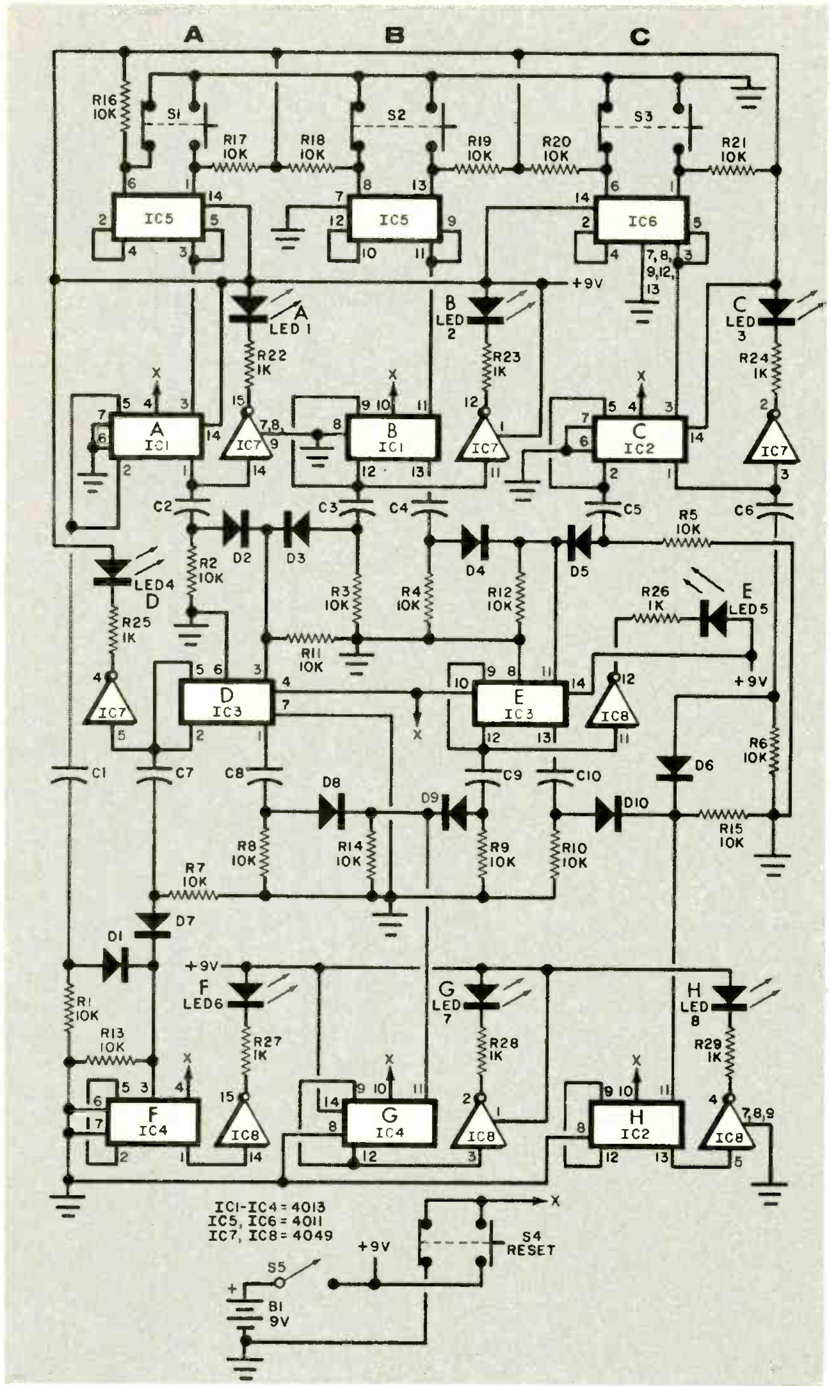


Fig. 1. Schematic of "Flip." Details on making the two-sided PC board for this computer game are given elsewhere in this Handbook.

PARTS LIST

B1—9-volt alkaline mercury battery
C1-C10—0.033-μF disc capacitor (low voltage)
D1-D10—Silicon diode (1N914 or similar)
IC1-IC4—CD4013 integrated circuit
IC5,IC6—CD4011 integrated circuit
IC7,IC8—CD4049 integrated circuit
LED1-LED8—Any light-emitting diode
R1-R21—10,000-ohm, ½-watt resistor
R22-R29—1000-ohm, ½-watt resistor
S1-S4—Spdt switch, momentary closed (Alco MSP-105F or similar)
S5—Spst switch
Misc.—Battery connector, suitable cabinet, "dry-transfer" type, adhesive tape, etc.

ready to solder and use a grounded soldering iron. Low-temperature solder and a low-power iron should be used.

Diodes *D1* through *D10* are not critical; low-current switching types (silicon) were used in the prototype.

The circuit can be assembled on a perf board or on a pc board as shown in Fig. 4. To avoid complexity on the pc

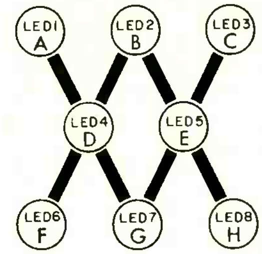


Fig. 2. Arrangement of LED's on the front panel of Flip.

board, some short cuts have been taken. Note that *C1* through *C10*, *D1* through *D10*, and *R1* through *R10* are attached together as shown in the insert in Fig. 4 before inserting the loose ends in the pc board. Note that the capacitor end is called out as A, the diode end as B and the resistor end as C on the overall component layout.

There are 19 jumpers that must be made of thin insulated wire and connected between similarly numbered points in Fig. 4 (point 1 to point 1, etc. up to point 16 to point 16). The last three jumpers are from point 17 on *IC1*, *IC2* and *IC3* to point X, the reset circuit.

The eight LED's and the three switches are mounted on the front panel as shown in Fig. 2 and the photo. Also mount the reset and on/off switches on the front panel. The lines connecting the lights on the front panel can be added in any way desired.

Testing. Turning on the power

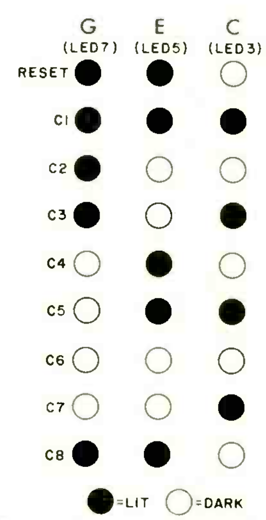
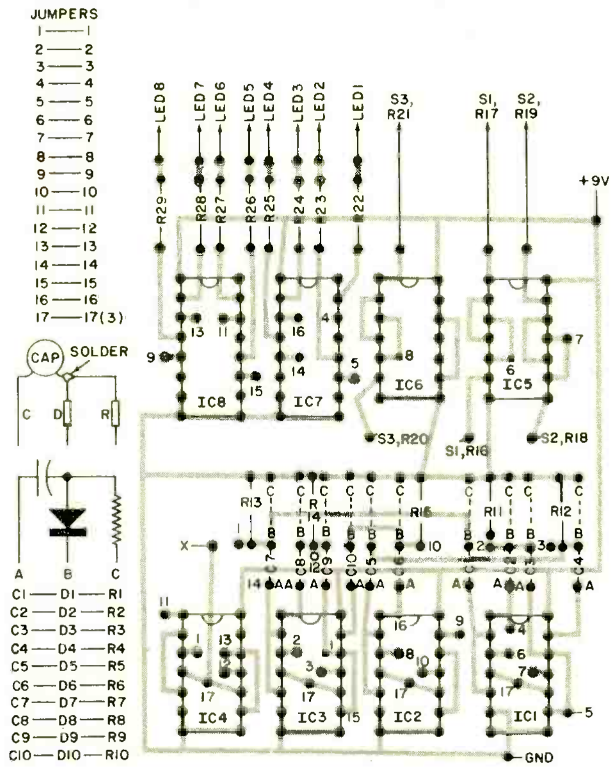


Fig. 3. It takes eight operations of a pushbutton to make the cycle. This shows which LED's come on in sequence.



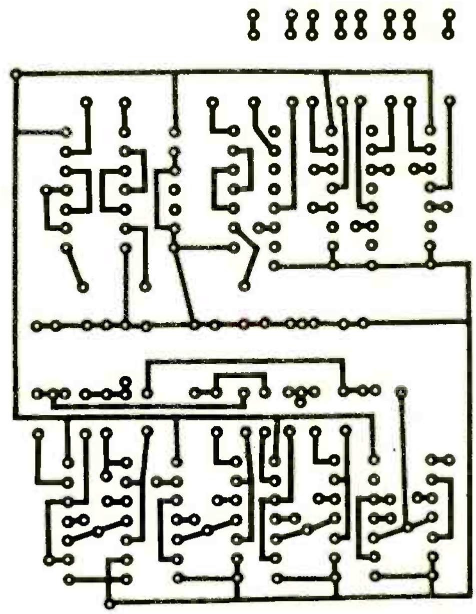


Fig. 4. Either a perf board or printed circuit board can be used for the circuit. Note how the C-D-R assembly is made. Be sure to install the jumpers.

switch should cause a random pattern to appear on the LED display. Pressing the reset switch should result in the P1 pattern of Fig. 5. If it doesn't, check the reset wiring and voltage connections. After obtaining the P1 pattern, press switches *A*, *B*, and *C* one at a time to verify that all flip-flops are being triggered properly as indicated in Fig. 3. Check signals and wiring for any that fail to operate peroperly. If the signals to a flip-flop are correct but it still fails to trigger, replace the chip.

Use. Fig. 5 shows how Flip is used to solve puzzles. Pressing reset switch *S4* provides the pattern of lights shown at P1. As a sample problem, try to get from pattern P1 to pattern P2 by pressing one or the other of the input switches just 7 times. The other patterns in Fig. 5 can be obtained with the indicated number of switch operations.

An interesting game that can be played is to try to generate specific patterns, with players taking turns pressing just one switch at a time. Starting with the reset switch operated to set the original pattern, the goal is to obtain a pattern consisting of a triangle of lights (either *ACDEG*, or *BDEFH*). It doesn't matter if additional lights are on as long as one of the two winning triangles appears. Of course, other patterns, easier or harder, can be chosen as the winning pattern. Since it is possible to predict what pattern is going to appear next, considerable skill can be developed.

Flip provides some insight into why bugs occur in large computers after months or even years of use. These machines have thousands of possible states, many of which remain untested until someone happens to write a program that causes one of these states to occur. Flip, with only 8 flip-flops, has relatively few possible states, but it is still nontrivial in a mathematical sense. For example, how many of the potential 256 states (or patterns) can be obtained starting from the reset state? Can you develop an algorithm (set of rules) for finding the shortest sequence of switch depressions to transform one pattern to another?

Here is another interesting property of Flip. If the sum of the lights that are on in the top and bottom rows is even, then pressing *A*, *B*, and *C* any number of times will leave this sum even. In other words, the parity of these 6 bits (lights) can't be changed by the input switches. This concept of parity is used for error checking in computers. For example, a switch input can only change the parity of the 6 bits of the top and bottom rows if a circuit malfunction occurs. This condition could easily be detected and used to turn on an error light. ◈

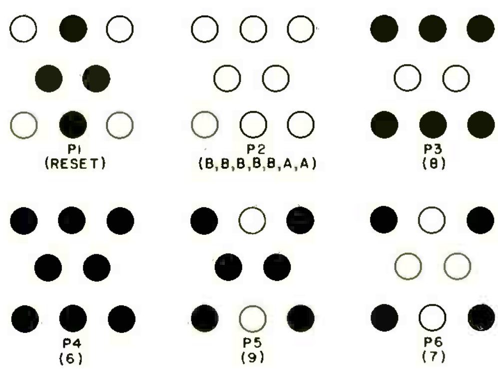
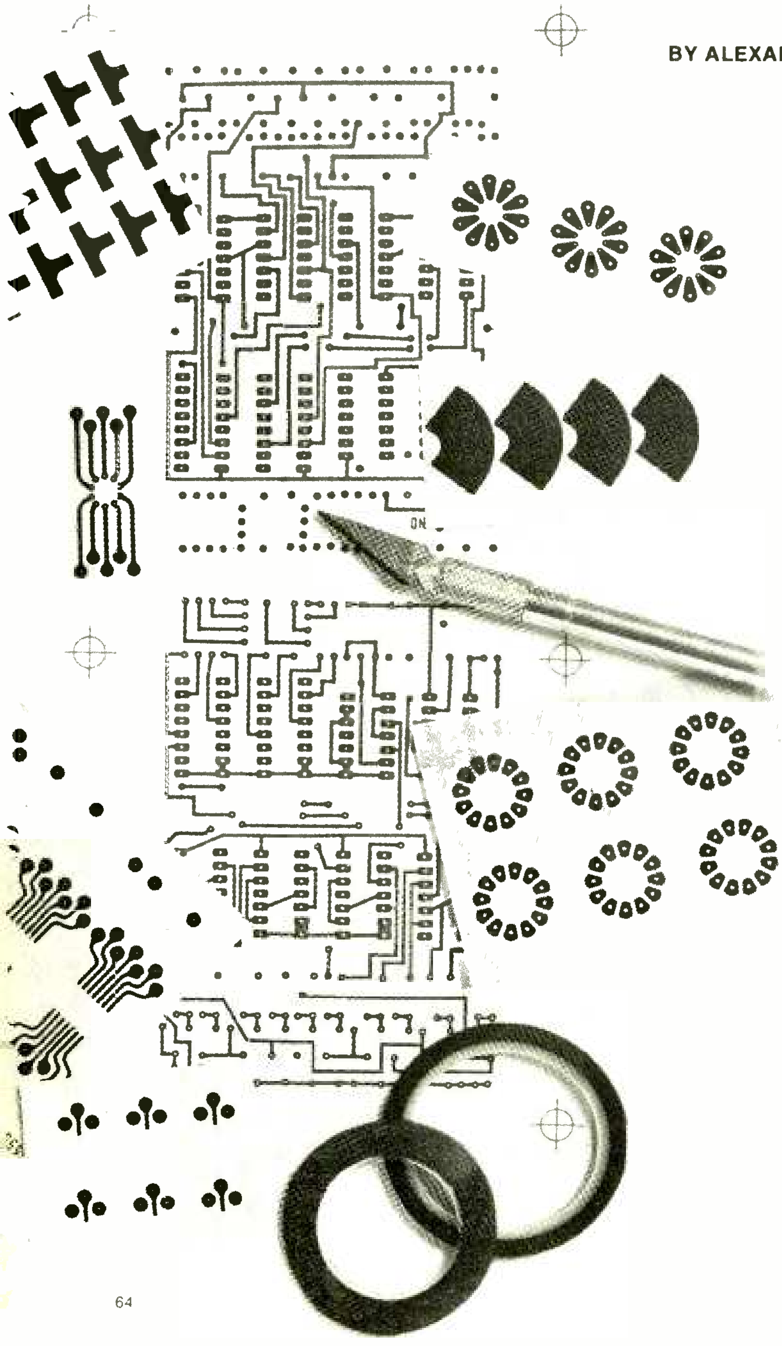


Fig. 5. Pattern after reset is P1. To get P2, press switches as shown. Other patterns take indicated number of switch operations.

HOW TO MAKE DOUBLE-SIDED PC BOARDS

Easy procedure lets you make professional-quality boards at home.

BY ALEXANDER W. BURAWA



ELECTRONICS experimenting is becoming increasingly more sophisticated — and complex — with each passing year. The widespread proliferation of IC's has precipitated an urgent need for serious experimenters to master printed circuit techniques — including the design and fabrication of double-sided pc boards. With the MOS era upon us, that need is growing to the point where you will either have to know how to make your own boards or get out of serious experimenting.

The double-sided pc board offers us many advantages over the single-sided board. For example, the routing of conductors is much more flexible when both sides of the board are used. You can also expect greater packaging densities. Wire jumpers will be only a memory. In the long run, the double-sided board is the most economical and least time-consuming means of assembling complex projects.

No special training is needed to design double-sided pc boards. *If you can trace a circuit, you can design just about any type of pc board.*

While the emphasis in this article is on double-sided pc techniques, the following step-by-step procedure is equally applicable to single-sided boards. The procedure can be performed in a home workshop. It is geared to making professional-quality exposure masks to be used with presensitized pc blanks. (The so-called "photo" process is the only practical way of making complicated pc boards.)

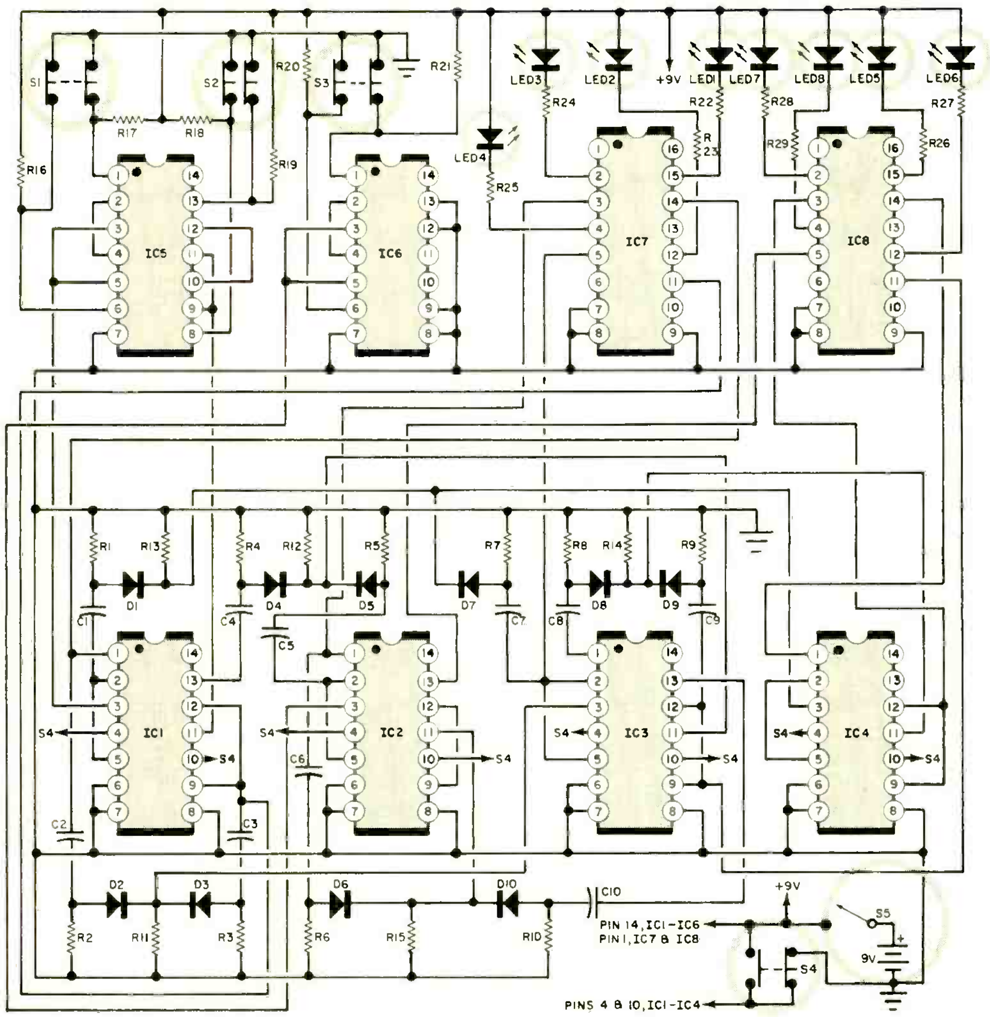


Fig. 1. Convert logic diagram to IC-package format. Indicate off-board components.

The Preliminaries. First, indicate on the project's schematic the components that are to be mounted off the board. We will use the "Flip" game computer to illustrate an actual double-sided pc-board design procedure. Its schematic, converted to an "IC-package" format with all the off-the-board components circled, is shown in Fig. 1. (Note: The IC-package diagram gives a better idea of the conductor pattern *as it applies to the IC lead configurations*. Hence, it is worth your while to convert all logic diagrams to the IC-package format.)

Tape a separate sheet of tracing paper over the schematic and over graph paper that has 10 divisions/inch. (Graph paper eliminates the need for a drafting setup. The 10-division/inch variety fits in well with electronics work since the common dual in-line package (DIP) IC leads are separated in 0.1-inch increments.)

Working on the graph-paper-backed tracing paper, redraw only the *conductor* pattern of the schematic. Start with a black pencil and draw a small circle for *each* component lead connection into the pattern. If three components share a common tie point (see *C1/D1/R1* in Fig. 1), there must be a circle for each connection at this point. Interconnect as many of these circles as you can *without crossing lines*. If necessary, reroute lines to obtain the maximum number of interconnects, but pay careful attention to the schematic when you do this.

Use a *red* pencil to interconnect the remaining circles. You can cross the black but *not* the red lines in this step. And do not forget to use the two-color scheme while plotting your progress on the schematic's tracing paper.

You will find that, in a circuit as complex as the Flip's, no amount of rerouting will permit all circles to be interconnected without breaking the line-crossing rule. However, the interconnections can be made by alternating between the red and black patterns, as shown in Fig. 2. Wherever the lines alternate between the patterns, indicate these points with small circles.

When you are finished, check your drawing against the schematic. Then count the red lines. If there are very few, you can opt for a single-sided board, wiring in jumpers for the red lines. On the other hand, many red lines indicate the need for a double-sized board.

If size is of little importance in your project, you can proceed directly to the pencil layout phase of the design procedure. But if you want the board to be as small as possible, you must rearrange your drawing to satisfy this objective. You might have to try several arrangements before settling on the most compact one. This will prove the most time-consuming part of the design procedure, especially with your first few projects. But with a little practice, you will soon acquire an instinct for arrangements.

The Flip's conductor pattern that yields the most compact layout is shown in Fig. 2.

Pencil Layout. You are now going to make a pencil layout of the etching

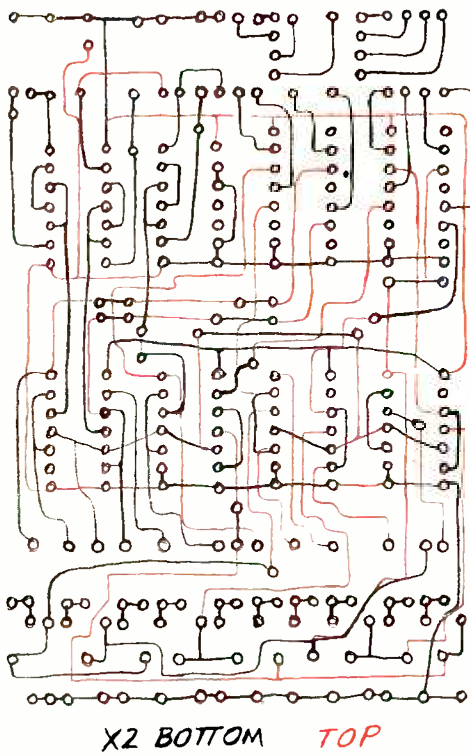


Fig. 2. Rearrange conductor pattern, using two colors, to obtain minimum-size layout.

guides, scaling it to the sizes of the components you will be using in the project. Since, from Fig. 2, you already have a rough idea of component arrangement, choose a point at which to start with an IC or transistor pad.

As good a place as any to start in our example is the *IC1-IC4* group of pads. Count the vertical red lines, black lines, and alternating-pattern circles between each IC. Then count the horizontal lines and circles between the *IC1/IC4* and *IC5/IC8* groups of pads. Make a list of your counts. Such a list for Fig. 2 might look like:

IC1-IC2: 1R 3B OC   IC5-IC6: OR 3BC
IC2-IC3: 3R 2B OC   IC6-IC7: 2R 2B OC
IC3-IC4: 1R 3B OC   IC7-IC8: 1R 2B OC
IC1/IC4-IC5/IC8; 6R 6B 5C

The R, B, and C mean red, black, and circle. Close examination reveals that the circle in the *IC5-IC6* entry does not interfere with the lines between the IC's and can be disregarded. Similarly, the two red lines in the *IC6-IC7* entry do not interfere with each other; they can be counted as one line.

Armed with your list, draw on graph-paper-backed tracing paper the IC-pad circles. It is a good idea to work in a 2:1 scale to avoid possible confusion. Pay strict attention to component-lead spacing.

Once the IC-pad circles are properly located and spaced, write X2 BOTTOM in black pencil on the bottom of the tracing paper. Next to this, in red pencil, write TOP. These references tell you that the scale is 2:1 and that the black and red lines in the pattern you are about to draw refer to the bottom and top etching guides, respectively.

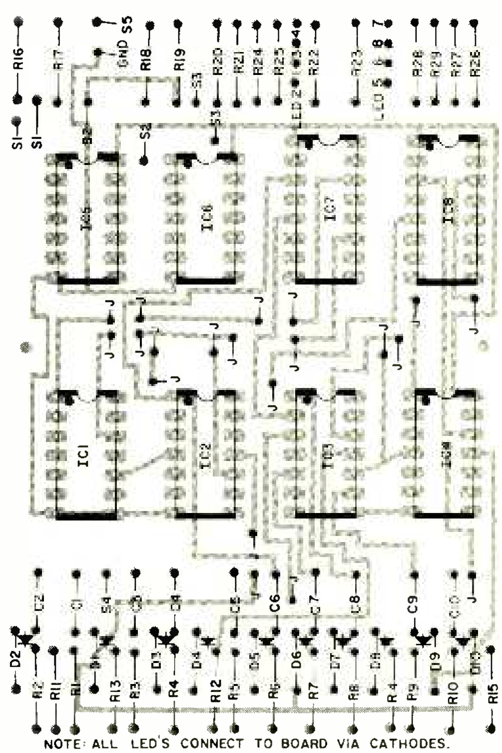
Working very carefully, transfer all of the pattern information contained in your rearranged composite drawing to the tracing paper on which you drew the IC-pad circles. Use the two-color scheme. You do not have to be very neat, but you must be accurate. Our drawing in Fig. 2 shows the minimum-size arrangement of the schematic in Fig. 1 and is accurately sized to the components used in the Flip, although it is shown reduced to conserve space.

As you become expert in laying out double-sided pc etching guides, you will also learn to combine the rough and finished pencil layouts into one accurately sealed drawing operation. But until you gain familiarity, it is best to perform the two steps separately.

Place another sheet of tracing paper over your pencil layout. On this, indicate all component locations and orientations and all points where feedthroughs are to be used. The component placement guide for the Flip, indicated on the top etching guide, is shown in Fig. 3. The J's indicate the feedthrough points.

Again, carefully check your work against the schematic. It is essential that you catch errors before proceeding to the finished etching guide steps. Experience has revealed that you will be more alert if you allow sev-

Fig. 3. Indicate the exact location and orientation of each component on the layout diagram.



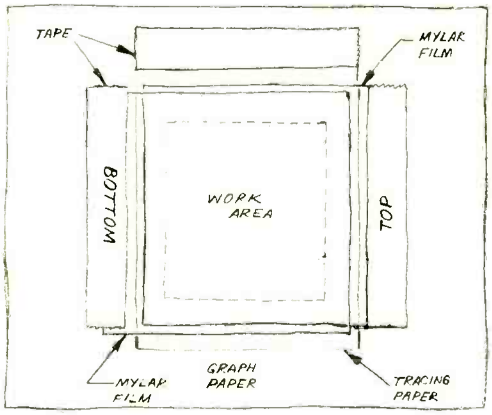


Fig. 4. Set up work area on graph paper. Tape down and identify Mylar film so that sheets open alternately to left and right.

eral hours, preferably overnight, of rest between finishing the layout and checking it out.

Exposure Masks. To compose the actual-size etching guides that will be used as exposure masks with presensitized pc blanks, use drafting aids and tapes obtained only from pc materials suppliers. You will need clear Mylar® film (designed for pc work) on which to compose the guides. Also, have handy an X-acto® knife and graph and tracing paper, and work in a well-lighted area.

Measure the length and width of your pencil layout, and divide these figures in half. You now know the sizes of your etching guides and the size of your working area. Add one inch all around; then cut two pieces of Mylar film and one piece of tracing paper to the latter dimensions.

Tape down a piece of Mylar film on a sheet of 10-division/inch graph paper. Very carefully lay out on it the bottom etching guide's pattern (black lines in your pencil layout) with the appropriate drafting aids and tape. To do this, you must *first turn over your pencil layout* to properly view and lay out the bottom etching guide. When you turn over the layout, carefully realign it on its graph-paper backing and put aside the components-placement guide. Divide all spacings in half, and transfer the circles and black lines to the film.

When the bottom guide pattern has been transferred, flip over the film and pencil layout. Carefully realign them on their respective sheets of graph paper. When you tape down the bottom etching guide, do so along only one edge to allow it to swing open to the left or right and write BOTTOM on the tape. Follow this with the blank Mylar film, taping it along the opposite edge and writing TOP on the tape. Finish up with the tracing paper taped to permit it to swing toward the top. (See Fig. 4 for details.)

Set the bottom etching guide in place. Burnish down the bottom etching guide pattern with a blunt instrument. (A Popsicle stick or tongue depressor will do nicely.) Burnishing is necessary to seat the drafting aids and tapes on the film. Apply firm strokes, but not so firm that they shift the aids or tapes.

Swing the blank Mylar film into place on the bottom etching guide, but not the tracing paper. Very carefully repeat **all** pads from the bottom etching guide on the blank film. Pay special attention to alignment. Then slip the tracing paper between the two sheets of film. It will prevent any black-on-black confusion from cropping up, while allowing a clear view of the bottom etching guide. Now, complete the top etching guide by interconnecting the appropriate circles indicated in the red pencil layout. Burnish down the drafting aids and tapes.

Remove both guides from the graph paper and place them artwork-side-up in front of you. Apply to the bottom of each a strip of Scotch® Magic transparent tape. Follow by using a ball-point pen to write the project's name, FOIL SIDE, and TOP and BOTTOM on the respective guides.

Set aside the top etching guide. Then use a crow-quill pen and India ink to fill in all transparent component-lead holes in the pads of the bottom etching guide. The filled-in holes will provide for a small registration error between the top and bottom pattern when the board is etched and drilled. If these holes are not filled in, it is possible that drilling might remove too much copper from misregistered copper pads.

PC MATERIALS SUPPLIERS

Following is a partial list of manufacturers and suppliers of materials for use in making double-sided pc boards. Included are summaries of items available from each.

Bishop Graphics, Inc. (7300 Radford Ave., North Hollywood, CA 91605): Quantity sales of drafting aids and tapes, precision graphed glass and film, polyester drafting film, etc. (Send 50¢ for Technical Manual & Catalog No. 105.) Also available are no-etch "Circuit Zaps."

GC Electronics (400 S. Wyman St., Rockford, IL 61101): Small-quantity sales of drafting aids and tapes, layout film, developing and etching trays, photoresist chemicals, etchant, pc blanks, exposure frame, kits. (Send 50¢ for Printed Circuit Handbook No. FR-161 for complete instructions on how to make single-sided pc boards. Handbook includes listing of complete line of pc materials available.)

Kepro Circuit Systems Inc. (3630 Scarlet Oak Blvd., St. Louis, MO 63122): Pc blanks, photo-resist chemicals, etchant, photo layout kit (includes tapes and drafting aids), all-in-one kits, photo-reversing (film) kit.

Techniques Inc. (235 Jackson St., Englewood, NJ 07631): All types of drafting and fabrication kits, etchant, photoresist chemicals, pc blanks, tools, reversing film kit, etc.

Vector Electronic Co., Inc. (12460 Gladstone Ave., Sylmar, CA 91342): Direct positive photoresist kits, double-clad pc blanks, drafting aids, chemicals.

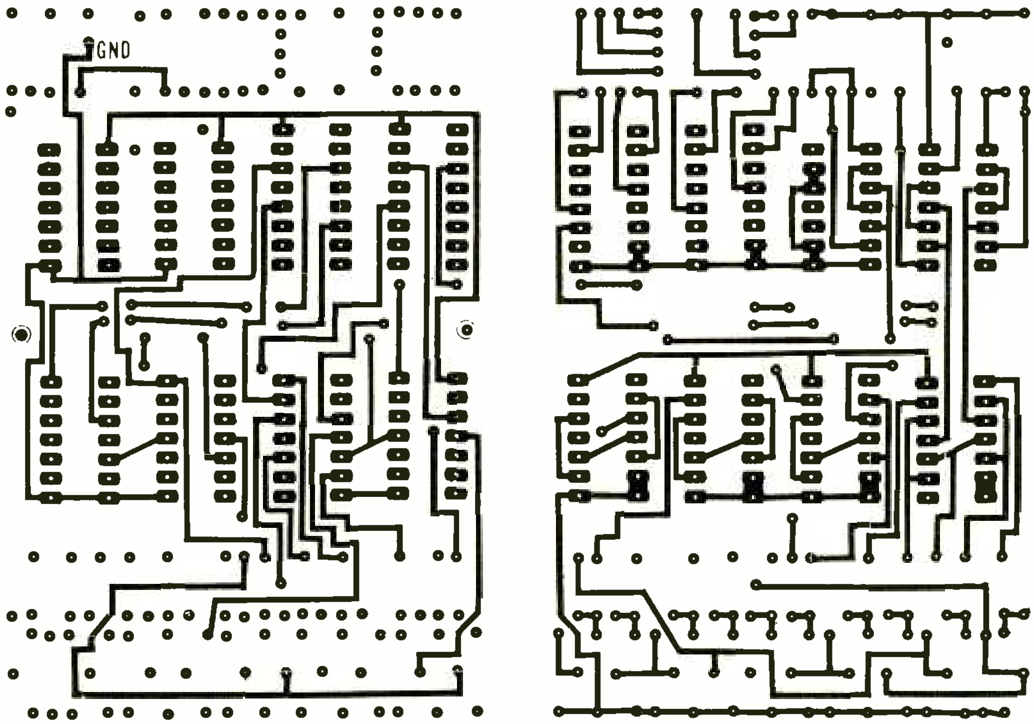


Fig. 5. Double-sided etching guides for "Flip" are shown from the foil sides.

You now have etching guides that can be used just as they are to expose positive-resist pc blanks. But if you are using negative-resist blanks, the guides must be reversed. This is a simple process that is easily accomplished with a reversing-film kit available from some pc materials suppliers.

The etching guides for the Flip are shown in Fig. 5. For component placement and orientation, refer back to Fig. 3.

Exposing the Blank. To expose a presensitized pc blank with double-sided board masks, start by carefully aligning the two masks, back-to-back, and taping them together so that they cannot shift. Working in a safe-lighted area, tape the mask pair down on a presensitized pc blank. Then drill two or more small holes through both masks and the blank. Use holes in the pattern. Remove the masks and replace the blank in its light-tight shipping container.

Cut off the heads of as many small wire brads as you have holes drilled. Select brads that are just large enough to fit into the drilled holes with the absolute minimum of play without binding. File flat the cut ends of the brads.

Place a sheet of flat black art paper on a block of rigid polystyrene foam (available from florists and plastics specialty shops). Go back to safe lighting after separating the exposure masks. Place the presensitized blank through which the holes were drilled over the paper-covered foam block and fill each hole with a brad. Press down on the brads until only about 1/8 inch protrudes above the surface of the blank.

Align the holes in the appropriate exposure mask with the protruding brads and force the mask flat against the blank. Place a sheet of glass over the whole assembly, pressing down only until the exposure mask is in intimate contact with the blank. Expose the blank according to the manufacturer's directions.

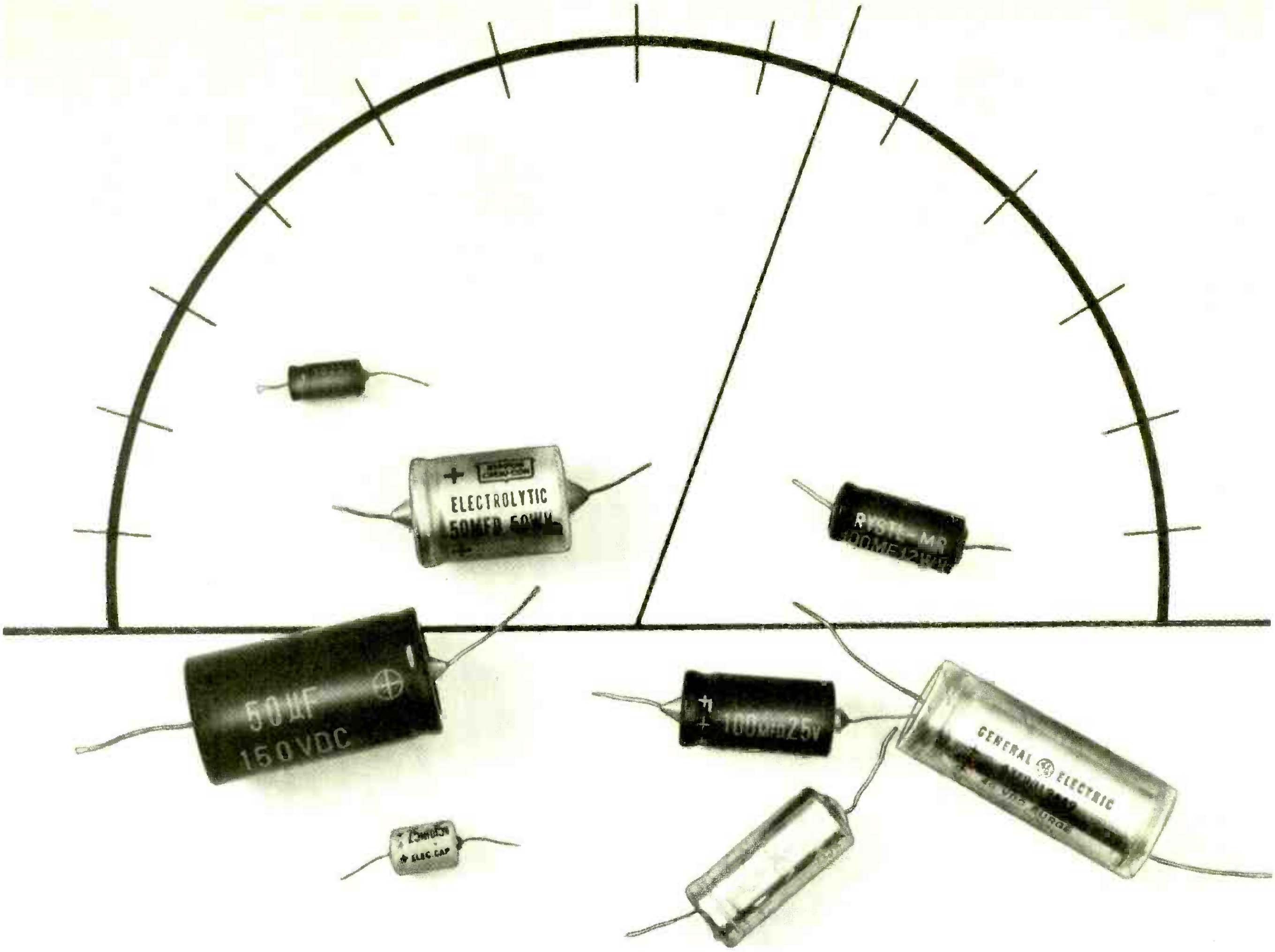
Switch back to safe lighting and remove the glass and mask. Remove the blank, handling it only by its edges, and immediately flip it over. Remove the brads from the foam block. Then place the flipped-over blank on the paper-topped block and replace the brads in the holes. Follow the procedure outlined above to set up and expose the second side of the blank. Make absolutely certain that the second exposure mask is properly oriented.

When both sides of the blank have been exposed, develop the blank according to the manufacturer's instructions. Then, after inspecting the developed blank to check that the exposure has taken, etch away the unwanted copper.

Final Steps. The etched board (it is a board once etching has taken place) can now be trimmed to size and all holes can be drilled. Drill from the top of the board, keeping the tool perpendicular to the board's surface. Check frequently for proper hole alignment in the top and bottom copper pads.

After drilling all holes, refer to your component placement guide and immediately solder into place the feedthroughs. Solder both sides of the board; then clip away the excess wire as close as possible to the board. Mount the components in their respective locations, soldering their leads to the foil pattern on both sides of the board. (Note: Because the holes in homemade boards are not plated-through, you must solder to the patterns on both sides of the board. This means that you cannot use IC and transistor sockets that do not provide top-of-the-board access to their leads. If you wish to use sockets, substitute Molex Soldercons®.)

You have now designed and fabricated your own double-sided pc board. Good luck on your project. ◈

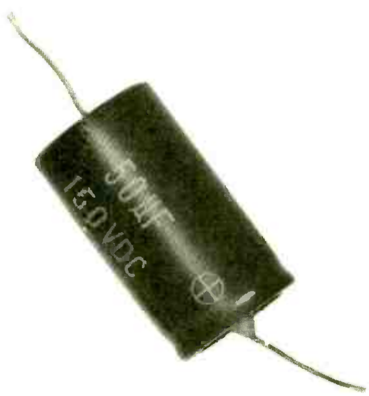


A HIGH-VALUE

ELECTROLYTIC CAPACITOR METER

Checks capacitance from 10 to 100,000 microfarads and indicates leakage.

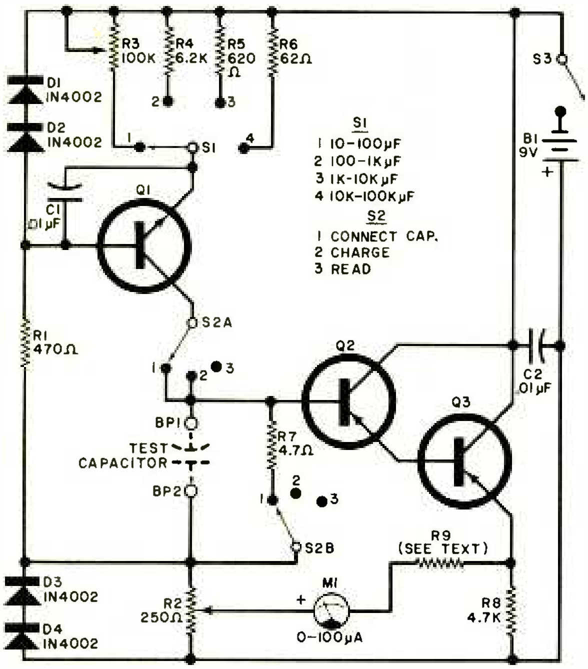
BY JOHN D. RICHARD



THE ACTUAL values of many electrolytic capacitors are sometimes different from those marked on the cases. More often, the values are illegible due to ink blurring, obliteration, etc. These are only two of the problems the experimenter faces in using electrolytics.

Among others, how do you apply a polarizing voltage to make sure the electrolyte in the capacitor is "formed" and that the unit is really operating properly? How do you tell whether or not an electrolytic capacitor is leaking? There are, of course, costly test instruments that can be used to solve these problems. But the expense of precise measurements is not always warranted because electrolytics have relatively broad tolerances.

At a low cost, you can build the electrolytic capacitor meter described here and get the information you need. It measures capacitance values



PARTS LIST

B1—9-volt battery
BP1, BP2—Five-way binding post (one red, one black)
C1,C2—0.01-µF capacitor
D1-D4—1N4002 diode
M1—0-100-µA meter (see text)
Q1—HEP735 transistor
Q2,Q3—Any general-purpose silicon pnp transistor
R1—470-ohm, 10%, ¼-watt resistor
R2—250-ohm miniature potentiometer
R3—100,000-ohm miniature potentiometer
R4—6200-ohm, 2%, ¼-watt resistor
R5—620-ohm, 2%, ¼-watt resistor
R6—62-ohm, 2%, ¼-watt resistor
R7—4.7-ohm, 10%, ¼-watt resistor
R8—4700-ohm, 10%, ¼-watt resistor
R9—See text
S1—One-pole, four-position rotary switch
S2—Two-pole, three-position rotary switch
S3—Spst switch
Misc.—Suitable metal chassis, perforated board, knobs, battery holder and connector, mounting hardware, etc.

Fig. 1. The constant-current source charges unknown capacitor and the meter circuit reads voltage level.

from 10 to 100,000 microfarads in four ranges with an accuracy of 10%. It will form the capacitor, and it will indicate if there is too much leakage.

About the Circuit. As shown in Fig. 1, the meter circuit is in two sections: a constant-current source consisting of *Q1* and a high-resistance voltmeter circuit consisting of *Q2, Q3 and M1*.

When the unknown capacitor is connected between *BP1* and *BP2* (positive side to *BP2*), switch *S2* is first placed in position 1 to discharge the capacitor through *R7*. Then *S2* is moved to position 2, and the constant-current source starts to put a charge on the unknown capacitor. The voltage across it increases linearly with time and is measured by the meter circuit. The voltage increase (in volts per second) is equal to the current (in amperes) from *Q1* divided by the capacitance in farads. Thus, with 1 ampere and 1 farad, the voltage increases at a rate of 1 volt per second. The ratio remains constant so that the voltage increases 1 volt per second for currents of 1 µA, 10 µA, 100 µA and capacitances of 1 µF, 10 µF, 100 µF, respectively.

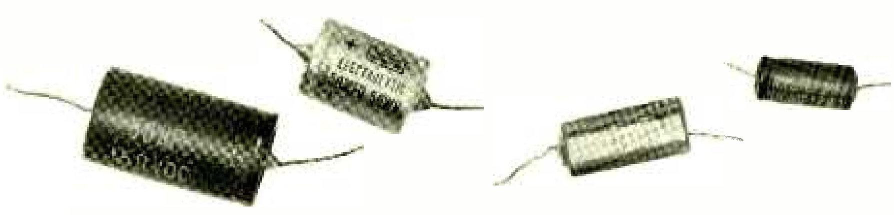
In this capacitance meter, a charge is applied to the unknown capacitor for 5 seconds and then the voltage on the meter is read. (Full-scale deflection is 5 V.) Thus, if the constant current is 100 µA and the meter indicates full scale after 5 seconds, the value of the capacitor is 100 µF. Larger values of capacitance will produce lower voltage indications.

The amount of current supplied by *Q1* is determined by the setting of *S1*. In position 4, the current is 10 mA; in position 3, 1000 µA; in position 2, 100 µA; and in position 1, 10 µA. Resistor *R3* is a preset potentiometer because the leakage current in *Q1* may cause the required current to be slightly different from the calculated value. (Also because the low forward current results in a small voltage drop across the base-emitter junction.) Tests have shown that, once *R3* is set, the collector current will remain constant at 10 µA.

Transistors *Q2* and *Q3* form a Darlington pair having a very high input resistance. The emitter load, *R8*, carries about 1 mA when the potential across it is 5 volts. Meter *M1* uses a series resistor *(R9)* of a value (50 kilohms minus the meter resistance) such that the meter will indicate full scale when 5 V is applied to the combination.

Because there is a voltage drop between the base of *Q2* and the emitter of *Q3*, binding post *BP2* is raised above ground by diodes *D3* and *D4*. However, in practice it was found that the voltage across the two diodes was slightly higher than that across *R8*, so the positive side of the meter is connected to potentiometer *R2* so that the meter can be zeroed.

Capacitors *C1* and *C2* remove any tendency of the circuit to oscillate on range 4 when long test leads are used on the binding posts.



Construction. The circuit can be assembled on perforated board and enclosed in a suitable metallic case. Put the three switches, meter, and binding posts on the front panel. Be sure to identify the switches and their positions properly. The power supply is a conventional 9-volt battery mounted in its own holder.

Adjustment. To set *R3*, place *S1* in position 1 and *S2* in position 3. Connect a 10-µA dc meter between the collector of *Q1* and the positive side of the battery. Set *R3* for maximum resistance and then turn on the power.

Carefully reduce the value of *R3* until the test meter indicates 10 µA. Do not allow too much current to flow or the transistor or meter may be damaged.

Fixed resistors *R4*, *R5*, and *R6* should provide the correct currents. However, for greater accuracy, small trimmer potentiometers may be substituted—10,000, 1000, and 100 ohms respectively. Then adjust the potentiometers to get 100 µA, 1 mA, and 10 mA respectively.

With the circuit adjusted, and with no test capacitor attached to the binding posts, set *S2* to position 1, and adjust *R2* for a zero indication on *M1*.

If desired, *M1* and *R9* can be replaced with an external dc voltmeter having a 5-volt scale and at least a 10,000-ohm/volt input resistance. In this case, connect the positive lead of the external meter to the rotor of *R2* and the negative lead to the junction of *R8* and the emitter of *Q3*.

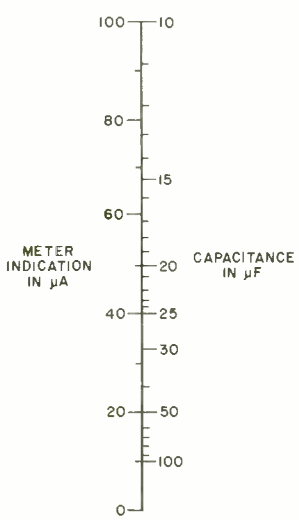
Operation. With an unknown electrolytic capacitor connected to *BP1* (minus) and *BP2* (positive), place *S1* for the desired range position and set *S2* to position 1. Wait a couple of seconds for the unknown to be fully discharged. Then turn on the power *(S3)*.

Observing the sweep-second hand of a clock or watch, place *S2* in position 2 for five seconds and note that *M1* indicates upscale. At the end of the 5-second interval, place *S2* in position 3 and read the meter. The capacitance can be found by using the conversion scale shown in Fig. 2 and the setting of *S1*. If you are using the external 5-volt dc voltmeter, use the conversion scale shown in Fig. 3.

If the capacitor being tested has not been used for some time, it is advisable to give it several charging runs on the capacitance meter before making the actual measurements. This permits the electrolyte to form so that the capacitor settles down at its final value.

Some readers may feel that the test capacitor will start to discharge through its own leakage resistance or because of the base current through *Q2* when *S2* is in position 3. In practice, it has been found that modern electrolytic capacitors will provide a meter reading that is steady enough to get a good indication. If the capacitor being tested has excessively low leakage resistance, the meter indication will start to fall rapidly; but it will still be possible to get initial indication. ◈

Fig. 2. Use the conversion scale at left for readings on M1 as shown in Fig. 1.



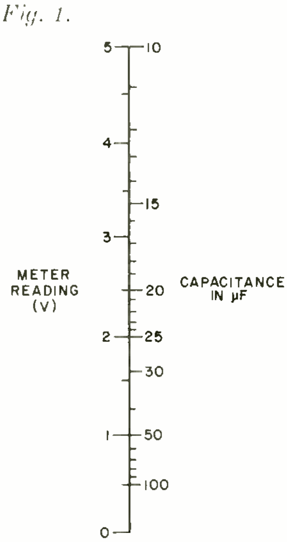


Fig. 3. Conversion scale for external 5-V meter.

3-WAY (SOUND LIGHT MANUAL) PHOTO FLASH TRIPPER

FOR NOVEL STOP-ACTION EFFECTS

BY JOHN F. HOLLABAUGH

SOME exciting and different photographic effects can be obtained with a strobe flash rigged to trigger from stimuli independent of the normal shutter switch. The photoflash tripper described here can initiate and delay the flash cycle with a sound or light stimulus or by completing an electrical circuit. For example, after the tripper receives a sound stimulus, a delay starts. After a preset time, the flash fires and exposes the picture.

About The Circuit. The common part of the flash timer is the delay circuit consisting of *SCR1*, *SCR2*, and *Q4* (see schematic). The cycle is begun by firing *SCR1* via a sound input at *SPKR*, light at *LDR1*, or mechanical trip wires connected to terminal strip *TS1*.

When *SCR1* fires, it applies voltage from battery *B1* to the *R10/C5* circuit, and *C5* begins to charge through *R10* at a rate determined by the value of the resistor. (The lower the value of *R10*, the shorter the charging time.) When *C5* has charged sufficiently to forward bias the emitter junction of *Q4*, a rapid rise in the current between the *B1* and *B2* terminals of *Q4* generates a positive pulse across *R11*.

This positive pulse is applied to the gate of *SCR2*, causing it to conduct current (from inside the flash unit connected to the tripper via *SO1*) and fire the electronic flash. After the cycle is complete, the circuit is reset to its initial conditions by momentarily depressing and releasing pushbutton switch *S3*.

Placing *S1* in position L (light) powers the *Q5* circuit and sets the system up for light tripping. Light falling on the light-dependent resistor *LDR1* causes the circuit to trip. Potentiometer *R12* serves as a sensitivity control.

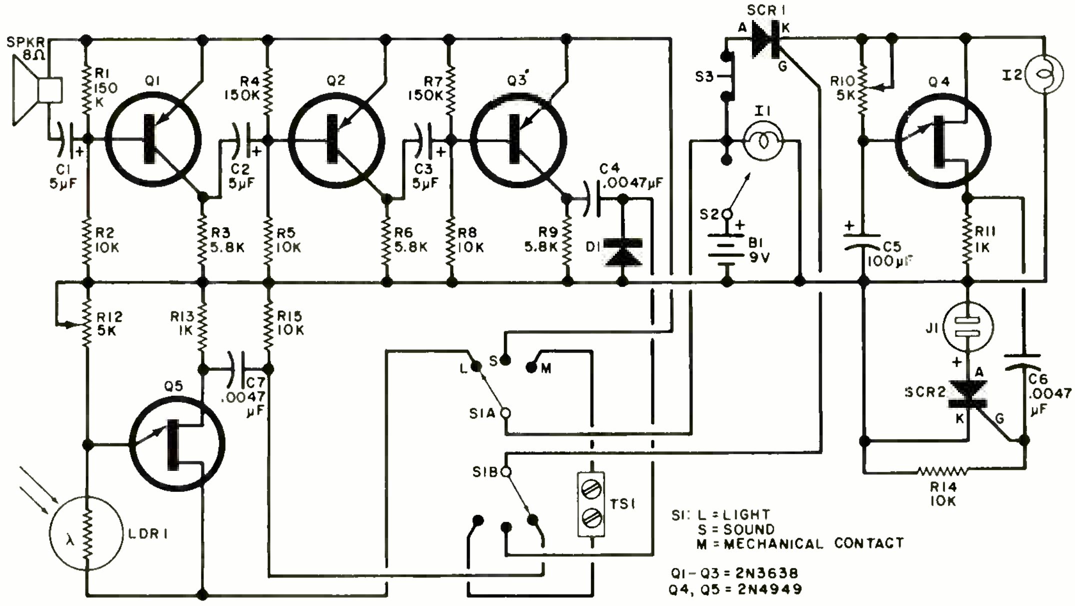
When *S1* is placed in position S (sound), power is applied to the audio amplifier circuit consisting of *Q1* through *Q3*. The speaker (*SPKR*) at the input of *Q1* is used here as a microphone. When a popping or other sharp sound is picked up by this microphone, a pulse is produced which is amplified sufficiently to trigger *SCR1* into conduction and start the timing cycle which, ultimately, fires the flash unit.

The final position of *S1* is marked M for mechanical contact. In this position, neither the light nor the sound circuits is powered. A pair of wires, terminated in a switch or left bare, is connected to terminal strip *TS1*. To start the timing cycle, the switch at the end of the wires need only be momentarily closed or the bare wires momentarily touched together.

The time lag between the firing of *SCR1* and the completion of the cycle with the firing of *SCR2* can be varied by adjusting potentiometer *R10*.

Construction. The circuit of the photoflash tripper is very simple, lending itself nicely to almost any type of chassis assembly. Just be sure that you observe proper polarity and basing connections.

When you mount *LDR1* in the chassis box you have chosen for your proj-



The delay circuit, composed of two SCR's and Q4, is triggered by signals from either the audible input through speaker, light striking LDR1, or a switch action at TB1.

PARTS LIST

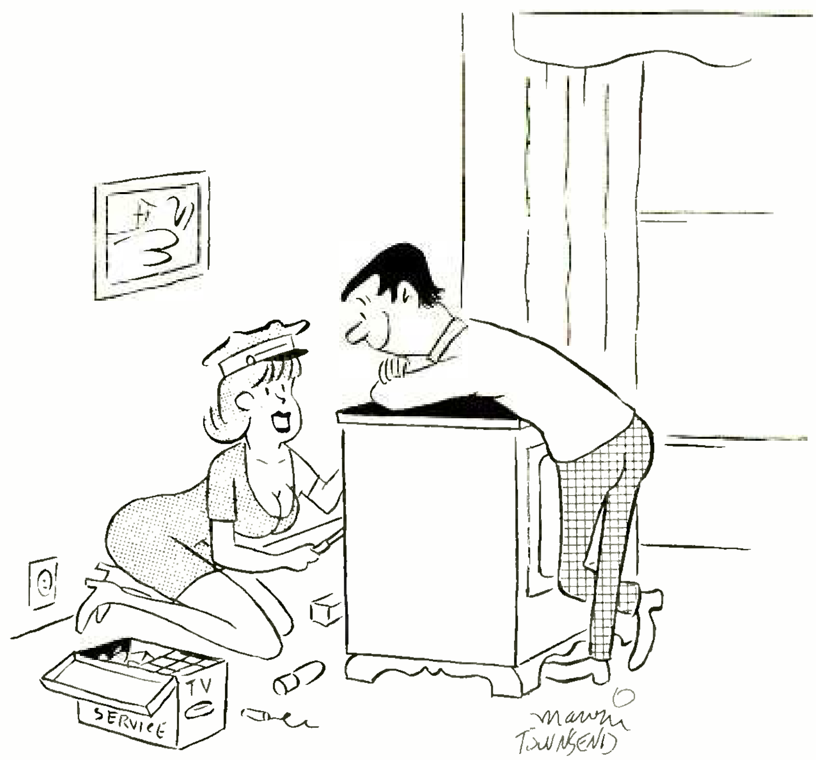
B1—Six 1.5-volt AA cells in series
C1-C3—5-μF, 15-volt electrolytic capacitor
C4,C6—0.0047-μF ceramic capacitor
C5—100-μF, 25-volt electrolytic capacitor
D1—1N4001 silicon diode
I1,I2—Miniature 10-volt panel lamp
J1—Camera shutter jack (includes length of cable)
LDR1—Light-dependent resistor (Clairex No. CL704 or similar)
Q1-Q3—2N3638 transistor
Q4,Q5—2N4949 unijunction transistor
R1,R4,R7—150,000-ohm, ½-watt resistor
R2,R5,R8,R14,R15—10,000-ohm, ½-watt resistor
R3,R6,R9—5800-ohm, ½-watt resistor
R10,R12—5000-ohm linear-taper potentiometer
R11,R13—1000-ohm, ½-watt resistor
S1—Double-pole/3-throw non-shorting rotary switch
S2—Spst switch (part of R10)
S3—Normally-closed pushbutton switch
SCR1,SCR2—Silicon controlled rectifier (1 ampere, 200 volts)
SPKR—8-ohm, 2¾-in., diameter speaker
TS1—Two-lug, screw-type terminal strip
Misc.—Bakelite or metal utility box; perforated board and solder clips; battery holder; pointer knobs (2); rubber grommet (for J1 cable exit hole); hookup wire; solder; hardware; etc.

ect, make certain that there is an access hole for the light to fall on the active element of this component. A good mounting method is to use an ordinary plastic pill container, its inside surfaces painted flat black, to hold the LDR.

When you wire the shutter cord into the tripper (this cord is terminated in *J1*), make certain that it is properly polarized. If it is improperly wired, the photoflash will not trigger because current flow through *SCR2* is unidirectional.

How To Use. Photography with the tripper requires the use of "red blind" ortho film. This permits the setup to be made in an area illuminated by only a dark red safe light.

Immediately before action begins, open the camera's shutter and leave it open until after the flash has fired. Setting the amount of delay required for any given filming sequence will have to be determined by trial and error. You can estimate how much delay is required by observing the event in total darkness. ◈



"I do hope you're not one of those men who object to women entering the electronics field."

BASIC DIGITAL LOGIC COURSE

BY FORREST M. MIMS

THE emergence of experimental digital IC projects has been so rapid that many people tend to get lost amid strange-sounding names like "quad 2-input positive NAND gate" and "BCD to 7-segment decoder/driver." Such terms describe the building blocks of digital electronics. To provide an introduction to logic for beginners and refresher information for more advanced experimenters, here is a brief "Digital Logic Course."

Number Systems. Early man was forced to count with small pebbles or knots on a string when he wanted to inventory his possessions. As time went on, and perhaps because he found it convenient to count with his fingers, man eventually devised a number system with ten digits. This provided a far more convenient and versatile counting system since, for example, the number 16 could be represented with merely two digits rather than 16 pebbles or knots.

The comparatively recent development of electronic digital computers has revived interest in number systems based on numbers other than ten.

A system based on two digits is of particular importance in electronic digital computers. The reason for this is that an electronic circuit can be made to occupy only one of two states: on or off (saturated or cut off). Of equal significance is that any form of logic statement can be reduced to contain only true and false assertions.

Since electronic circuits required to implement true and false logic statements are very simple, a computer can be designed based on a two-digit number system, in which one digit corresponds to "true" and the other to "false" The two-digit, or base-two, number system is called the binary system and its digits, called bits (for *bi*nary digi*ts*), are 1 and 0.

The Binary System. The easiest way to understand the binary system is to learn to count in binary fashion. One basic rule governs counting in any number system: record successive digits for each count until the count exceeds the total number of available digits; then start a second column to the left of the first and resume counting.

Since the binary system has only two digits, counting is very easy. You can prove this to yourself by counting to the equivalent of the decimal number 10 in binary. The binary of decimal 0 is 0. The binary of 1 is 1. Here the similarity ends. To express 2 in binary, you must start a new column since both binary, bits have been used in the first column. Hence, the binary of 2 is 10 (read one-zero—*not* ten). Three is expressed as 11 (one-one) in binary, which uses up both binary bits for the first two columns. So, a new column must be started for binary 4, which becomes 100, while 5, 6, and 7 become 101, 110, and 111. With 8, represented by the binary 1000, we must once again start a new column.

Binary Arithmetic. By learning how to count in binary, we have also derived three basic rules for addition: (1) 0 + 0 = 0; (2) 0 + 1 = 1; and (3) 1 + 1 = 10 (1 + 1 = 0, carry 1). These rules can be used to add any two binary numbers. For example, let us add 12 and 9 in binary:

$$\begin{array}{r} 1100 \\ +1001 \end{array}$$

Start with the right-hand column and add the *least* significant digit. Then continue adding each successive column, working from right to left, finishing up with the *most* significant bit:

$$\begin{array}{r} 1100 \\ +1001 \\ \hline 10101 \end{array}$$

Note in the above example that the addition of the two most significant bits yielded a 0 with a 1 carry. A carry can also occur within the addition as in: 1011 + 1101 = 11000.

Converting Binary to Decimal. Binary numbers are fundamentally easy to work with. But how do you convert a string of 1's and 0's to easily recognized decimal numbers? The process is simple, using a technique known as "expansion." Each digit column of a decimal number corresponds to a power of the base-10 to which it must be raised. Let us use the number 846 as an example:

$$\begin{array}{ccc} 10^2 & 10^1 & 10^0 \\ \hline 8 & 4 & 6 \end{array}$$

$$\begin{array}{rcrl} 6 \times 10^0 & = & 6 & \\ 4 \times 10^1 & = & 40 & \text{(add)} \\ 8 \times 10^2 & = & 800 & \\ \hline & & 846 & \end{array}$$

A binary number can be expanded in the same way and converted into a decimal number. For example, let us expand $(10111)_2$. The subscript denotes the base of the number system—in this case, 2 or "binary"—and helps in preventing confusion. The expansion is as follows:

$$\begin{array}{ccccc} 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \\ \hline 1 & 0 & 1 & 1 & 1 \end{array}$$

$$\begin{array}{rcrl} 1 \times 2^0 & = & 1 & \\ 1 \times 2^1 & = & 2 & \\ 1 \times 2^2 & = & 4 & \text{(add)} \\ 0 \times 2^3 & = & 0 & \\ 1 \times 2^4 & = & 16 & \\ & & (23)_{10} & \end{array}$$

Since the position of each digit in a binary number determines the power of 2 invoked, it is easy to convert binary to decimal simply by assigning the decimal equivalent to each column. A 0 in a column means that the column's power-of-2 decimal equivalent is *not* invoked. Therefore, the decimal equivalents of all columns containing a 1 are added to find the total decimal equivalent. Let us convert 10011 to decimal:

$$\begin{array}{ccccccccc} 16 & & 8 & & 4 & & 2 & & 1 \\ \hline 1 & & 0 & & 0 & & 1 & & 1 \\ 16 & + & 0 & + & 0 & + & 2 & + & 1 = (19)_{10} \end{array}$$

Manual binary arithmetic involving numbers containing more than three or four bits is both tedious and cumbersome when you are accustomed to counting in a decimal system. But an electronic computer can perform thousands of lengthy binary additions in fractions of a second. This ability is vital to the success of digital computers and calculators, since all arithmetic operations can be performed by addition or its variations. Subtraction is the inverse of addition, while multiplication is simply repeated additions and division is the inverse of multiplication.

These facts about addition are important because they mean that even the most complicated arithmetic operations can be solved by addition. In practice, manual arithmetic rarely invokes this process. After all, you would find it inconvenient to multiply 641 by 197 if you had to write 197 times the number 641 and add the columns. But an electronic computer does the equivalent of this in only a few milliseconds.

The Octal System. Sometimes binary numbers are condensed into other number systems to further simplify computer processing. Since the binary system has only two digits, it does not take long to accumulate a string of seemingly endless 1's and 0's. A decimal number with only two digits, for example, requires five binary bits. A six-digit decimal number requires 19 bits.

Complicated binary numbers can be simplified by dividing them into groups of three or four bits and encoding the results in other number systems. Since the binary numbers for the decimal digits 0 through 7 form groups of no more than three binary digits each, a long binary number can be reduced to a third of its length by converting it to a base-8, or *octal*, number system.

You can use a table of octal numbers and their binary equivalents to convert a long binary number such as 11101100001101 into octal. First, divide the number into groups of three bits each, beginning with the least significant bit:

11 101 100 001 101.

Then assign the octal equivalent to each three-bit group, using the octal-to-binary equivalents given in the table:

Decimal	Binary	Octal
0	0	0
1	1	1
2	10	2
3	11	3
4	100	4
5	101	5
6	110	6
7	111	7
8	1000	10
9	1001	11
10	1010	12
11	1011	13
12	1100	14
13	1101	15
14	1110	16
15	1111	17
16	10000	20
17	10001	21
18	10010	22
19	10011	23
20	10100	24

$$\begin{array}{ccccc} 11 & 101 & 100 & 001 & 101 \\ 3 & 5 & 4 & 1 & 5 \end{array}$$

Hence, $(11101100001101)_2$ equals $(35{,}415)_8$. It is obvious that the latter number is easier to process than the former.

Sometimes the base-16 (*hexadecimal*) number system is used to further simplify long binary numbers. The hexadecimal technique requires that the binary number be subdivided into groups of four bits each, again starting with the least significant digit. The result is a hexadecimal number that is only a fourth the length of the original binary number.

Boolean Logic. In 1847, George Boole, a British mathematician, published his *Mathematical Analysis of*

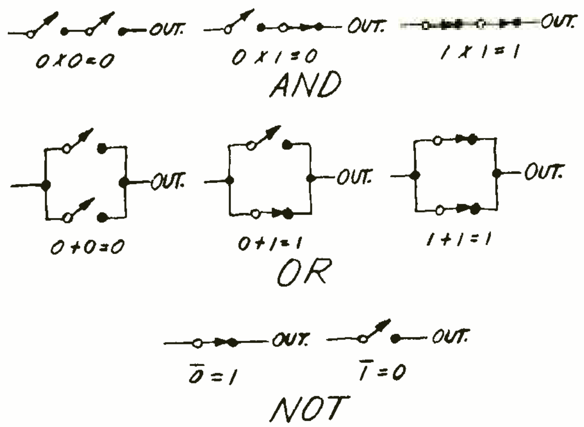
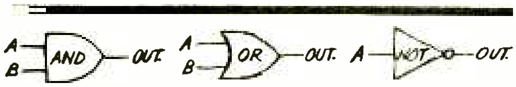


Fig. 1. Switches are arranged to illustrate three basic digital electronic functions.

Logic. This booklet did not equate mathematics with logic, but it did demonstrate how any logic statement can be analyzed with basic mathematical relationships. Boole published a much longer and refined version of his theory of logic in 1854. To this day, all practical digital computers and countless other electronic digital circuits are based on the concepts pioneered by Boole.

Boolean logic (or algebra) makes the important assumption that a logic statement is either true or false. Since electronic circuits can easily be made to operate in either of two states, on or off, it is convenient to equate "true" with "on" and "false" with "off." Similarly, we can equate the binary 1 with on and the binary 0 with off. With the foregoing in mind, let us review Boole's basic logic concepts.

The mathematical explanation of logic put forth by Boole can be simplified into three basic logic functions: AND, OR, and NOT. The AND function requires that one logic state or condition *and* at least one other be true before the entire statement is true. The OR function requires that one logic state *or* at least one other be true before the entire statement is true. The NOT function simply reverses a statement from true to false, or vice versa. Electronic NOT circuits are commonly referred to as "inverters" because their function is to invert the polarity of the signal.



A	B	OUT.
0	0	0
0	1	0
1	0	0
1	1	1

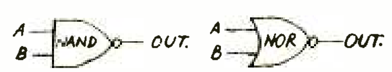
A	B	OUT.
0	0	0
0	1	1
1	0	1
1	1	1

A	OUT.
0	1
1	0

Fig. 2. AND, OR, and NOT symbols are shown with truth tables.

The above definitions can be tabulated into a table such as shown in Fig. 1. Such a table is useful in showing the relationships among Boole's three logic functions and their electronic and arithmetic counterparts. This type of table is sometimes called a "truth table" since it sets forth the various logic conditions for which each statement is true. Generally, truth tables are arranged in a more compact form similar to those shown for the three basic logic functions in Fig. 2.

Truth tables can be created for *any* logic function. Specification sheets for digital logic circuits almost always include a truth table.



A	B	OUT.
0	0	1
0	1	1
1	0	1
1	1	0

A	B	OUT.
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 3. NAND and NOR symbols with associated truth tables.

Logic Symbols. Boolean logic statements can be implemented by simply writing them on paper, using alphabetic symbols to correspond to "true" and "false" conditions. Electronic logic diagrams, however, are much easier to design and interpret if a sort of block diagram of the circuit is presented. For this reason, standardized logic-block symbols have been devised for the three basic logic functions. They are shown in Fig. 2.

Compound Logic Circuits. Two circuit combinations (the NOT-AND and the NOT-OR) are used so frequently that they are treated as basic logic elements and given their own logic symbols and truth tables.

When the AND function is followed by a NOT statement, the meaning of the AND function is reversed to NOT-AND, commonly called a NAND function. Similarly, when the OR function is followed by a NOT statement, the meaning of the OR statement is reversed to NOT-OR, commonly referred to as a NOR function. The logic symbols and truth tables for the NAND and NOR functions are shown in Fig. 3.

DeMorgan's Theorem. About the same time Boole developed his logic theories, Augustus DeMorgan was also developing some fundamental theories of logic. His most important contribution, known as DeMorgan's Theorem, relates the AND, OR, and NOT functions as follows:

$$\overline{A + B} = \bar{A} \times \bar{B}.$$
$$\overline{A \times B} = \bar{A} + \bar{B}.$$

The arithmetic symbols + and × mean OR and AND, respectively. The bar, or vinculum, over a letter indicates the NOT function. Thus $\bar{A}$ means NOT A.

The importance of DeMorgan's Theorem is that an AND circuit containing a NOT at each input corresponds to an OR circuit followed by a NOT. Similarly, an OR circuit with a NOT at each input corresponds to an AND circuit followed by a NOT. This does not equate the NAND and NOR functions, but it does mean that NAND circuits can be used to implement NOR functions, and vice versa.

Complex Logic Systems. Logic systems that contain three or more basic logic elements are termed "complex." One of the simplest of the complex logic systems is the EXCLUSIVE OR (sometimes written XOR) function shown diagramatically in Fig. 4. From the truth table, note that this function is identical to the OR function with one important exception: A true condition exists only when one *or* the other condition, but not both, is true.

The EXCLUSIVE OR function completes the connection between Boolean logic, the binary number system, and electronic switching circuits, for it can be used to add two binary bits.

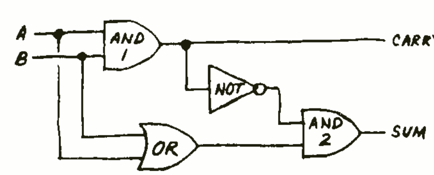


Fig. 4. Logic array for XOR circuit.

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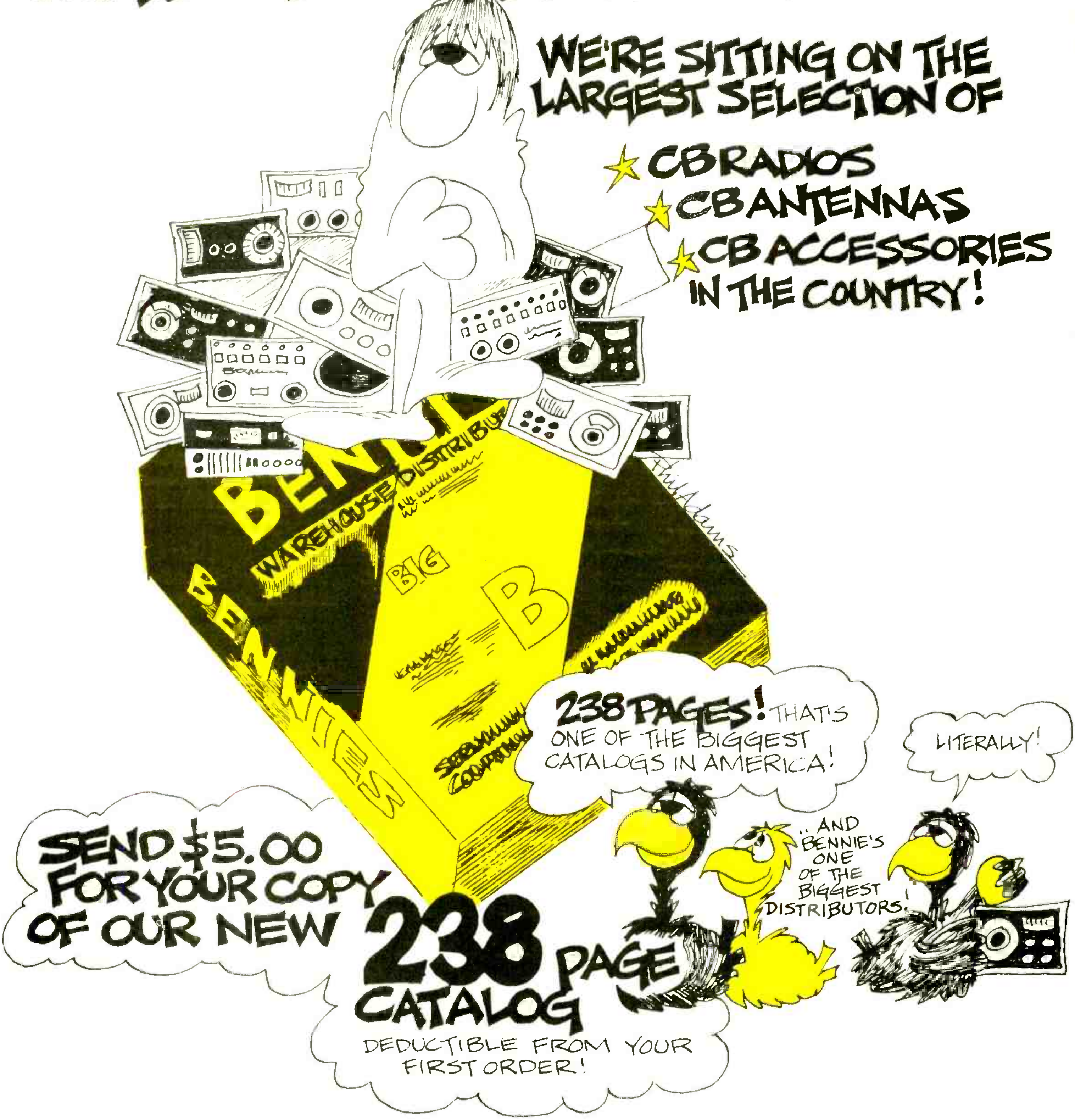

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To see how this is accomplished, assume a logic 1 at input A and a logic 0 at input B in the EXCLUSIVE OR circuit shown in Fig. 4. Since only one input is enabled (input A), AND circuit 1 does not turn on. Hence, a 0 is present at the CARRY output. OR circuit 1 does turn on, since only one input need be present. Since the NOT circuit inverts the 0 from AND circuit 1 into a logic 1, AND circuit 1 has two input signals and is therefore turned on. The result is a logic 1 at the SUM output. (The circuit has added 0 + 1 to obtain 1.)

The EXCLUSIVE OR circuit is often called a "half-adder." Try verifying its operation yourself by adding 1 + 1 in binary.

Practical Logic Circuits. Figure 1 demonstrated how simple switching circuits can be used to implement each basic logic function. However, it is usually not practical to employ switches in real systems. Instead, transistors, SCR's, tunnel diodes, or other solid-state switches are employed.

The most commonly used switch in digital electronics is the transistor. Relatively simple circuits that combine diodes, resistors, and transistors can be used to implement the AND, OR, and NOT functions. Thanks to integrated circuit (IC) technology, several or even dozens of individual logic circuits can be placed on a single compact silicon chip. Resistor-transistor logic (RTL) was once the most popular type of digital IC, but it has been largely replaced by the more noise-immune transistor-transistor logic (TTL) type.

In recent years, field-effect transistor (FET) technology has been adapted to integrated logic circuits of amazing complexity. By insulating the gate of a FET with a layer of silicon dioxide, extremely high impedances are made possible. The result is a logic circuit that requires microamperes or nanoamperes of operating current at relatively low voltages.

Insulated-gate fabrication techniques are collectively known as MOS (for metal oxide semiconductor) technology. Since MOS transistors are unipolar (p- or n-type) and do not require separate p and n sections like conventional bipolar pnp and npn transistors, MOS IC's can have a much higher component density than most conventional IC's. The result is large-scale integration (LSI). So, the next time you read or hear the phrase "MOS LSI," you will know that it refers to a large-scale integrated circuit employing metal oxide semiconductors.

Once you understand the material presented here, you should find that designing digital circuits—even complex ones—is mostly a matter of common sense and familiarity with what each element does.

Flip-Flops. The flip-flop is the basic memory circuit used in digital electronics. It has two stable states that can be simulated by the two-switch analogy shown in Fig. 5A. The switches are arranged in such a way that, if one is closed, the other must be open, with control circuits determining the states.

The logic diagram of a toggle flip-flop is shown in Fig. 5B. When a pulse appears at the toggle, or T, input, the Q and $\overline{Q}$ (said "not-Q") outputs will change state. The small circle at the T input indicates that, to toggle the flip-flop, the input must go from "high" (logic 1) to "low" (logic 0). The other two inputs are labelled P for preset and C for clear. These allow the flip-flop to be set to a specified condition no matter what was the previous condition. For example, if a 0 is applied to the P input, the Q output would be 0. Bear in mind that the two outputs are complementary; that is, if Q is at 0, $\overline{Q}$ will be at 1.

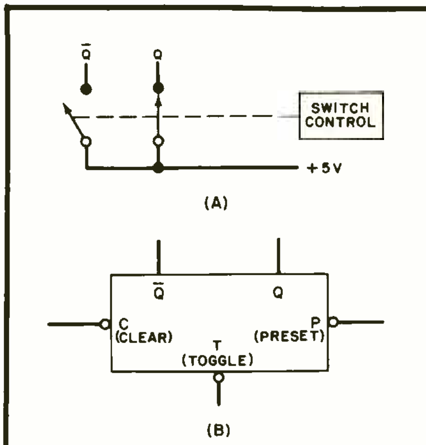


Fig. 5. Switch analogy (A) and logic (B) of a flip-flop.

Semiconductor manufacturers make at least 50 different types of flip-flops. Do not be intimidated by this number. The flip-flops are still flip-flops, and all you need to understand any specific one is its data sheet, which you can obtain from the manufacturer.

Designing a Computer Terminal. Combining what you now know about flip-flops with what you learned earlier, you have the knowledge needed for designing a VLCT. In the following pages, we will design a VLCT that will allow you to convert from octal to binary and back to octal, decimal, or hexadecimal logic. Not only will the VLCT prove instructive in terms of digital logic, it will also be invaluable for interfacing with other digital devices. (In particular, it can be used with the Altair computer introduced in the January 1975 issue of POPULAR ELECTRONICS.)

The VLCT performs seven functions: (1) converts the operator's octal input to binary format; (2) eliminates any bounce that might be present in the key switches; (3) loads the binary data into and retrieves it from a regis-

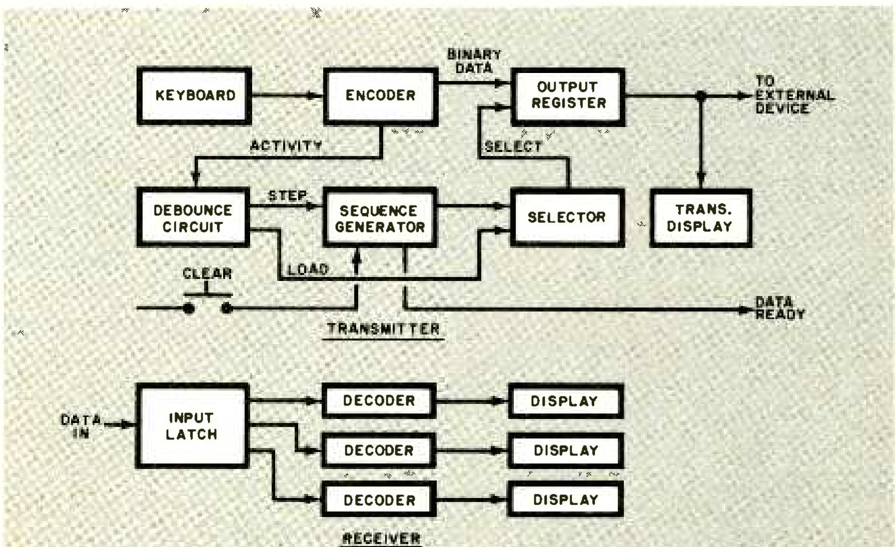


Fig. 6. Logic flow diagrams of transmitter and receiver.

ter and stores it until transmission; (4) determines where each piece of data goes in the output register; (5) transmits a "ready" signal after the third octal number is entered; (6) receives and stores binary data from the computer; and (7) decodes this computer data in either octal, decimal, or hexadecimal display format. The overall block diagram of the terminal shown in Fig. 6 should be consulted whenever any question concerning functions arises.

The complete logic diagram for the transmitter portion of the terminal is shown in Fig. 7. The terminal employs transistor-transistor-logic, or TTL, devices—by far the most widely used logic family. It has the following basic characteristics: a logic 1 is any potential level between 2.4 and 5 volts, and a logic 0 is any potential between 0 and 0.4 volt. A detailed discussion of TTL can be found in a number of books devoted to the subject, but a brief explanation of how a typical TTL NAND works is given in the box.

Keyboard Encoder. In Fig. 7 the key switches labelled 1 through 7 are grouped together at the upper left, while the 0 key is located in the center of the diagram. NAND gates *NG1, NG2,* and *NG3* provide the encoding for key switches 1 through 7, while *NG4* detects the activation of any key.

Before any key switch is depressed, note that *NG1, NG2,* and *NG3* have a 0 output due to the 1 being applied to each of the four inputs. Note also that *NG4* has a 0 output as a result of the 1-level signals applied to its four inputs.

Now, to understand the logic used, assume that key switch 3 has been depressed. When this happens, one of the inputs of *NG1* and *NG2* is placed at logic 0 by grounding. This forces both of these gates to have a logic 1 at their outputs. (A 0 output of a NAND gate can occur only when all its inputs are a logic 1.) Keyboard output lines *B0, B1,* and *B2* then have the following conditions:

B0	B1	B2	
0	1	1	$= 3_8 = 3_{10}$.

As you can see, the octal input has been converted to a binary code. Note also that the output of *NG4* has gone to a 1, signalling that keyboard activity has occurred.

Depressing key switch 0 causes the output of *NG4* to go to 1, indicating that keyboard activity has occurred. However, this signal will have no effect on *NG1, NG2,* or *NG3*, all of whose outputs remain at 0. If you were to read the binary number at *B0, B1,* and *B2,* it would still be 000 (binary zero). But there would be a signal from activity gate *NG4* to indicate that a switch closure has occurred.

Debounce Circuit. The problem with many keyboard switches is that they have a mechanical "bounce." This bounce must be allowed enough time to damp out before attempting to load data into the output-register flip-flops (*FF3* through *FF10*). This delay is accomplished in the debounce circuit in which *NG5* and *NG6* form an RS flip-flop—the simplest form of flip-flops. To understand its operation, you need to realize that only one input at a time can be activated by a 0. If a 0 is applied to both inputs at the same time, the device will not operate as a flip-flop.

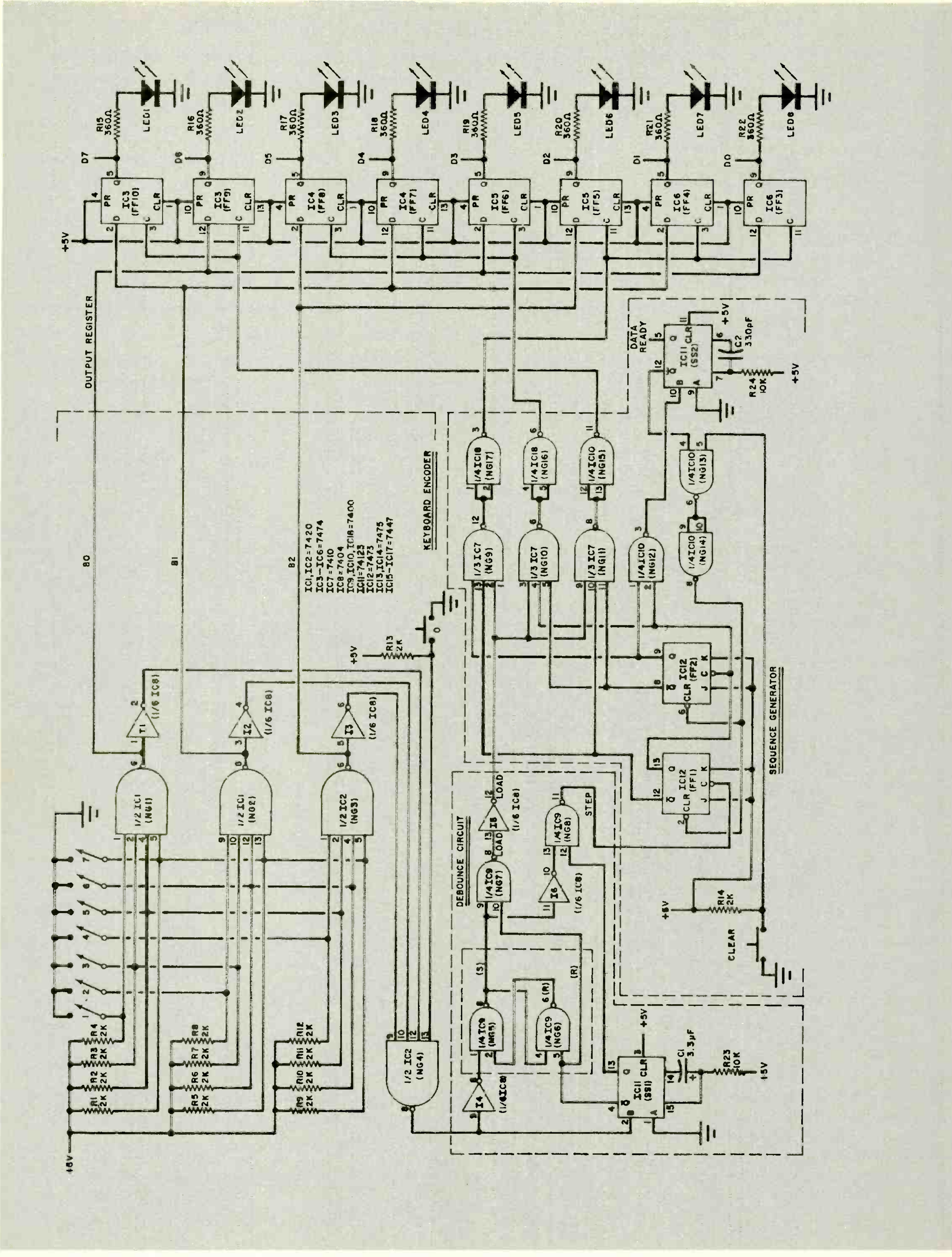
The activity line (output from *NG4*) goes to a logic 1 if any key switch is depressed. This signal is fed through inverter *I4* to one of *NG5*'s inputs. A 0 into *NG5* generates a 1 at the gate's output, which is then fed to one of *NG6*'s inputs. Assuming that the other input (pin 5) is also at 1, a 0 will appear at the output of *NG6*. If both inputs were allowed to go to 1, the RS flip-flop would remain as set by the previous 0. If a 0 is applied to *NG6* while a 1 is applied to *NG5*, the device will flip, causing a 0 output to be generated at *NG5* and a 1 output at *NG6*.

The mechanical-bounce switch problem occurs whenever a mechanical device is interfaced with digital electronics. The bounce time of the mechanical switch is very fast (say, 10

IC POWER CONNECTIONS

IC No.	Type	V_{cc}	Gnd	Function
1,2	7420	14	7	Dual 4-input NAND gate
3,4,5,6	7474	1,4,10,13,14	7	Dual D flip-flop
7	7410	14	7	Triple 3-input NAND gate
8	7404	14	7	Hex inverter
9,10,18	7400	14	7	Quadrature 2-input Nand gate
11	74123	3,11,16	8	Dual retriggerable multivibrator
12	7473	14,3,4,7,10	11	Dual JK flip-flop
13,14	7475	5	12	Bistable latch
15,16,17	7447	3,4,5,16	11	BCD-7-segment decoder
19	LM309		3	5-volt regulator

Front view of the computer terminal.


OUTPUT REGISTER
KEYBOARD ENCODER
DEBOUNCE CIRCUIT
SEQUENCE GENERATOR
IC1,IC2=7420
IC3–IC6=7474
IC7=7410
IC8=7404
IC9,IC10,IC18=7400
IC11=74123
IC12=7473
IC13,IC14=7475
IC15–IC17=7447
DATA READY
CLEAR
LOAD
STEP

PARTS LIST

C1—3.3-µF, 25-volt electrolytic capacitor
C2—330-pF disc capacitor
C3, C5—0.01-µF, 1-kV disc capacitor
C4—1500-µF, 16-volt electrolytic capacitor
D1 thru D4—1N4004 silicon rectifier
DIS1 thru DIS3—7-segment numeric LED display
F1—1-ampere fuse
IC1, IC2—7420 dual 4-input NAND gate integrated circuit
IC3 thru IC6—7474 dual D flip-flop integrated circuit
IC7—7410 triple 3-input NAND gate integrated circuit
IC8—7404 hexinverter integrated circuit
IC9, IC10, IC18—7400 quadrature 2-input NAND gate integrated circuit
IC11—74123 dual retriggerable monostable multivibrator integrated circuit
IC12—7473 dual JK flip-flop integrated circuit
IC13, IC14—7475 dual bistable latch integrated circuit
IC15, IC16, IC17—7447 BCD to 7-segment decoder/driver integrated circuit
IC19—LM309 5-volt regulator integrated circuit (Signetics)
LED1 thru LED8—Light-emitting diode (Monsanto RL-50 or similar)
R1 thru R14—2000-ohm, ¼-watt resistor
R15 thru R22—360-ohm, ¼-watt resistor
R23, R24, R27—10,000-ohm, ¼-watt resistor
R25—15-ohm, ½-watt resistor
R26—47-ohm, ¼-watt resistor
R28—100-ohm, ¼-watt resistor
T1—8-volt, 1-ampere transformer
Misc.—Suitable enclosure: key-switch pad with 0-7, clear, and ready switches; red display filter; filter bezel; fuse holder; line cord; printed circuit boards; IC sockets (optional); insulated hookup wire; machine hardware; solder; etc.
Note: The following are available from MITS, Inc., 2450 Alamo S.E., Albuquerque, New Mexico, 87106: Complete kit, including power supply regulator and transformer, key-switch pad, hardware, case, and filter bezel for $140.00. Completely assembled unit $185.00.

Fig. 7. Complete logic diagram of the terminal is on opposite page.

pulses during a 10-ms interval), but it is exceedingly slow from an electronics viewpoint, since each individual pulse can be detected. A debounce circuit, therefore, should be included to remove any extraneous pulses.

The debounce circuit employed in the VLCT consists of an RS flip-flop made up of *NG5* and *NG6* and a retriggerable monostable multivibrator (sometimes called a single-shot multivibrator), *SS1*. The *SS1* circuit is basically a form of unstable flip-flop. When a trigger pulse is applied to it, the multivibrator changes states only for a period determined by an external time-delay network, which in this case consists of *C1* and *R23* to yield a 10-ms delay. After the delay, *SS1* switches back to its initial state.

Let us trace a signal through the debounce circuit. With a 1 coming from the output of *NG4*, the output of *I4* is 0. This causes the RS flip-flop to change states, with the S output going to 1. The logic-1 activity signal from *NG4* is also fed to the B (trigger) input of *SS1*, causing the multivibrator to go into its unstable state for 10 ms and apply a 0 to the other input of the RS flip-flop—which is a violation of the rules for this circuit. But the violation can be disregarded because *SS1* applies this signal for only 10 ms before control reverts back to the activity input, which sets the S output of the flip-flop to 1. This signal is then applied to one of the inputs of *NG7*, while the other input comes from *SS1* which, after 10 ms will apply a 1 to completely enable this gate and generating a 0 at its output.

The 0 output is inverted by *I5* to produce the "load" signal for the output register. It is important to note that the load command did not occur until 10 ms after the keyswitch was originally closed. This assumes that the switches will not be bouncing for more than 10 ms. If there were any bouncing after the 10-ms delay, a longer time constant would be needed at *SS1* by selecting appropriate *C1* and/or *C2* values.

When the key switch is released, *SS1* is reset and a "step" pulse is generated by *NG8* for use by the sequence generator.

Sequence Generator. To load eight bits of data into the output register with an octal keyboard, three switches must be operated because each key depression generates only two or three bits. For example, assume you want to load the octal number 365 into the output register. The first step is to load the 3 into the first two bits, the 6 into the next three bits, and the 5 into the bottom (least-significant) three bits. Note that the first key depressed can use only two bits. This means that a 3 is the largest digit allowable on the first key depression. The next two key positions can be any octal number.

The sequence generator consists of *FF1*, *FF2*, *NG9* through *NG14*, and *SS2*. Let us assume that at the beginning of the cycle *FF1* and *FF2* are both cleared so that the Q output of each is 0 and the $\overline{Q}$ output is 1. Under these conditions, *NG11* has a 1 at two of its three inputs. Now, when a load pulse occurs, caused by a key switch depression, the third input goes to 1 and the output of *NG11* goes to 0. After inversion by *NG15*, a clock pulse is applied to *FF9* and *FF10* to cause the data on *B0* and *B1* to be loaded into *FF9* and *FF10*.

When the key switch is released, a "step" pulse is generated at *NG8* and is fed to the C (clock) input of *FF1*, causing this flip-flop's Q output to go from 0 to 1; *FF2* will be unaffected because the change is positive-going. When the next key switch is depressed, *NG10* will be the gate selected. This will load *FF6*, *FF7*, and *FF8* with data from the keyboard. When the switch is released, the step pulse will again cause *FF1* to change states. But this time, the change will be from 1 to 0 at the Q output.

The Q output of *FF1* is now 0 and the Q output of *FF2* is 1. This selects *NG9*, which will load *FF3*, *FF4*, and *FF5* on the next key switch depression.

When the 3 key is released, the step pulse will again cause the *FF1*/*FF2* counter to step, resulting in a 1 on both Q outputs. This is detected by *NG12* and causes *SS2* to be triggered for 1 µs. Then *SS2* clears *FF1* and *FF2* and transmits a "data-ready" signal to the computer or other digital devices connected to the output. The CLEAR button can be used to reset the counter in the event an error was made during entry.

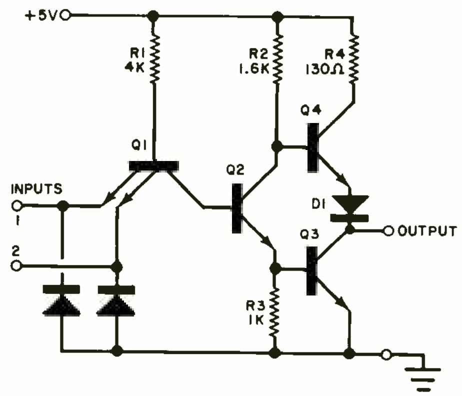
Output Register. The output register consists of *FF3* through *FF10*. These eight flip-flops store data until the three key entry sequences are completed. They are called data flip-flops, or D flip-flops. Their function is to load the bit present at the D input whenever the C (clock) line goes to 1.

HOW TTL WORKS

Transistor-transistor logic (TTL) is a positive-logic system. The circuit of a typical gate, in this case one gate in a 7400 quadrature NAND IC, is shown below.

If neither input of the gate is grounded, or both are connected to a positive-voltage source, the base-collector junction of *Q1* is forward biased so that current can flow through *R1* and the B-C junction of *Q1* into the base of *Q2*. Transistor *Q2* goes into saturation, producing a voltage drop across *R3*. This provides a bias to turn on *Q3* and at the same time the voltage at the collector of *Q2* drops.

For *Q4* to conduct, its base must be at about 1.8 volts. The values of *R2* and *R3* are selected so that, when *Q2* is conducting, the voltage drop across *R3* is high enough to turn on *Q3*. But the voltage at the collector of *Q2* is not high enough to cause *Q4* to conduct. The "0" output is then only a junction away from ground (through *Q3*). Note that in this state, the output (via *Q3* to ground) can *sink* a reasonable amount of current—approximately 16 mA. This is why TTL is sometimes referred to as "current-sinking logic."



If one or both inputs of the gate is grounded, *Q1* conducts and its collector voltage drops to near ground potential, cutting off *Q2*. Almost no current flows through *Q2*'s C-E junction, and the base voltage of *Q3* (voltage drop across *R3*) is close to zero. Transistor *Q3* then forms an open circuit. The collector of *Q2* approaches +5 volts, which causes *Q4* to conduct. The output (1) is then a function of *R4*, the C-B resistance of *Q4*, and the forward resistance of *D1*. The output voltage is then about 3.5 volts.

In the regular TTL family, about 1.6 mA flows through any input grounding circuit. In the event grounding is through a resistor, there will be a voltage drop across the resistor. Because the maximum permissible low-state input voltage is about 0.8 volt, the external resistor cannot have a value in excess of 500 ohms, and any low input connection must hold the input below 0.8 volt.

In some TTL devices, a protective diode is connected from each input to ground. If a negative voltage (with respect to ground) greater than 0.6 volt is accidentally applied to either input, the diodes conduct to protect the gate. The protective diodes also prevent high-frequency ringing when long connection leads or sharp risetime pulses are used.

The truth table for a two-input NAND gate is as follows:

INPUT 1	INPUT 2	OUTPUT
0	0	1
1	0	1
0	1	1
1	1	0

The 0's and 1's represent "low" or logic 0 and "high" or logic 1 conditions, respectively. Note that the only time the output of the gate changes state from its normal 1 output condition to 0 is when both inputs are "enabled" (have a 1 applied to them simultaneously). If neither input, or only one input, is enabled, the output of the gate remains at 1.

This data then appears at the Q outputs. The flip-flops ignore anything on the D inputs unless the clock pulse is present.

The output display consists of light-emitting diodes *LED1* through *LED8*. The LED's glow whenever their respective data lines are at logic-1. This provides a binary readout. It is these data lines that are coupled to the external computer or other digital device.

Receiver. Shown in Fig. 8 is the receiver portion of the system, consisting of latches *IC13* and *IC14* (each with four D flip-flops for a total of eight flip-flops); *IC15*, *IC16*, and *IC17* 4-bit binary to 7-segment decoders; and *DIS1*, *DIS2*, and *DIS3* 7-segment display readouts.

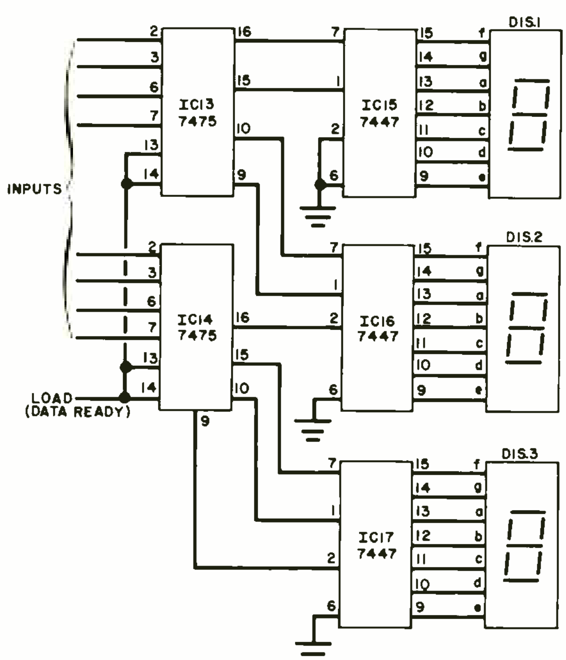


Fig. 8. Complete logic of the receiver with 7-segment readouts.

Assume that the transmitter drives the receiver directly (receiver inputs directly connected to transmitter outputs). Each time the transmitter receives three key switch operations during number entry, it transmits a "data-ready" signal to the receiver. This signal is coupled to the LOAD inputs of quadrature latches *IC13* and *IC14* and causes the eight input signals to be read into the two latches and stored. The outputs of the latches are connected to the 7-segment decoders, each of which consists of approximately 80 gates arranged to convert a 4-line binary signal into a 7-segment drive signal for a numeric readout on the displays.

Since the system under discussion is octal-based, one of the inputs of each decoder is not used. Therefore, each readout displays only the digits 0 through 7. If desired, the fourth input can be used, resulting in a full decimal and hexadecimal format.

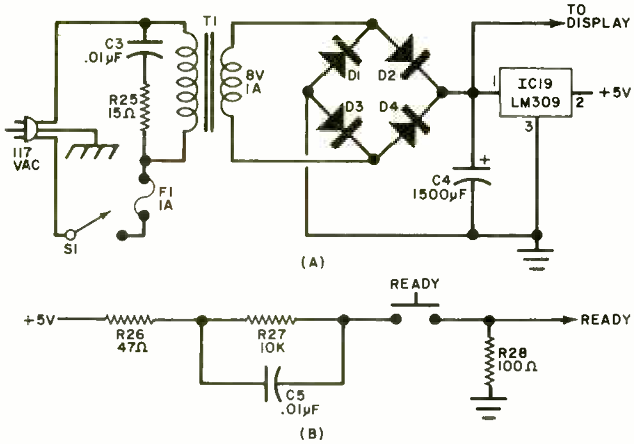


Fig. 9. Schematic of power supply (A) and "ready" circuits to be used when terminal feeds a computer (B).

Power Supply. Shown in Fig. 9 is the power supply for the VLCT. The dc voltage from *T1* and the bridge rectifier consisting of *D1* through *D4* is applied to 5-volt regulator *IC19*. (The +5-volt and ground lines go to the IC's as shown in the table.) The regulator is current and temperature protected. Capacitor *C4* filters the output of the bridge.

The VLCT requires about 500 mA of regulated current for the logic elements and about 150 mA of unregulated current for the LED displays, both at 5 volts dc.

Checkout. The checkout procedure consists of making certain that the transmitter is connected to the receiver and that power is delivered to both circuits. Once it is verified that power is properly delivered to the circuits, depress three keys on the transmitter and note that the displays indicate the proper sequence. This procedure checks all transmitter and receiver logic. ◈

A MICROCOMPUTER PRIMER

COMPUTER BASICS FOR BEGINNERS

BY LESLIE SOLOMON

The first commercial digital computer, "Univac I," installed in 1951, is compared to today's microprocessor chip (small square on white card.)

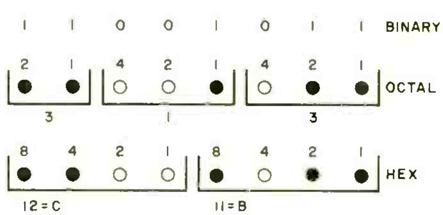
FROM a miniscule beginning a few years ago, hobby computers have blossomed into a full-fledged industry. Here are some ground rules concerning home computers that electronics enthusiasts can use as a foundation for getting into this new hobby.

A computer is a collection of electronic *hardware* that performs calculations, manipulates data, and makes decisions based on that data. The difference between those room-size computers and present-day microcomputers used by hobbyists lies in that one word—*hardware*.

Hardware means all the electronic and mechanical devices that make the computer "look" like a computer. What can this collection of parts do? By itself, absolutely nothing except rust! This, of course, leads us to *software,* the "intelligence" behind the hardware. These are usually called *programs* because they program the hardware to perform a desired task. Since most programs exist on paper (books, magazines, or tapes), they are for obvious reasons called software. There is one other expression you may bump into—firmware. Being neither hard nor soft, they are actually programs that have been written into an electronic memory where they can be used as desired, or erased. Since this material is actually software, yet resides in hardware, we split the difference and call it firmware.

How did this whole thing start? Computers are not new. The abacus (beads on wires within a wooden frame) has been around for at least 2000 years. A good abacus manipulator can handle some pretty hairy numbers as fast as your favorite calculator. To be an abacus authority, remember that a Chinese abacus has two beads above the bar and five beads below it, while the Japanese abacus has one bead above and four below.

In the 17th Century, Blaise Pascal devised his arithmetic machine (at age 19, if you are curious) that used a system of eight wheels bearing the numbers 0 to 9 around each circumference. Each wheel had a "carry" arm so that when you cranked in a digit greater than 9, the carry arm would activate the next wheel. This machine was closely followed by the Leibnitz machine that used the same technique as Pascal, but was also capable of multiplication and division. In the early part of the 19th Century, Charles Babbage devised his "analytic engine" that, surprisingly, could be programmed with punched cards! It also had a primitive "memory" and an output device for printing results.



Although Babbage did consider the use of punched cards, it wasn't until the late 19th Century that Herman Hollerith assembled his punched-card reader. In fact, the 80-column Hollerith code is still in use for punched cards. In 1911, the company started by Hollerith merged with another small company and the combination eventually became IBM.

By the end of World War II, the computer revolution was in full swing. At that time, computers were built using large numbers of electromechanical relays and then large numbers of vacuum tubes. In one computer, over 18,000 vacuum tubes were used with a tube-failure expected every 7½ minutes! The designers (Mauchly and Eckert) had to hand-test each tube until their computer could work for days at a time without failure. The designers later formed the Univac division of Sperry-Rand.

It was in 1946 that John Von Neumann first proposed that operating instructions could be stored in the computer along with the data. This approach is the one used by hobbyists today.

The next question would probably be—what is a microcomputer (or is it a minicomputer)? According to one source, a microcomputer is a general term referring to a complete computing system, consisting of hardware and software, which usually sells for less than $500, whose main process-blocks are made up of integrated its (IC's). In function and structure, a micro is similar to a minicomputer. The main difference is considered to be price, size, speed of execution and computing power. A minicomputer ranges from $1000 to $25,000, can have 8, 12, 16, 18, 24, or 36-bit word lengths and can have semiconductor or magnetic core memory, and ultra-fast cycle times.

Here's a very brief and basic description of what a computer is.

Basic Computer. A computer system is like two people communicating by mail. One person (the computer operator) sits down and writes some instructions (program) for the other person to follow. The program (in letter form) is then placed in his mailbox (*output port* . . . actually the *input port* of the system). A mail truck which always follows the same pickup route (read-only memory) picks up the program and deposits it in the post office (memory). Here, the *address* is checked and the program placed in one particular slot in the mail bin (random-access memory). A postal delivery man who also uses a fixed routing looks into that particular memory location and sees that there is a message to be delivered. He then takes the message, checks the address to which it is to be delivered, and carries it to its destination. Once there, he inserts the message into the second person's mail box (his *input port).* The second party looks at his input port, sees that there is a message for him, and picks it up. He then performs the operation written within.

The post office mail bin *(memory)* does not keep the message permanently; just on a temporary basis until called for. This simulates the *random-access memory* or RAM. The mail bin can, at any time, be empty or contain a message, depending on the mail to that address.

Number Systems. We live in a decimal world because we have ten fingers (the original computer). Because of our familiarity with this number system, we will not discuss it any further.

Digital systems have no fingers and the best they can do is to be either on or off. In the case of a light switch, the lamp being controlled is either on or off. This approach is called "binary" because there are only two states. We call these states "1" or "0," high or low, or simply on or off. Simply stated, the binary-number — or base-2 — system consists of a collection of 1's and 0's that can identify any number or letter you can think of.

Each of these 1's and 0's is called a *bit.* How many bits does the hobby computer need? Most hobby computers use the 8-bit system for *data* entry simply because most available *microprocessors* are designed around 8 bits. The use of 8 bits allows 256 different combinations to be entered. (Present microprocessors do not have 256 instructions that can be used.)

Many hobby microcomputers use eight front-panel switches for *data* entry. There are two switch positions — up and down (there is that base-2 again!) usually up for a "1" and down for a "0." You can operate these switches in various combinations to enter the series of instructions you wish to give the microprocessor. This leads us to another number system.

Since the processor instructions involve all of the 8 bits, someone has to remember this combination of eight 1's and 0's in the correct order and then, hopefully, switch them in correctly.

If we take a look at the eight switches, all in a row, we can divide them up into groups of three starting from the right. This gives us three switches, three switches, and on the extreme left, only two switches. Each trio is then identified, starting on the right, as 1, 2, 4 (note that this is binary). The two switches at the left then become just 1, 2. This is called the *octal* system. The switches then form 2-1 space 4-2-1 space 4-2-1. As an example of use, let us assume that you wish to input the instruction "313" (this comes from the processor instruction set). It is unimportant what 313 means here, but it's an example of octal use.

In binary code, this is 11001011, a formidable array of digits! To convert this array to octal, simply start at the right and divide the digits up into two groups of three and the last of only two. The array now becomes 11 001 011. Using the 4-2-1 approach (see diagram), adding up the numbers in each group, this now becomes 313. Of course, the process is easily reversed if you switch up 313 it comes out 11001011 in binary. Now you can see the advantages in using octal. In some cases, the octal number is identified by a small subscript "8" after the 313.

Then there is "hex" for hexidecimal. This word simply means using base-16 as the number system. Why such a strange approach? If you take another look at the switches, you will note that you can readily divide the 8 switches into two groups of 4. These can now be broken down into 8-4-2-1 space 8-4-2-1 (which forms a base 16). If you add up each set, it should total 15. There is one catch, though. If you start counting up from zero, what do you do after you reach 9? There aren't any more digits. Why not use letters? We then use capital letter A for 10, B for 11, C for 12, D for 13, E for 14, and F for 15. Now let us return to the 11001011 instruction again. If you set this up on the switches, and count each set, you will arrive at the hex equivalent of "CB" (no, not Citizens Band radio!). These two letters can then express a rather large binary array and are very easy to remember. The diagram shows how simple this all is.

Thus far, we have been calling the binary code "a bunch of 1's and 0's." In computereze, this group of 8 bits is called a *byte* or sometimes a *word.*

Programming. Essentially, this means making the computer do what you want it to do. Programming is logical because computers are logical and must receive full instructions or they will output "garbage."

As an example of programming, we assume that most readers have used a calculator — even a simple "four banger." Let us go through the program to add two digits (2 + 2). The program starts with turning on the calculator (power up). Next we can operate the CLEAR key to cause the internal logic to reset to zero. The calculator is now "empty." We then operate the "2" key to insert this step into the calculator. The internal logic does not actually receive a digit 2, but rather the digital logic version of that number. We follow this by pressing the "+" key. This tells the internal logic to set up the particular algorithm (program) to add two digits. Next we key another 2. The two digits are now programmed (temporarily) in the logic. When we operate the "=" key, the digital logic starts to run through the algorithm, works it out, and displays the result on the readouts. The system then goes into a "wait" mode, waiting for further instructions.

Note that the "=" key did several things. First it started the little "computer" within the calculator (run), caused it to run through the fixed algorithm (program), stored the result in a volatile memory, and displayed the results on the digital readouts (output port). Keep in mind, that there was a fixed series of steps that had to be taken, each in logical order, before the calculator was able to produce the desired results. If you jumble up the steps, the system won't work.

The bulk of programming you most likely will do will be in a "language." For hobbyists, it is usually BASIC. This language, developed at Dartmouth College many years ago, is one of the easiest computer languages to learn because the computer appears to "speak" to you in English. Most of the hobby games are in this language. There are several, slightly different versions of BASIC, but it is easy to convert from one to the other. It's analogous to a New Englander, a New Yorker, and a Texan who all speak the same language, but with regional differences. There are many other computer languages, each with its own purpose, and own advocates. When the BASIC language is in the computer, a "partnership" is set up between the computer and a human. Since there are many excellent and easy-to-understand publications on BASIC, the reader is advised to purchase one of these for further study.

Hardware. There are many terms you will hear in this area, so we will make a short pass at some. The first, and most important, is MPU (micro processing unit), sometimes called CPU (central processing unit). This IC is the "brains" of the system. You'll hear them called "names" such as 8080, 6800, etc. These numbers usually identify a particular manufacturer's (and sometimes a second manufacturing source) entry in the microprocessor race. Each chip has its own instruction set, its own loyal following, and each is somewhat different than the others. However, all are "8-bitters."

You can visualize an MPU as a large number of digital logic arrays that can be hard wired to form circuits that add, subtract, etc. Within an MPU, however, there is no major hard wiring. It's actually a large-scale IC, with connection points that interconnect the various logic blocks in the correct order to perform required functions as determined by the CPU instructions. All MPU's have eight data input/output lines, up to 16 memory address lines, and the various "handshaking" signals. These multiple lines are used to form the computer "bus" by which all the external elements can be "talked to" and, in turn, "talk to" the MPU. There is no "best MPU," as each has its own ballpark to play in. Each manufacturer makes available considerable material (some at a price) that explains how his MPU works.

ROM. This is an abbreviation of *read-only memory*. It is, essentially, a semiconductor device that produces a fixed, repeatable output when fed a particular input code. This is like the printed page of a book. No matter when you look at it, the material is always the same. You can erase it with some effort and re-print other data, but this is not usually the case. One example of a ROM is the 7-segment decoder that drives a readout display. When the input code is applied, the decoder turns on the seven segments to form a particular digit (depending on the code). You can't make it form the letter K, for example, because this is not in its memory (nor on the readout). It is dedicated to *numeric* output.

However, there are some ROM's whose contents can be changed. These are called programmable ROM's (PROM's) and their contents can be erased electrically or by ultraviolet methods. They are used for long-term, temporary data storage. ROM's do not change their internal bit structure when power is turned off.

On the other hand, the *random-access memory* (RAM) has a volatile memory, which means that it is easy to both store and read out a bit pattern. But, the RAM "forgets" everything when the power is turned off. This versatile memory chip contains a number of "memory cells," each of which can store a 1 or a 0. RAM's are usually organized into words. They come in all sizes, identified as "x-number of bits" by "x-number of bits." For example, the popular 2102 RAM is organized as 1024 × 1, which means you would need eight of these to form 1024 8-bit words (commonly known as a 1K memory).

There are two kinds of RAM's: dynamic and static. In dynamic RAM's, a tiny built-in capacitance stores the data charge. Unfortunately, this voltage has to be "refreshed" often so that the charge does not leak away. This means that some computer time has to be taken to do this. Because dynamic RAM's are "faster" than static types, some hobbyists argue that the refresh time removes this speed advantage.

The other type of RAM — static — consists of a number of flip-flops. Once a flip-flop is set or reset, it does not have to be refreshed and remains in that state until it is deliberately changed, or the RAM loses its d.c. power. This is the most common RAM used by hobbyists. The two types of RAM's are organized in the same numerical way.

Ports. There are two types of "ports" — input and output (commonly called I/O ports). They enable one to "talk" to a computer and for the computer to "talk" to you. The classic example of something to connect to an I/O port is the Teletype. This ubiquitous machine consists of two discrete sections — a transmitter (keyboard or associated tape reader) and the receiver (printer or tape perforator). The transmitter loop consists of the keyboard, the computer input port, and a common 20-mA current source (the Teletype is designed to work this way). Operation is similar to a flashlight. Push the button and the lamp goes on. In the case of the TTY (the common abbreviation for Teletype), the computer is the lamp, the keyboard is the switch, and the current loop is the power source. The only difference is that, when a Teletype key is activated, the series current loop is broken up to form the ASCII code equivalent of the key identification. Before going on, a word about ASCII. This is an acronym for American Standard Code for Information Interchange. The full ASCII code uses combinations of seven 1's and 0's to identify every character in the alphabet (upper and lower case), all punctuation marks, special symbols, and machine commands (carriage return, for example).

The computer input port recognizes each unique ASCII code and passes that data along to the computer. When the computer "answers," its output port keys the current loop and the printer becomes the lamp. In this case, the answer is in ASCII, and the printer responds accordingly.

The RS-232 approach you hear about uses the ASCII coding, but instead of working with a current loop, it works with different voltage levels (one side is positive and the other negative). This approach is usually used with full electronic keyboards and CRT displays.

There are two ways into and out of computers. These are called "serial" and "parallel" I/O. In the serial approach, each bit moves along "Indian file" — one behind the other. The speed of bit transmission is called "baud rate" or bits-per-second. Baud rates vary with the terminal, ranging from 110 for the TTY to several thousand for high-speed work with an electronic (CRT) terminal. Control of speed is via a UART (see definitions at end).

The other approach, called "parallel," is similar to the big-bang theory. Everything gets dumped in and out of the computer at once. The parallel approach is much faster than the serial method and is preferred by many hobbyists, although many use both.

Definitions. Here are brief descriptions of computer expressions:

Bootstrap. A brief set of instructions to the MPU that allows the computer to accept input data and directs how to handle it. Putting in BASIC via a tape is a good example. This brings up the question of why the bootstrap can't be put on the tape. It can't because it has to "tell" the computer to look at a particular input port and do something with the data about to come in.

Bus. A set of communications lines that makes electrical contact with all the devices plugged into the bus (memory, I/O ports, etc.) The bus includes all data lines, address lines, power and ground, and the various "handshaking" signals.

Character Generator. A ROM that produces alphanumeric characters when it receives the appropriate input signals.

Cursor. A means of identifying where the *next* character is to appear in a CRT display. It can look like a block, an under or over dash line, and it can be fixed or blinking.

DMA. Direct-memory access. This is a technique for getting directly to the memory, using some special control signals and circuitry.

Dot Matrix. A method of creating alphanumeric characters by using a matrix of dots (usually 5×7, or 7×9) and illuminating certain dots (via the character generator) to form the character on the CRT screen.

Handshaking. The interface between two circuits in which one side "asks" for data, accepts it from the other circuit, and then acknowledges it.

Hard Copy. Printed material such as received on a Teletype or typewriter.

K. Abbreviation for thousand. Usually used in expressions such as 4K or 8K memory. This really means 4096 or 8192 bytes.

Modem. Acronym for modulator-demodulator. A means of interfacing between a data system and a communications channel (such as the phone line) and into another data system.

Parity. This is an error-testing technique (all data systems are not infallible) in which one special bit is used to make the total of 1's in a word an even or odd number. If a transmission error occurs, and there is an odd (or even) number of 1's, then an error is signaled.

Programming. This defines the sequence of events that a computer must follow.

Rollover. Because most of us are not very good typists, keyboards come equipped with rollover so that if we operate two keys at once, the keyboard doesn't transmit the one that was struck last, although the time difference is miniscule.

Screen Read. Once you think you have the program properly written on the terminal screen, this technique allows you to "dump" the program into the computer.

TVT. Abbreviation for TV-typewriter, a low-cost CRT terminal.

UART. Acronym for Universal Asynchronous Receiver Transmitter. This mouthful describes a specialized IC that converts data from parallel to serial form and vice versa. Usually used as the I/O port.

Update. Changing part or all of the data displayed on the terminal.

Video. A TV-like signal consisting of horizontal and vertical sync pulses and the video to be displayed. This is in a *voltage* form, not r-f.

Video Bandwidth. This determines the quality of the CRT picture. In most cases, the higher the bandwidth, the more clearly defined the alphanumeric characters. Most TV sets can get to about 4 MHz, color sets somewhat less. Dedicated CRT monitors can run out to 10 MHz or more.

Word. A group of six to eight (the usual) bits that define a command or character.

Write. To place information in memory, or to change the memory contents.

How Much Memory Do You Need? This is one of the most commonly asked questions and the answer is simple. More than you presently have! It depends on what you want to do with your computer, of course. If you want a language such as BASIC, you will need a minimum of 4K, 8K, or 12K, depending on which BASIC you get. This means that the BASIC will fit into that amount of memory, with a little left over to play with. Once you get a language up and running (another nice buzzword), you will invariably find that the really good games always need 1K more memory than you have, except in the case of the umpteenth version of "Star Trek," which needs 12K more! Memory expansion is at the heart of the computer hobby. It will undoubtedly continue to be as more and more interesting programs are made available by computer club members and manufacturers. ◈

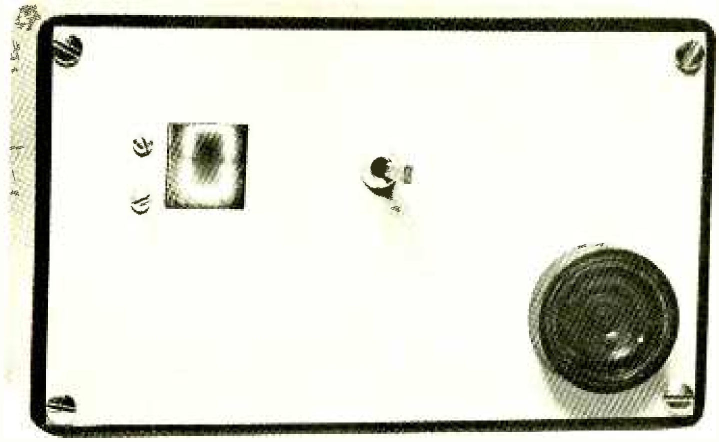
COMPUTER HOBBYIST CLUBS/FAIRS/CONVENTIONS

Computer hobbyists around the country have formed local amateur computer clubs to share knowledge and experience in this new, booming avocation. So it's not surprising to discover that there are also computer fairs (the latest held August 28-29 in Atlantic City, New Jersey), and manufacturers who hold computer conventions and sponsor mobile computer caravans to display their equipment to the public. Pictured here are some views of MITS' computer convention held in New Mexico, where exhibits and seminars were featured. (A list of computer clubs is available free of charge to readers who accompany this request with a stamped, self-addressed envelope to: ELECTRONIC EXPERIMENTER'S HANDBOOK, One Park Ave., New York, NY 10016.)

First-prize winner at the MITS Computer Convention, Don Alexander (left) used a computer in a ham DX contest. At right is POPULAR ELECTRONICS' technical editor, Les Solomon.

Author Lee Felsenstein displays Processor Technology's video display module and a data transmission modem, "Pennywhistle."

CONSTRUCTION



THE EXECUTIVE DIGITAL TEMPER COUNTDOWNER

Counts and displays for ten seconds—followed by an audible "blow-your-top" signal

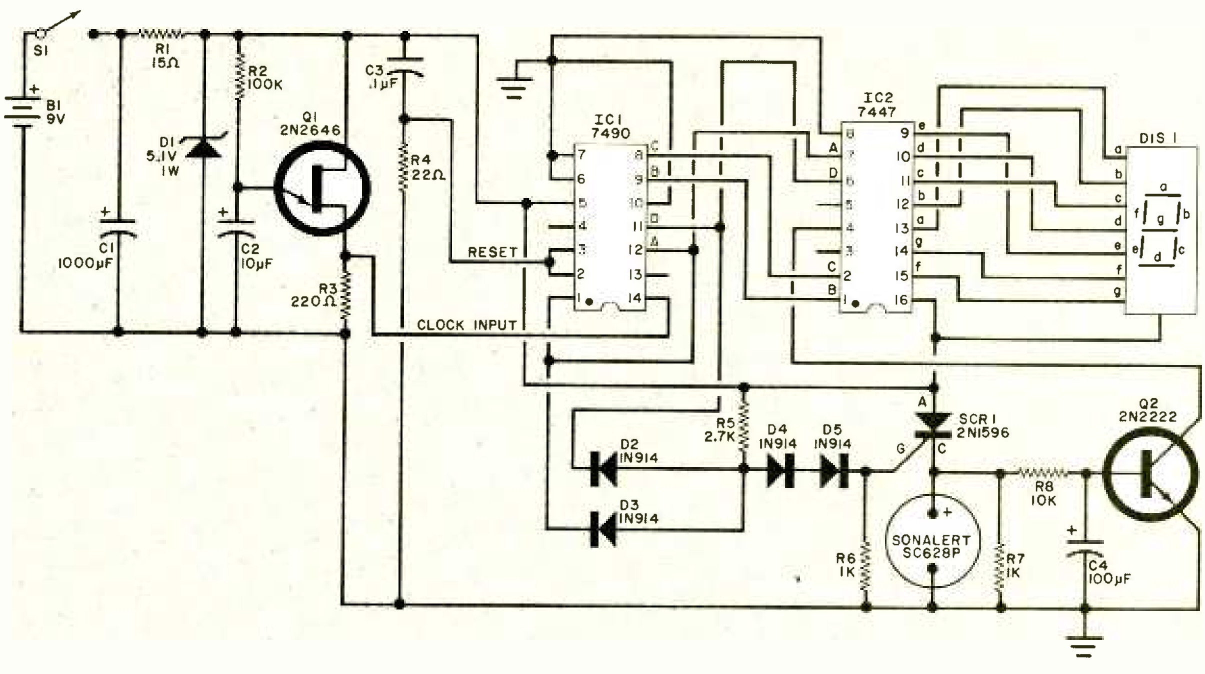
BY ROBERT D. PASCOE

"COUNT to ten before you blow your top" is familiar advice to help avoid losing one's temper. Here's a novel temper controller—a perfect gift for the executive who has everything—that does the counting for you.

Activating the temper timer starts the visual display of ten numerals (0 to 9), followed by an audible sound that means "*now* you can blow your top."

About the Circuit. The temper timer is a clock, whose pulse rate is 1 Hz; a decade counter and seven-segment display; and a Sonalert beeper. The schematic is shown below.

When switch *S1* is closed, power is supplied to the temper timer. Resistor *R4* and capacitor *C3* form a differentiator which is connected to the reset



PARTS LIST

B1—Six C or D cells in series (see text)
C1—1000-μF, 25-volt electrolytic capacitor
C2—10-μF, 25-volt electrolytic capacitor
C3—0.1-μF, 50-volt disc capacitor
C4—100-μF, 25-volt electrolytic capacitor
D1—5.1-V, 1-W zener diode (Motorola HEP Z0406)
D2, D3, D4, D5—1N914 diode
DIS1—Numitron (2000 series) or other 7447-compatible seven-segment display
IC1—7490 integrated circuit
IC2—7447 integrated circuit
Q1—2N2646 unijunction transistor (Motorola HEP 310)
Q2—2N2222 transistor (Motorola HEP 736)
R1—15-ohm, 1-watt resistor
R2—100,000-ohm, ½-watt resistor
R3—220-ohm, ½-watt resistor
R4—22-ohm, ½-watt resistor
R5—2700-ohm, ½-watt resistor
R6, R7—1000-ohm, ½-watt resistor
R8—10,000-ohm, ½-watt resistor
S1—Spst switch
SCR1—2N1596 silicon controlled rectifier (Motorola HEP R1102)
1—Mallory No. SC628P Sonalert®
Misc—Suitable plastic enclosure, battery holder, machine hardware, hookup wire, pc board or perforated board, solder, etc.

terminal of the decade counter. This arrangement insures that the counter starts at zero every time the sequence is initiated.

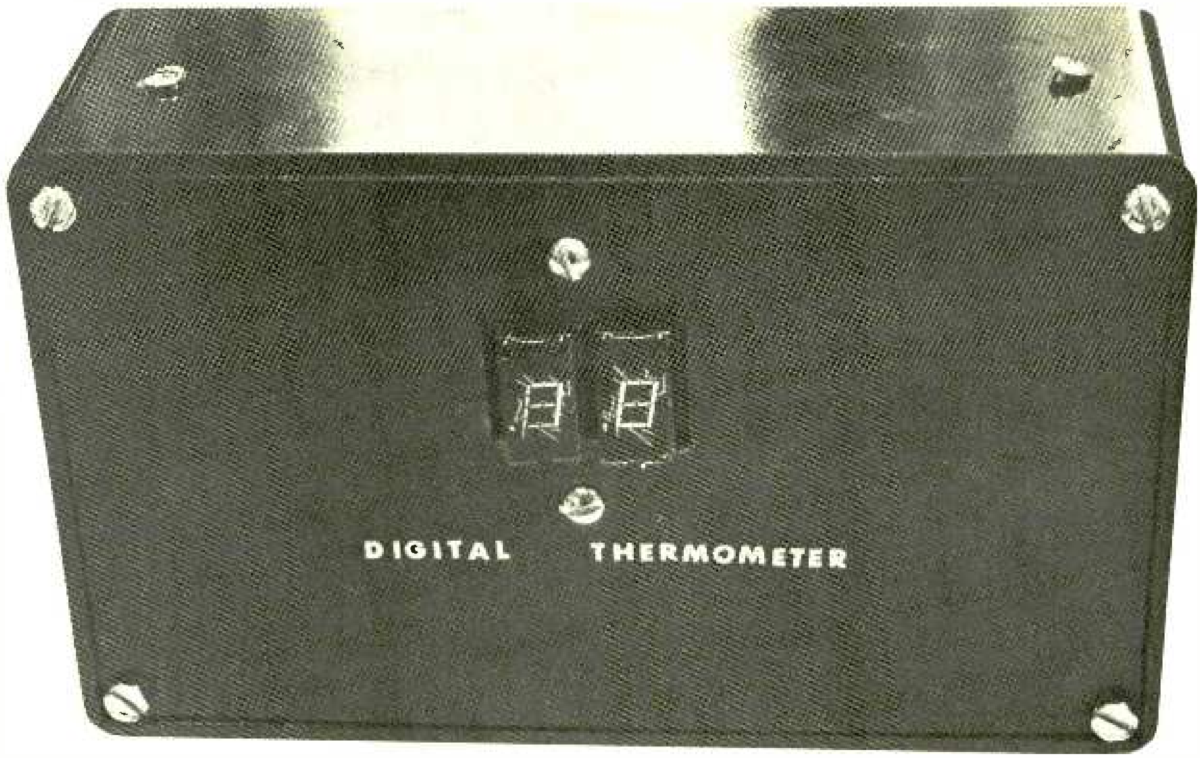
The UJT timing oscillator, *Q1*, generates one pulse per second which is fed to the clock input of the counter (*IC1*). The outputs of the 7490 up-counter are introduced into the inputs of the BCD-to-seven-segment decoder, *IC2*. A 7447 chip is used for this function. The outputs of *IC2* are connected to the display. A Numitron (2000 series) was used in this project, but any seven-segment display compatible with the 7447 decoder can be substituted.

A diode AND gate, composed of *D2*, *D3*, and *R5*, controls the beeper and display-off sequence. When a 9 appears at the output of the 7447, the ouput of the AND gate goes high, and *SCR1* is triggered. Once *SCR1* is on, the Sonalert is activated, and audible beeps are emitted until the power switch is opened. The output of the gate also is connected to an inverter (*Q2*). When the output of the inverter goes low, the display is turned off. This is done to reduce power consumption. A small delay is introduced by *C4* to allow the last digit (9) of the count to appear on the display.

Any 5-volt supply capable of delivering 250 mA to the temper timer is suitable. For portability, six C or D cells can be used in the zener-regulated supply shown in the schematic. If longer battery life is desired, alkaline cells should be used.

Construction. The placement of components is not critical. Parts may be mounted on perforated board or a pc board. Leads should be run from the board to the display, rather than soldering the display directly to the board. This will afford a large degree of flexibility in mounting the board and display in an enclosure. The author used a plastic box (6¼" × 3" × 2") with an aluminum cover panel. A ¾" square hole was cut out of the panel for the display, and a bracket made from scrap aluminum was used to hold the Numitron securely.

Operation. The device may be used any place and any time that your temper flares up. It is a good conversation piece for the home or office, and correct use of the temper timer, in conjunction with self-restraint, may well keep some conversations going that otherwise would have led to blows. ◈



Build a VERSATILE DIGITAL LED THERMOMETER

Low-cost, accurate device can be used as
- *indoor/outdoor thermometer*
- *heater/cooler thermostat*
- *temperature alarm*
- *fishing thermometer*

BY THOMAS R. FOX

THE digital thermometer described here was designed for low cost and simplicity, as well as accuracy. If you use a conventional thermistor and check well-known, semiconductor mail-order firms, you can build the thermometer for about $15. If you decide to use a precision thermistor, the cost will be about $20. Since the thermometer operates from a +5-volt line, it can be used equally well in a car, boat, or camper. With a line-powered 5-volt supply, it can be used in the home.

It is possible to use two switchable thermistors to check temperature differentials—such as between the outside and inside, or between two rooms. If a long lead is used between the thermistor and the electronic circuit, the project can be used as a fishing thermometer.

How It Works. The frequency of the CMOS multivibrator (Fig. 1) depends on the resistance of thermistor *TDR1*, which is determined by the ambient temperature. Thus, if the temperature goes up, the frequency of the multivibrator goes up, and vice versa. Trimmer potentiometer *R23* is used to adjust the linearity.

The two-transistor multivibrator (*Q1* and *Q2*) automatically resets the two

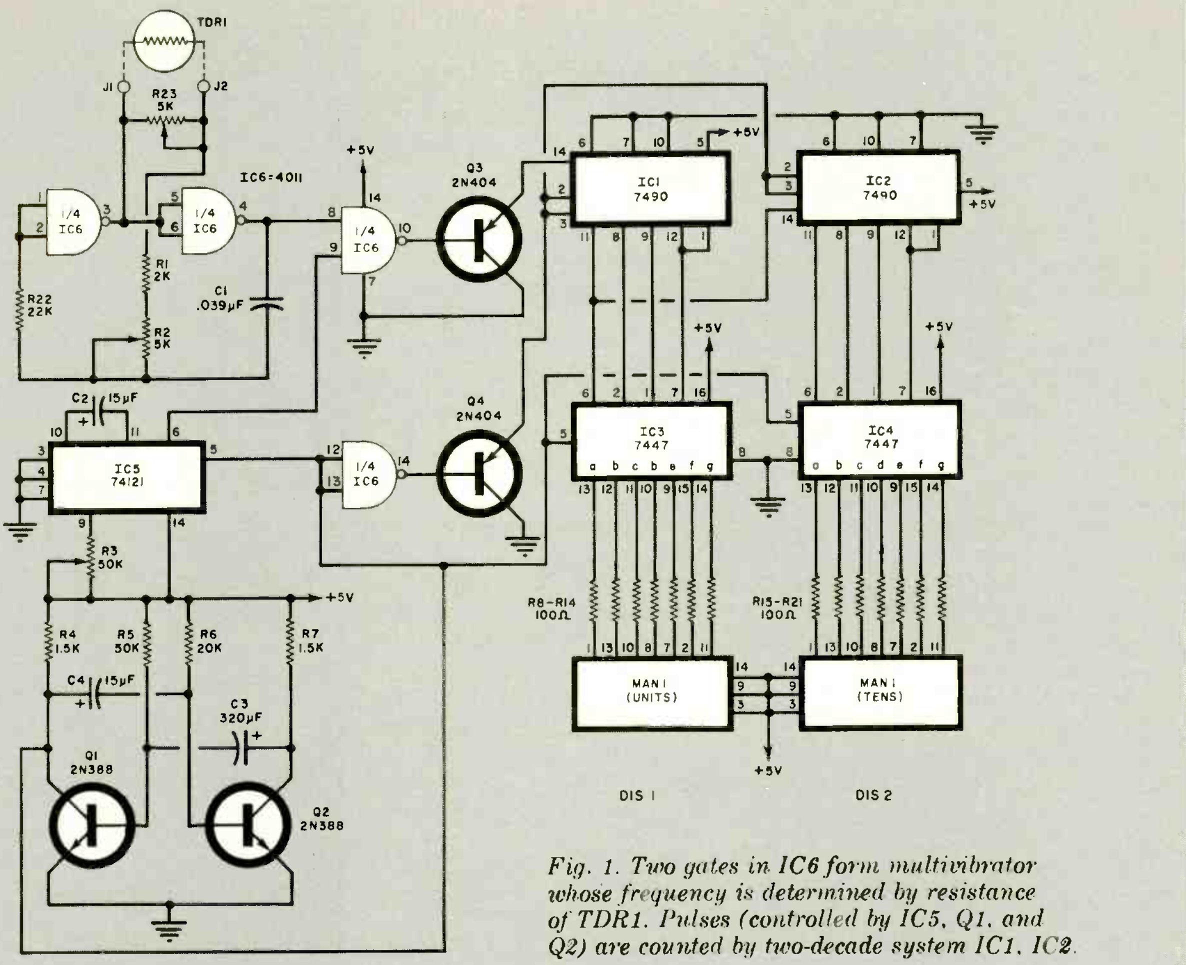


Fig. 1. Two gates in IC6 form multivibrator whose frequency is determined by resistance of TDR1. Pulses (controlled by IC5, Q1, and Q2) are counted by two-decade system IC1, IC2.

PARTS LIST

C1—0.039-µF silver mica capacitor
C2—15-µF, 10-V tantalum capacitor
C3—320-µF, 10-V electrolytic capacitor
C4—15-µF, 10-V electrolytic capacitor
DIS1, DIS2—LED display (Monsanto MAN-1 or similar)
IC1, IC2—7490 TTL decade counter
IC3, IC4—7447 TTL decoder/7-segment driver
IC5—74121 TTL monostable multivibrator
IC6—Quad CMOS NAND gate (RCA CD4011 or similar)
J1,J2—Banana jacks
Q1,Q2—2N388, HEP641 or similar
Q3,Q4—2N404, HEP739 or similar
R1—2000-ohm, 5%, ¼-watt resistor
R2,R23—5000-ohm miniature trimmer potentiometer
R3—50,000-ohm miniature trimmer potentiometer
R4,R7—1500-ohm, ¼-watt resistor
R5—50,000-ohm, ¼-watt resistor
R6—20,000-ohm, ¼-watt resistor
R8-R21—100-ohm, ¼-watt resistor
R22—22,000-ohm, 5% ¼-watt resistor
TDR1—1000-ohm, negative coefficient thermistor (USI 44003, available from Yellow Springs Instruments, Box 279, Yellow Springs, OH 45387 or equivalent)
Misc.—Suitable enclosure, flexible wire for thermistor leads, rubber glue, optional 9-oz plastic jar and cover, optional switch for two thermistors, mounting hardware and sockets.

decade counters (*IC1* and *IC2*) and *IC5*, which triggers the monostable multivibrator. When *IC5* operates, it closes the CMOS AND gate and allows the output of the temperature-dependent multivibrator to pass to the counters. The length of time that *IC5* is on is determined by the value of *C2* and the setting of *R3*.

Construction. The circuit can be assembled on perforated board, using sockets for the IC's and transistors. Everything is on one board except the power supply and thermistor.

Choose an enclosure that will accommodate the board, the power supply, and the two readouts. Be sure you have access to the three trimmer potentiometers (*R2*, *R3*, and *R23*) through suitable holes. If you use the thermistor called for in the Parts List, you can use an 1800-ohm fixed resistor for *R23*. Other 1000-ohm thermistors will require some adjustment of *R23*. For stability, *C1* should be silver mica and *C2* should be tantalum.

The on and off times of the display are determined by the values of *R5*/*C3* and *R6*/*C4*, respectively. These can be varied to suit individual choice of times.

If the temperature of more than one area is to be measured, a simple switching scheme can be arranged between *J1* and *J2*.

Carefully solder the flexible two-wire cable to the thermistor and insulate the joints. If the thermistor is to be used only indoors, coat it with some rubber glue. If it is to be used outside, it must be protected from the direct rays of the sun and other weather conditions. In this case, mount the thermistor in a plastic jar (about 9-oz capacity), being sure to drill many ventilation holes. The thermistor (mounted through the cover) should not come in contact with the jar. The jar must be positioned so that it does not get the direct rays of the sun.

Power Supplies. Three possible power supplies are shown in Fig. 2. Select the one that suits your needs. Any 5-volt supply that can deliver at least 300 mA can be used. If the digital thermometer is for fishing, use the ac-powered circuit. In this case, omit the transformer and diodes and use a battery holder to mount four 1.35-volt mercury cells, with an spst switch to control power.

Calibration. Connect the thermistor to *J1* and *J2* and apply power to the circuit. Allow it to warm up for at least 30 minutes. You will see a numerical display that will "blink" as the multivibrator operates every few seconds.

Fill a glass with ice cubes and top it off with cold water. Fill another glass with water that is as close to 90 degrees as possible. (Use an accurate mercury thermometer.) Set *R23* to its midpoint; and place the thermistor in the ice water *adjacent* to an ice cube. Without disturbing the glass or thermistor, adjust *R3* until the display indicates 33. Place the thermistor in the 90° water. If the display shows greater than 90, increase the value of *R2* until a reading of 90 is obtained. If the display indicates below 90, decrease the value of *R2*.

Insert the thermistor back in the ice water and touch up *R3* if the reading is less than 33. These adjustments will have to be repeated several times to get the readings as accurate as possible. If you encounter difficulty in attaining a linear display, adjust *R23*. In general, a decrease of resistance in *R23* results in an increase in sensitivity near the high end and a decrease in sensitivity at the low end.

Once calibration is complete, the digital thermometer should be within 1 degree between 0° and 90° F and usable between −50° and 130° F. Although this project was designed for the 0-90 range, it could be used to take readings of temperatures below zero and above 100° F. A reading of 90 on a bitter-cold winter day would mean that the true temperature is −(100-90) or −10°F. A display of 5 on a hot summer day means the temperature is 100 + 5 or 105° F. ◈

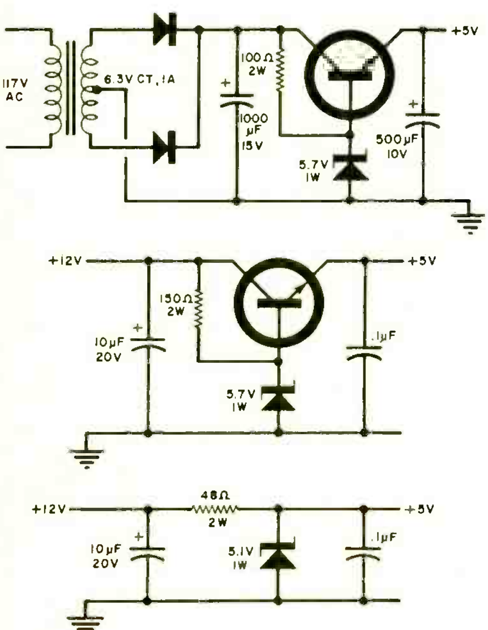


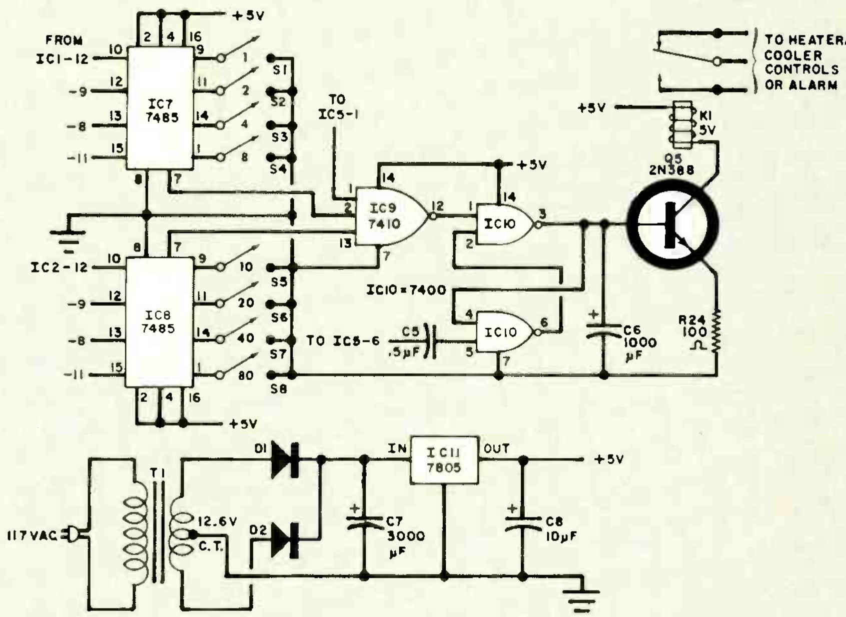
Fig. 2. Three typical power sources for thermometer. Top is for line power, other two are for mobile operation.

THERMOSTAT CONTROL MODIFICATION

You can convert the digital thermometer described in this article into a multi-purpose heating/cooling thermostatic control with a 0° to 99° F temperature range by adding to it the circuit shown below. Relay *K1* and any alarm or circuit connected to it can be made to trip at any temperature selected by switches *S1* through *S8*.

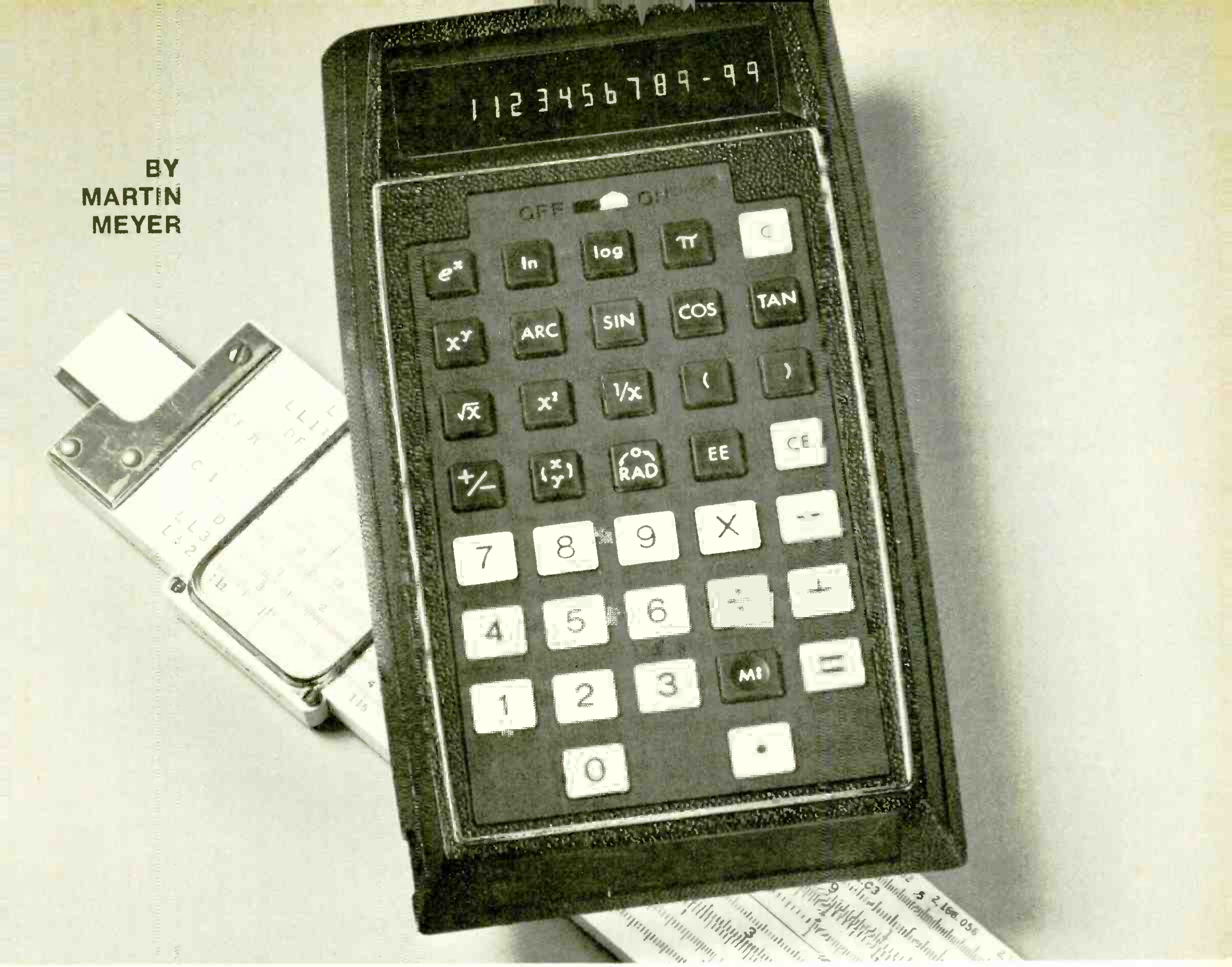
The reference temperature selected by the switches is the sum of the closed-switch designations. For example, to set the system up for 34° F, you would close *S3, S5,* and *S6* (4° + 10° + 20° = 34°). If the sensed temperature falls below 34°, *K1* will sound an alarm or turn on the heat. Conversely, if the reference temperature is 99° and the sensed temperature rises to 101°, *K1* can sound a different type of alarm or turn on the cooling system.

The use of a 5-volt relay for *K1* and suitable connections for its contacts to the heating/cooling controls produces a state-of-the-art environmental control system that eliminates troublesome mechanical thermostats. For the most reliable thermostatic operation, increase the value of *C3* to at least 2000-µF and change the value of *R5* to 100,000 ohms. Also surround thermistor *TDR1* with ¼-in. (6.35 mm) of insulating material and protect it from drafts.



ADD-ON PARTS LIST

C5—0.5-µF disc capacitor
C6—1000-µF, 10-volt electrolytic capacitor
C7—3000-µF, 20-volt electrolytic capacitor
C8—10-µF, 15-volt electrolytic capacitor
D1,D2—1-ampere silicon diode (1N4001 or similar)
IC7,IC8—7485 magnitude comparator integrated circuit
IC9—7410 triple 3-input NAND integrated circuit
IC10—7400 quad 2-input NAND integrated circuit
IC11—7805 5-volt regulator integrated circuit
K1—5-volt relay with spdt contacts
Q5—2N388 (or similar) transistor
R24—100-ohm, ½-watt resistor
S1-S8—Spst switch
T1—12.6-volt, 1-ampere filament transformer



BY
MARTIN
MEYER

Build An Under-$30 Scientific Calculator

Ten digits of mantissa with 2-digit exponent and a full range of scientific operations, including double-nested parentheses.

THE inexpensive four-function calculator is an eminently practical tool for everyday home and primary-school use; however, high-school students, engineering and science majors in college, and practicing engineers and scientists require more sophisticated equipment. Fortunately, there is a new breed of calculators that is rapidly gaining popularity in professional and advanced-student circles. Going by such names as "scientific" and "slide-rule" calculators, they expand by several magnitudes the number of functions and the information-handling capacities of "ordinary" calculators for limited uses.

Scientific calculators may be capable of obtaining *n*th roots and *n*th powers; trigonometric functions (sine, cosine, tangent, etc.); natural and common logarithms; degrees-to-radians conversions; and many other functions. As a general rule, these calculators also feature at least one level of store/retrieve memory, a 10-digit mantissa with two-digit exponent, and separate displays to indicate negative quantities (in both mantissa and exponent) and overflow and disallowed functions.

This full-function 200-decade scientific calculator costs only $29.95 in kit form. It is 3⅜" wide, 6" long, and 1½" thick.

What It Does. What can you, as an electronics experimenter, do with such a calculator? The answer is, just about anything you want to do in problem solving. For example, suppose you wanted to know the equivalent resistance of a network of three resistors (560 ohms, 390 ohms, and 670 ohms) in parallel. By hand, this problem might take you 10 minutes or more. With the calculator, less than 30 seconds is needed to get the answer (171.1638788.).

Approaching a more difficult prob-

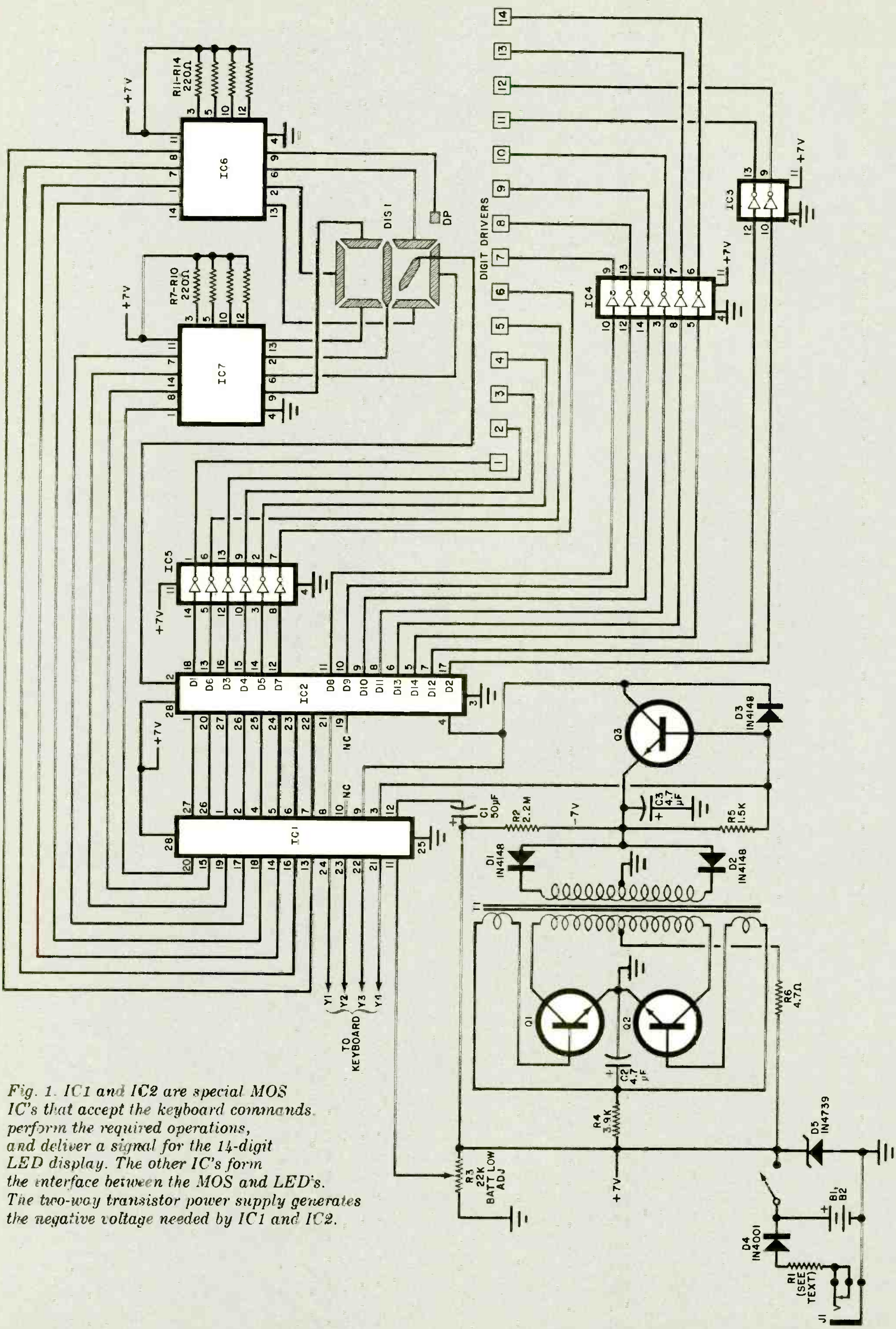


Fig. 1. IC1 and IC2 are special MOS IC's that accept the keyboard commands, perform the required operations, and deliver a signal for the 14-digit LED display. The other IC's form the interface between the MOS and LED's. The two-way transistor power supply generates the negative voltage needed by IC1 and IC2.

With the IC's still in the carrier, determine which is which and the locations of pins 1. Pin 1 is near the small bump on each IC. To be absolutely certain of pin 1 on each IC you can use a small magnifying glass to check the IC leads near where they enter the packages. Only pin 1 in each case has a tiny hole drilled through it.

With the forefinger of the hand you have grounded pressed against the metal plate on top of *IC1* remove the IC from its carrier. Check to make sure its leads are in straight lines. Then carefully install the IC in its appropriate connectors on the board. First engage the pins along one side of the IC in the connectors. Once this is accomplished, work the leads along the other side into their connectors. Apply firm, even pressure to the IC to seat it in its connectors. Do not force the IC into the connectors or subject it to torsional forces or you might misalign or even break off pins. If insertion is difficult, replace the IC in its carrier. Then, insert and remove an old IC in the connectors several times to "form" them. Any DIP IC will do; just make sure to cover all connectors. Now, install the IC from the carrier.

Repeat the above procedure for *IC2*.

The display comes as a completely wired assembly, with its 24 connector pins already mounted in place. Just make sure that the pins are in a straight line. Carefully fit the display-board pins into their respective connectors on the main board. Press the display board into place so that it rests on the five upper IC's with a slight tilt.

The keyboard also comes as a complete assembly, including connector pins. Straighten any out-of-line pins and engage them in the connectors along the lower edge of the main board. Gently seat the keyboard assembly in place until the narrower portions of the upper two plastic posts on the keyboard assembly engage the smaller of the holes above the negative-terminal battery contacts on the main board.

Slide the entire assembly into the top half of the calculator case until the two small plastic tabs on the bottom end of the keyboard engage the molded slots in the case top. At this time, two threaded plastic posts should appear through the holes immediately above the negative battery contacts on the main board, and *J1* should slightly protrude through its slot in the case.

Holding the board assembly in place in the case, secure the two together with small nuts over the threaded posts. (Note: Because of possible interference between nut and close-by foil conductor near the left post, precede the nut here with a thin insulating washer.)

Place the power switch in the OFF position, and tape it in place until the batteries have been installed. The batteries are marked with + and − signs. The + sides are protected by sleevings that extend beyond the bodies of the batteries. The sleevings are notched in such a manner that the batteries will fit into their respective locations in only one way. Slip the batteries into place. This completes construction.

SAFE HANDLING OF MOS IC'S

Prior to any construction and before removing MOS IC's from their protective carriers, it's imperative that certain precautions be understood and followed:

All insulated-gate MOS devices can be permanently damaged by excessively high electronic fields. Random electrostatic charges *must* be kept away from MOS devices. Anyone who handles the devices should wear anti-static clothing (preferably cotton) and, if possible, cotton gloves. Do *not* wear synthetic fabrics, particularly nylon; they readily build up static charges.

All working surfaces where MOS devices are handled should be conductive and at ground potential. Before handling, you should also be grounded. And avoid dropping MOS devices because of possible contact with charged surfaces or objects.

All apparatus that is to come into contact with MOS devices must be grounded, including your soldering iron's tip. Never insert or remove a MOS device in a powered circuit. When inserting or removing a MOS device, touch the grounded surface only after you have grounded yourself. If possible, ground the conductor pattern around the area where the device is to be installed with conductive tape or aluminum foil during installation and removal. When a good MOS device is removed from a circuit, immediately install it in a protective carrier.

You can ground the tip of your soldering iron by wrapping around its thick portion a copper strap and fastening the strap to a length of meshed cable. The free end of the cable then goes to a good ground. To ground yourself, use a similar procedure. Wrap a length of meshed cable snugly around your working-hand wrist and connect the free end of the cable to a good ground.

Checkout and Adjustment. Plug the recharger into *J1* and let the batteries charge for a few hours. Then disconnect the charger. Remove the tape from the power switch and set it to ON. The right-hand mantissa digit and its decimal point should come on, displaying 0. Leave the power applied and, after about a 30-second delay, the 0 and decimal point will blank out, being replaced by a minus sign in the exponent display. This indicates that the battery-saver feature is working.

Press the clear (C) key to restore 0. to the display. Feed in the numbers 1 through 0; operate the +/− and EE (enter exponent) keys; feed in 88; and press the +/− key. The display should now read −1234567890−88. Press the degrees-to-radians key; a small diagonal bar segment should come on to the extreme left of the display. Operate this key again, and the bar should extinguish. Press the C key.

Press the π key. The display should now read 3.141592654. Depress C. Now, with 0. displayed in each case, press log (common logarithm), 1n (natural logarithm), and 1/x (reciprocal). In each case, before depressing C, the disallowed function indicator, an inverted L, should show at the far left of the display.

To adjust battery-low indicator potentiometer *R3*, it is necessary to first fully charge the batteries. Plug the battery charger into *J1* and the ac outlet. With the power switch set to OFF, charge the batteries for about 8 hours. Then use the calculator for about 4 hours. Then, with the power ON, adjust *R3* with a thin-bladed screwdriver through the hole in the bottom of the main board, until the battery-low indicator (an L at the left of the display) comes on.

Install the back of the calculator case by inserting the two bottom "hooks" into their respective slots at the bottom end of the calculator. The top end simply snaps into place. A narrow slot at the top of the case is provided to permit the case to be reopened as desired with a coin or screwdriver blade. Simply twist.

The calculator can be operated from fully charged batteries for about 4 to 5 hours. When the charge runs down, simply plug in the recharger. Recharging takes 8 to 10 hours. The battery charger can also be used as a convenient battery eliminator. However, *under no circumstances should the recharger be used if there are no batteries in the calculator.* ◈

BITS TO DOTS

How digital information is transformed into video displays.

BY LEE FELSENSTEIN

THE popular image of computers includes huge display screens flickering with impossibly complex graphic designs or sarcastic comments in large block letters. These displays operate in dimly lit rooms accessible only to holders of triple-ultra-security clearances.

If it ever were like that it's not that way any more. The common, ordinary home-TV set, modified to have a direct video input, is becoming the new standard display device for the upcoming generation of amateur-oriented computers.

This article is intended to fill the reader in on the technical limitations and possibilities of this kind of display. We'll try to define some terms and explain why they matter. We hope that you will be able to use this information in selecting a display device if that's in your plans. Or perhaps reading this article will cause you to change your plans one way or another.

Raster vs Display. *Vector* display is the name given to the oscilloscope-type displays on which the screen is dark and the computer draws lines of varying lengths and angles. This requires a large-screen oscilloscope on which the electron beam can be positioned at random. There are not too many of these available that are not surplus radar-scopes.

Raster display is display based on a fixed network of scan lines which is regularly generated on the display tube. Images are generated by changing the brightness of the spot at the right times. This is the technique used by standard broadcast video systems to transmit and display images.

Raster rhymes with faster. It is the name of the pattern of horizontal scan lines which we can see crawling across the face of our TV picture tubes. Formally speaking, the U.S. standard raster consists of 525 scan lines which occur once each 63.5 microseconds, or 15,750 times a second. The picture, or frame, is broken up into two fields, each having half the total number of raster scan lines and each lasting 1/60 second. One field consists of the odd-numbered scan lines, the next the even numbered ones. The two fields are said to be *interlaced* when this is happening.

The reason for this interlace is to confine the 30-Hz flicker, which would otherwise be objectionable, to the space between alternate scan lines. Thus, instead of the picture seeming to flicker over its entire length, alternate lines seem to flicker. This results in the familiar "crawling" effect of the scan lines on the picture tube, and nothing worse.

Sync or Be Sunk. It is of vital importance to the successful display of raster-type video that the raster of the displaying device be in exact synchronization with the raster upon which the transmitting device is basing its signals. Synchronization pulses, (just *sync pulses* for short) are therefore included in the video signal. The video signal is permitted only a certain range for picture information. Zero percent modulation (TV signals are amplitude modulated) is pure white, 75% modulation is pure black. When the signal jumps up to 100% modulation (blacker-than-black), that causes the sync circuits in the receiver to trigger and return the beam to the left-hand margin to start the next line. This retrace is assumed to take about 10 microseconds out of the 63.5 microseconds between sync pulses.

After 240 scan lines the raster has progressed to the bottom of the screen. Now the sync pulses get fat—in fact they take up almost all of the scan line. An integrating network in the receiver's sync circuitry detects this and starts charging a capacitor. If the fat sync pulses continue to occur for several lines, this capacitor will charge sufficiently to trigger the vertical retrace, which sends the beam back to the top of the screen. 22½ scan lines are allowed for this process, along with the time for "equalizing pulses" which guarantee that the next interlace will occur and the next field will hit between the lines of the last field.

It's pretty tricky to generate sync signals with interlace, but it's simple to generate non-interlaced sync signals. Since you can still do a lot with 240 scan lines, most inexpensive video display devices leave out the interlace.

Bandwidth Limitations. Closely packed detail in a picture means that the video signal must change from dark to light and back again at a high rate as the beam scans across the screen. Broadcast standards prevent this rate from being greater than 4 MHz, and frequencies higher than that are filtered out inside the TV receiver. If the signal is going to be fed into the TV set through the antenna, there's no way you can get more than that.

Well, how much is 4 MHz in terms of dots? If the visible portion of the scan line is 50 microseconds, that amounts to 200 *dot pairs*. Note well — a cycle of video is equivalent to a pair of dots, one white, one black. Any other pattern requires less bandwidth. Therefore, 4 MHz is equivalent to 8 million dots per second, or 400 dot positions across the screen.

Alpha-numeric characters are usually 5 or 7 dots wide, depending on the type of character generator. Does this mean (allowing for an extra dot between characters) that you can display 66 to 50 characters through a 4 MHz receiver?

It does if you plan to shrink the picture in so that the edges of the raster are visible. This means tampering with the width and the horizontal linearity controls, both of which are screwdriver adjustments deep inside the set. It also means that the set will display funny-looking squashed-in pictures with black edges if someone wants to watch TV on it. If the TV is to be used without modification, 15 to 33 percent of the visible portion of the scan line must be allowed for "overscan." This reduces the usable portion of the scan to between 42 and 32 microseconds, or 56 to 42 characters (assuming 6 dots per character and 4 MHz bandwidth).

This explains why video display devices intended for use with unmodified TV sets have from 16 to 40 characters per line. Most of these devices were designed before the FCC came out with very tough rules for adapters which convert video signals to modulated r-f to allow operation through the antenna terminals.

After those regulations were brought out a lot of interest started cropping up in making display devices for TV's with added video inputs. (One manufacturer is still allowed to make r-f converters under an FCC "grandfather clause," but no manufacturer can incorporate them in other equipment.) If the 4.5 MHz "trap" circuit in a TV is bypassed, most solid-state TV video sections are good for 6 to 10 MHz. This allows a display of from 64 to 80 characters.

Techniques. The basic device for converting a multiple-bit data word to dots is a shift register. You load the bits in and clock the shift register once for each dot. The output of the shift register is the video signal.

At this point some budding genius will jump up and shout, "That's it! All I have to do is connect a shift register to a parallel data output port of my microcomputer and feed it to the T.V! I'll do all the pattern generation in the computer through software!" This person has yet to learn about the bandwidth of the computer.

Suppose you hook up a shift register like that and wanted to get a full 400 dots across the screen. That means 50 8-bit bytes loaded into the shift register in 50 microseconds, or one byte per microsecond. Most microprocessors couldn't even finish a single instruction in one microsecond, let alone the sequence of instructions required to output, fetch the next byte, and output again.

For such "bit mapping" displays you need specialized hardware which bypasses the processor and performs what is called *direct memory access* or DMA. The hardware commands the processor to stop and takes over control of the memory address bus. It then reads out data from the memory faster than the processor can read data. After a while it has had enough, so it lets the processor resume control of the address bus. Different processors have different ways of dealing with this situation, and most have maximum data transfer rates for their DMA channels. These rates are given in words or bytes-per-second, and multiplied by the number of bits-per-word or byte, yield a figure in terms of bits-per-second. That is the bandwidth of the data channel, and you won't get more than that through it no matter what you do.

Of course, this is only a problem when you want to display complex random patterns like pictures. If the information to be displayed is limited to the ASCII alpha-numeric character set (64 characters, 96 including lower-case, 128 if control characters are displayed), the required data rate is much lower. Although a character takes 35 to 63 dots to make up its display, it requires only seven bits to specify which character. The bit pattern for the display is contained in a ROM (read-only memory) of from 2240 to 8192 bit capacity. Each line of characters across the display screen is made up of from seven to twelve scan lines. The character generator ROM is fed the seven-bit number specifying the character and a three-to-four-bit number from the sync generating circuitry specifying which scan line is occurring. The ROM then puts out the proper row of dots for that scan line of the character (See Fig. 1.) as a 5- or 7-bit word. This word is loaded into the shift register and shifted out to become the video signal. Space between characters consists of extra "black" bits loaded into the shift register and shifted out after the dots.

Storage. The row-scan character display technique implies that the data for an entire line of characters must be presented to the character generator once for each scan line in the character line. If the display device had to go back to the computer for the same row

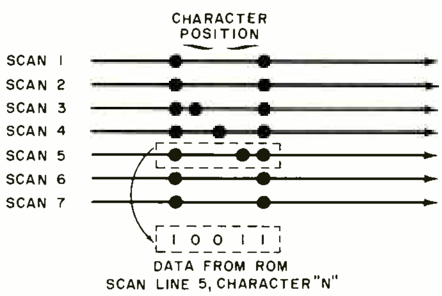


Fig. 1.

of data each time, it would require DMA and take up a lot of the computer's available memory access time.

There are several ways of avoiding this kind of jam-up, all of which use some kind of storage in the display device. One of the oldest and still most workable is the line buffer. This is a shift register; or more accurately a batch of shift registers, one for each bit of the data word, long enough to hold all of the data for a single character line of the display. It is arranged so that as the data is shifted out it can be "recirculated" back into the front end. If the line buffer is clocked once for each character, it will repeat the data line for each scan line. After all of the scan lines have been taken care of, the recirculate feature is disabled and the next line of data is shifted into the buffer from the computer.

If the display device is located at a distance from the computer, this next line can come from a memory in the display, usually another shift register. This one, called the screen buffer, is long enough to hold all of the data for an entire screen's display. It is constantly recirculating and the external circuitry decides when to insert new characters.

If the display is plugged into the computer's memory bus, this next line can come from a DMA transfer out of the computer's memory. This scheme reduces the time required for DMA transfers to a reasonable level so that the operation of the processor is not impaired.

Another scheme used in some display devices is a random access memory shared by the processor and the display. The display can access this memory without shutting down the processor, and so can go whizzing through without need for a line buffer, pulling out the same data line over and over for each scan line. The only other thing the memory has to do is to be loaded with new characters by the processor every now and then.

Display devices using this "two-port memory" are now made both as stand-alone terminals and as plug-ins to the computer bus. If they are plugged into the bus, the computer can address any character in the display's memory at random, allowing some rather interesting effects. When used stand-alone, its operation is more like a standard terminal, with new characters being entered in sequential locations on the screen. Of course, the stand-alone versions will operate through very low bandwidth data channels, such as a telephone (through a modem) or RTTY (radioteletypewriter).

Bless the Cursor. Every display device has to have some means of indicating to the user one or more special locations on the screen. Usually this is the place where the next character will be displayed, but on more elaborate display schemes these special locations can indicate "protected" data areas where new data may not be entered, "blocks" of data set up for transmission to some communications device, or just special characters on the screen which the programmer wants to make conspicuous.

The display must therefore have a "cursor," usually an underscore or a solid white block, sometimes an overscore or a "video inversion" in which the black turns to white and vice versa. In stand-alone terminal type displays the cursor can exist in only one location and marks the next point of data entry. It is usually moved around one step (left or right, up or down) at a time, although in some displays certain control characters can be used to indicate a new location on the screen to which the cursor jumps. This is called an "addressable cursor."

Displays which plug into the computer bus can have "software-controlled" cursors. Usually this means that there is no counter in the display which holds the address of the screen location at which the cursor is to be displayed, but an extra bit on the data is used to flag any character with a cursor condition. This means that any number of cursors can be placed anywhere on the screen by software. This also changes the significance of the cursor to a general marking device, with no necessary connection to the point of entry of the next data character.

Very often the display will have some means of causing the cursor to flash. Many people are distracted by the flashing, and this feature is usually an option, controlled by software or by a switch or jumper connection.

Paging and Scrolling. "Paging" refers to a display mode in which the data begins filling the screen from the top and progresses to the bottom. When the bottom is reached, the screen clears and a new page begins. Paging is used in applications where the data will be coming in known bursts, usually under control of the viewer, so that there will be time to finish reading the page before it disappears. Often the display can store several pages of data and the user can look through them as if they were pages in a book.

"Scrolling" is the display mode in which data is entered at the bottom of the screen and is pushed up as each line is completed. It is more similar to the operation of teleprinters and is better suited for the display of information coming in continuously. The hardware required to generate scrolling is more complex than that required to generate paging.

Some displays which plug into the computer bus have no hardware for paging or scrolling, but just display whatever the computer writes into part of its memory. Thus, the way the processor re-writes what's in the memory area controls the way the data appears to move. Using that method the software could cause part of the screen to scroll and part to page. It takes processor time to do this, however, but not a tremendous amount.

Graphic Possibilities. Some displays which plug into the computer bus can display both alpha-numerics and graphics. These devices use a character generator for the alphanumerics but they bypass the character generator when the eighth bit of the data is set. When this happens, the lower six bits of data are displayed as a tiny "checkerboard" with six squares in the area reserved for that character.

This should not be confused with the "bit mapping" graphics displays which have no character generators, but which can display characters from patterns which the software generates. These characters are usually much larger than those which come from character generator ROM's.

Checklist for Video Displays. If you are considering getting a video display device, here are some questions which you should ask — and answer:

(1) What do I want my display to do: (a) complex graphics? (b) complex alpha-numeric characters? (c) simple terminal-type alphanumeric operation?

(2) If alphanumeric: (a) upper-case only or upper/lower case? (b) how many characters per line? (c) paging or scrolling mode?

(3) If graphic: (a) how many picture elements (dots) per line? (b) what are the limitations of the processor imposed by operation of the display: (1) how much memory is required to store the screen display? (2) what percent of the time is the processor disabled or slowed by DMA? (c) will the processor be able to change the number of picture elements desired per frame?

(4) If stand-alone (terminal type): (a) does the display have a keyboard? keyboard connector? (b) does the display have a serial transmitter/receiver? What baud rates are available? (c) what happens when the display fills a screen and the data keeps coming? (d) does the terminal have a current-loop and/or EIA-level connection? (e) does the terminal have screen-read capability and block transmission capability? Do I need these capabilities? (f) what happens when the terminal receives a carriage return? line feed? carriage return — line feed combination? null? delete (rub-out)?

(5) Regarding connection to the TV monitor: (a) what is the nominal bandwidth required by the display? (b) what kind of connector, if any, does it have? How long a cable? (c) will the monitor sweep size have to be adjusted? (d) does the display have centering adjustments?

(6) Regarding software: (a) how much space is required for this software needed to make the device perform as I want it to perform? (b) are timing loops necessary? (c) is interrupt operation possible?

Conclusion. By the time this article reaches you there will probably be new equipment which combines some of the functions which have been mentioned separately. There will be new attachments, like light pens, joy sticks and "mice" for feeding information to the processor about where on the screen you are looking. There will eventually be chips that do what PC. boards now do.

As usual, some of these will work better than others. Manufacturers' claims sometimes exceed performance and prices will be unpredictable.

Whatever the new wrinkles, one fact is certain — the display devices will get easier to use and program, and the ratio of fun to misery will increase.◈

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Processor Technology Corp. is constantly evolving new ways to expand your minicomputer system. The **Sol Computer** is our most recent development (an early version is detailed in Pop'tronics, July '76). We support the Sol Computer with **a full line of creative, innovative interfacing and memory modules.** (Also compatible with the Altair 8800 and the IMSAI 8080.)

3P+S Input/Output Module; our simple and inexpensive answer to handling a variety of peripheral devices. It has two 8-bit parallel I/O ports, and one serial I/O port—that's a lot of versatility!

ALS-8 Assembly Language Operating System; this useful software development tool allows you to write, edit, assemble, de-bug, and run your own programs. A highly sophisticated system, yet very easy to use. Optional simulator and text editing firmware available.

VDM-1 Video Display Module; our ultra-high speed video output device displays 16 lines, 64 characters each, both upper and lower case. All cursors display black-on-white or vice-versa, in any combination. Includes free terminal mode software.

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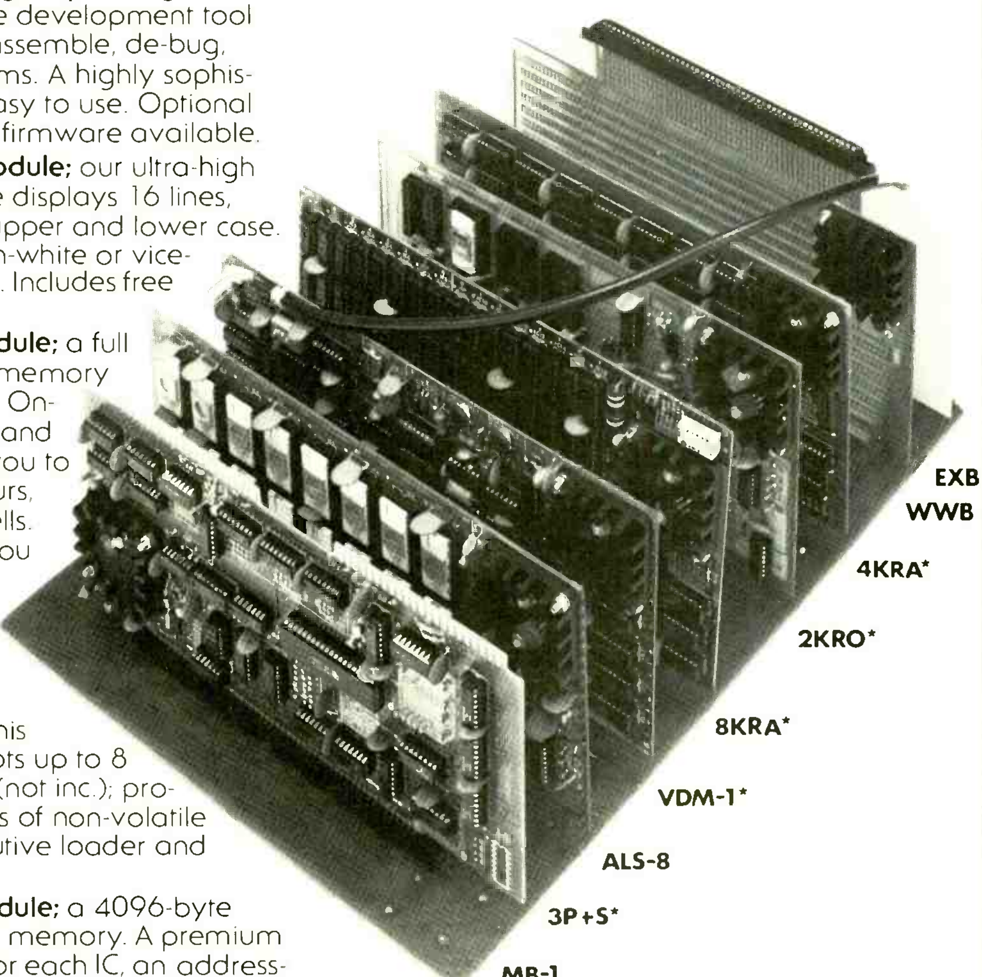


(*)Owner's Manual available separately for $4.95; price refundable with purchase of the kit.

Processor Technology Corporation
6200-H Hollis Street
Emeryville, CA 94608

DIGITAL ELECTRONICS / MICROCOMPUTERS PRODUCT DIRECTORY

COMPUTERS

APPLE

APPLE-1
Assembled microprocessor board using 6502 MPU, with video-display electronics; 4k RAM (8k on-board capacity, 65k external max.); monitor in PROM: ASCII keyboard interface on-board; power supply. Apple BASIC supplied free $666.66

APPLIED MICROTECHNOLOGY

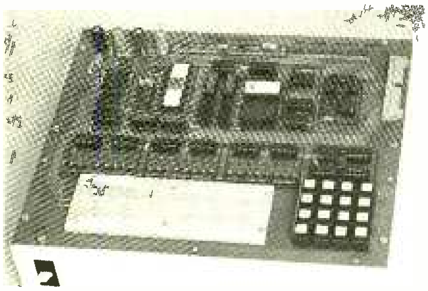
AMT 2650
Self-contained card microcomputer system using the Signetics 2650 MPU. Directly programmed from a switch panel mounted on the card, with 33 LED displays: 8 each for address and data; 8 each for the two fully-buffered TTL-compatible output data ports; one for run. Eight load switches for address and data entry, switches for address load, address increment, data load, step, run/wait, reset. Clock is adjustable. Contains 256 bytes of RAM; additional RAM, PROM and ROM can be interfaced via the edge connector $195.00
Power Supply $39.95

CROMEMCO

Z-1
Uses Zilog Z-80 MPU in a ready-to-run system featuring 8k RAM, PROM programmer, monitor in PROM, RS-232 interface, mainframe with 22 sockets, front panel with large paddle-handle switches. The Z-80 has 158 instructions, including the 8080's set of 78 instructions .. $2495.00

E&L

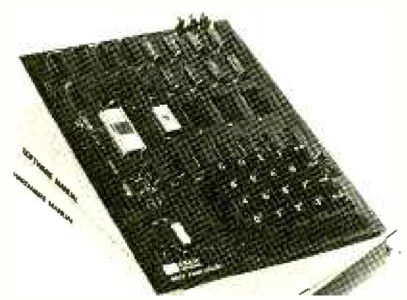
MMD-1 MINI-MICRO COMPUTER
Educational microcomputer system for classroom instruction or home study. Features: 8080A MPU, clock generator, 256 words of RAM, 256 words of PROM (preprogrammed to control keyboard entry), 16-key keyboard (numerals plus high address, low address, go, reset, deposit,



examine) three groups of 8 LEDs (high address, low address, memory contents), power supply. Integral solderless breadboarding and interfacing socket, connected to main bus. Kit-/assembled .... $350/$500.00
MMD-1/RAM. Extra 256 bytes of RAM .$15.00

EBKA INDUSTRIES

6502 FAMILIARIZOR
Single PC board mounting 16-key hex keyboard plus four control keys, 2-digit hex LED display, 6502 microprocessor. Can address 65k bytes of memory; on-board memory consists of 1k bytes of RAM and 256 bytes of PROM (monitor program); can add 3 more PROMS (768 bytes) on-board. One 8-bit TTL-compatible I/O port.



Hardware and software manuals. Monitor program in PROM allows loading, examine, run, debug, and modify your own program. Requires +5 volts at 1.2 amperes and −9 volts at 50 mA. Primary use is as microprocessor and programming trainer. Kit/assembled .... $229/$285.00
Power Supply $58.00

ELECTRONIC PRODUCT ASSOC.

MICRO68
Based on the 6800 MPU; 16-key hex keyboard; 6-digit hex LED display; 128 words of RAM; 512 words of PROM containing all service programs necessary to load, inspect, and edit programs; sockets for 768 words of RAM; power supply, hardwood cabinet; 16-bit I/O connector; RAM expansion to 64k. Ready to run; many options available $430.00
RAM increments, 128 words $5.50
PROM, 256 words programmed to your specs $10.00
MIK-BUG of 1k ROM for Teletype $28.50
6800 applications manual $25.00
6800 programming manual $10.00
TTY/CRT RS-232C adapter $51.50
8K static RAM memory board $320.00
Printer, 40-column, 100-cps $450.00

EXPANDED-68 COMPUTER
An expansion of the Micro88, with 8k memory, power supply, 16-digit keyboard, Teletype adapter, hex LED display, expansion cabinet, application manual, programming manual ... $1050.00

ELECTRONIC TOOL

ETC-1000
Based on 6502 MPU. Comes with 40-key keyboard, including set of hex keys for data and address entry, function keys such as Hold, Load, Reset, Examine Memory, and special keys that may be sensed under program control by the user. The 8-digit LED panel display may be operated under program control, segment by segment. Using optional PROMs, one or two full-duplex communications lines operate at speeds from 110 to 1200 baud: speed selection is automatic. Standard interface is 20-mA current-loop; RS-232C is optional. Basic unit consists of 6502, lk bytes of Ram, 256 bytes of EAROM containing system-control functions; RAM and ROM may be added in 4k and 8k increments to total of 65k bytes. Additional MPUs such as 8080A, 6800, and F8 can be plugged in for multiprocessing. Size is 17.5"W × 12.5"D × 8"H $645.00

1006. Memory parity $45.00
1001. Crystal-controlled clock $25.00
1020. Bus expansion, 8 spaces $72.00
1110. 4k RAM $235.00
1304. 4k EAROM $125.00
1406. 8080A CPU module $165.00
1407. 8080A CPU with 1k RAM $245.00
1408. 6800 CPU module $165.00
1410. F8 CPU module $165.00

GNAT

GNAT SYSTEM 1
Minimum system; uses 8080 in a CPU with power-up reset, manual reset, all ICs on sockets, full DMA, status indicators, 8 levels of vectored priority interrupts that are software maskable, low-power Schottky devices; 1k RAM; 512 words of ROM with Gnatbug system monitor: I/O serial and parallel interfaces; power supply; card rack with motherboard; connectors $925.00

GNAT SYSTEM 2
Minimum system for hardware checkout; 8080 CPU; 1k of RAM; front panel with all controls and status indicators; power supply; card rack with motherboard; connectors $985.00

GNAT SYSTEM 3
Minimum system for BASIC operation; 8080 CPU, 8k of RAM, 768 words of ROM with Gnatbug, serial and parallel interfaces for RS-232/20-mA; power supply; card rack with motherboard; connectors $1695.00

GNAT SYSTEM 4
Minimum system for PROM programming; 8080 CPU, 1k RAM; 1k ROM with Gnatbug: serial and parallel interfaces for RS-232/20-mA; PROM programmer for 1702A and 2708; power supply; card rack with motherboard; connectors. $1695.00

GNAT SYSTEM 5
Complete development system; 8080 CPU; 16k RAM; RAM/ROM to hold floppy-disk drivers; 4k ROM to hold monitor; I/O interface for TTY, CRT or high-speed reader and/or punch; interface for floppy-disk and Teletype 40 line-printer; complete front panel; 19" cage; 15 connectors; power supply; rack-mountable cabinet $2995.00
Lear-Siegler ADM-3. CRT terminal .$1300.00
Teletype 40. 300-lpm printer $2000.00
iCOM Dual Floppy-Disk System .. $3500.00
High-Speed Paper-Tape Reader ... $525.00

HAL

MCEM-8080
Single-board computer, excluding power supply. A 1k of ROM provides system monitor including bootstrap loader (both ASCII and Baudot) and serial I/O routines. Allows loading hex-formal files, and dump or display of memory. Subroutines in monitor include console input/output, reader input, punch output, list output, and other. LEDs indicate address, data, and control lines. Switches include reset, single-step, run/stop, manual output write, manual memory write. Breakpoint register for program debugging. Bus structure, three 8-bit parallel I/O ports; serial I/O

with current-loop and RS-232 levels; baud rate 45 to 300. Board accommodates 4k bytes of RAM; 1k bytes provided $375.00
MCEM-KB/VDU. Keyboard/video/display unit, 16 lines by 64 characters, 52 keys, ASCII/Baudot codes $300.00
MCEM-7K RAM-4K. Static RAM expansion board with 4k of RAM $245.00
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MCEM-PROM PROG. PROM programmer for RAM boards, programs 8704/8708 EPROMs $35.00
MCEM-32K CCD-8K. CCD memory board holds 32k of 2416 CCD memory. Comes with 8k bytes $300.00
Extra CCD memory, per 8K $140.00
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IMSAI

IMSAI 8080 SYSTEM
CPU board includes 8080A, clock, tri-state bus drivers, and control-signal timing. Front-panel control board plugs into one slot, features large paddle-handle address/data switches, and LED masks. Has 8 extra LEDs, program-controlled.

Power supply delivers up to 20 amperes at 8 volts, and 3 amps for ±16 volts. Heavy-guage aluminum cabinet has room for up to 22 cards. Memory expandable up to 65k bytes. Rack-mounted system is $20 more. Many mechanical options (fan, connectors, cables) available. Many hardware options, including memory (RAM, PROM, EPROM), multiprocessors and shared memory, I/O interfaces, disk drives, video display and keyboard terminals, printers, software including bootstrap louders, BASIC, floppy-disk operating system.
I-8080. Basic computer system. Kit/wired $599/$931.00
I-8080-1K. Basic system with 1k memory. Kit/wired $659/$999.00
EXP-22. 22-slot motherboard $52.00
RAM 4A-4. 4K RAM memory. Kit/wired $139/$279.00
PROM 4-4. 4K EPROM module. Kit/wired $399/$579.00
PIO 4-4. 4-port parallel I/O module. Kit/wired $156/$299.00
FDC. Floppy-disk drive, power supply $1095.00
CRT-2480A. CRT keyboard terminal $1595.00
PTR-30A. 30-cps printer $2895.00

INFINITE

UC 1800
For training or evaluation, uses RCA COSMAC 1802 MPU; 16-key hex keyboard; digital hex display of address, memory contents, I/O port; front-panel control of interrupt, DMA, I/O flag; 256-byte RAM expandable to 65k bytes of RAM or ROM internally; crystal-controlled clock; parallel and serial I/O data-line capability; special circuit saves memory content when unit is turned off $495.00
Option 001. Automatically recharged internal battery; allows program memory to operate up to four hours after power failure $25.00

INTERSIL

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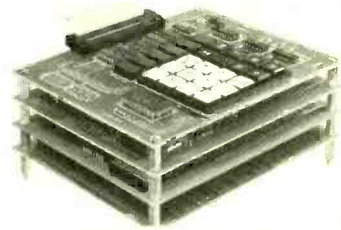
Tutorial microcomputer system using Intersil's IM6100 CMOS microprocessor and related CMOS devices. Recognizes DEC PDP-8/E instruction set. Multi-function alphanumeric keyboard, two four-digit LED displays, resident micro-interpreter, battery-powered. A non-volatile CMOS RAM permits extending memory up to twelve IM6518 1024 × 1024X1 CMOS RAMs. Optional power-strobed PROM module for up to 2k words of user program. Optional serial I/O for both RS-232 and TTY. Terminals provided for external 5 or 10-volt power supply. Assembled, tested, with batteries $281.00
RAM Module $145.00
PROM Module $74.65
I/O Module $81.70

M&R

ASTRAL 2000
Based on 6800 MPU. Comes with power supply, cabinet, front panel, motherboard (backplane), CPU board, 2k monitor ROM, 8k RAM board. Front panel plugs into backplane. Software-controlled real-time display with three sets f dual seven-segment LED displays read out time in hours/minutes/seconds or will output programs in hex. Interfaces provided: RS-232, 20-mA current loop. Provisions for cycle-stealing DMA. Options: video terminal board offers selectable line length of 64, 72 or 80 characters per line, provisions for optional light pen; EPROM board allows in-system program storage; I/O tape interface for audio cassette. Partially/fully assembled $995/$1250.00
8k RAM Board $245.00
VID-80. Video terminal board $189.95
8k EPROM Board (without EPROMs) $59.95
I/O Tape Interface $49.95
Software Package. Includes Astral BASIC $35.00

MARTIN RESEARCH

MIKE 3 (AT813)
Three-board system with 8080A MPU; crystal-controlled clock; 50-pin bus structure. Console board uses calculator-type keyboard and six



fully-decoded LED digits. Has PROM/RAM board with 512 bytes of RAM, monitor program in PROM; has capacity for 1k RAM and 2k PROM $395.00

MIKE 3 DEBUG (AT814)
Similar to AT813, but features diagnostic package that allows user to step through programs one instruction at a time using keyboard. After each instruction, user can inspect every data-register status, any desired memory location, and 8080 internal registers and flags. Can set breakpoint at any desired location, even in PROM or ROM. Also features 32-channel scope-display interface for external triggered-sweep scope, 16 channels at a time $495.00

MIKE 2
Three-board system similar to MIKE-3, uses 8008 MPU. Has 512 bytes of RAM monitor in PROM $359.00

MICROCOMPUTER ASSOCIATES

JOLT
Modular system, uses 6502 MPU; internal clock; can address 65k of memory directly; two index registers; 137 instructions; 11 "true" addressing modes; two interrupts; both single-step and address-halt capabilities. A 1k ROM debug/monitor self-adapts to any terminal speed from 10 to 30 cps (110 to 300 baud); allows display and alteration of CPU register and memory locations; also allows read, write, punch of hex-format data with write/punch BNPF format data for PROM programmers. Unlimited breakpoint capability; separate non-maskable interrupt entry. Includes 512 bytes of RAM; 64-byte interrupt vector RAM; on-board I/O for Teletype and RS-232, both full duplex; high-speed reader interface lines and 24 fully programmable bidirectional I/O lines plus two bit-serial I/O lines. Kit/assembled $159/$249.00
RAM Card. Static 4k bytes. Kit/assembled $199/$285.00
I/O Card. Two PIA ICs, 32 I/O lines, 4 interrupt lines, on-board decoding and standard TTL drive. Kit/assembled $96/$140.00
Power Supply. Kit/assembled $99/$145.00
Power Supply Booster. For memory expansion $25.00
Complete JOLT 4K System. Kit/assembled $339.50/$509.50
Powered JOLT 4K System. Kit/assembled $429.50/$644.50
Complete JOLT 8K System. Kit/assembled $499.50/$749.50
Powered JOLT 8K System. Kit/assembled $599.50/$889.50

Cabinets clockwise from top: CPU, Dual-cassette drive, Keyboard, 9" Monitor.

Meet The Digital Group

If you are seriously considering the purchase of a microcomputer system for personal or business use . . . or just beginning to feel the first twinges of interest in a fascinating hobby . . . the Digital Group is a company you should get acquainted with.

For many months now, we've been feverishly (and rather quietly) at work on our unique, high-quality product—a microcomputer system designed from the inside out to be the most comprehensive, easy-to-use and adaptable system you'll find anywhere. And our reputation has been getting around *fast*. In fact, you may have already heard a little something about us from a friend. We've found our own best salesmen are our many satisfied customers.

There's a good reason. Simply, the Digital Group has a lot to offer: state-of-the-art designs, a totally complete systems philosophy, unexcelled quality, reasonable software, affordable prices and the promise that our products will not become rapidly obsolete, even in this fast-moving, high-technology field.

The Advantages

Here are a few specific advantages of our product line:

- We offer interchangeable CPUs from different manufacturers (including the new "super chip"—the Z-80 from Zilog) which are interchangeable at the CPU card level. That way, your system won't become instantly obsolete with each new design breakthrough. The major portion of your investment in memory and I/O is protected.
- Digital Group systems are complete and fully featured, so there's no need to purchase bits and pieces from different manufacturers. We have everything you need, but almost any other equipment can be easily supported, too, thanks to the universal nature of our systems.
- Our systems are specifically designed to be easy to use. With our combination of TV, keyboard, and cassette recorder, you have a system that is quick, quiet, and inexpensive. To get going merely power on, load cassette and go!
- Design shortcuts have been avoided—all CPUs run at full maximum rated speed.
- All system components are available with our beautiful new custom cabinets. And every new product will maintain the same unmistakable Digital Group image.

The Features

Digital Group Systems—CPUs currently being delivered: Z-80 by Zilog 8080A/9080A 6800 6500 by MOS Technology

All are completely interchangeable at the CPU card level. Standard features with all systems:

- Video-based operating system
- Video/Cassette Interface Card
  512 character upper & lower case video interface
  100 character/second audio cassette interface
- CPU Card
  2K RAM, Direct Memory Access (DMA)
  Vectored Interrupts (up to 128)
  256 byte 1702A bootstrap loader
  All buffering, CPU dependencies, and housekeeping circuitry
- Input/Output Card
  Four 8-bit parallel input ports
  Four 8-bit parallel output ports
- Motherboard

Prices for standard systems including the above features start at \$475 for Z-80, \$425 for 8080 or 6800, \$375 for 6500.

More

Many options, peripherals, expansion capabilities and accessories are already available. They include rapid computer-controlled cassette drives for mass storage, memory, I/O, monitors, prom boards, multiple power supplies, prototyping cards and others. Software packages include BASICs, Assemblers, games, ham radio applications, software training cassettes, system packages and more (even biorhythm).

Sounds neat—now what?

Now that you know a little about who we are and what we're doing, we need to know more about you. In order for us to get more information to you, please take a few seconds and fill in our mailing list coupon. We think you'll be pleased with what you get back.

the digital group

P.O. Box 6528
Denver, Colorado 80206
(303) 777-7133

OK, I'd like to get to know you guys better.
Send me the whole package!

Name ______________________

Address ______________________

City/State/Zip ______________________

CIRCLE NO. 9 ON FREE INFORMATION CARD

MIKRA-D

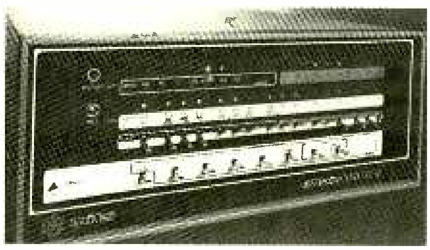
BASIC-8 SYSTEM

Consists of MTS-8 intelligent terminal plus BASIC software and special hardware. Fully Altair/MITS bus compatible, display format 80 characters by 24 lines; 1920-character capacity. Terminal consists of display CRT, 55-key keyboard with 64-character ASCII-compatible set, housing, CRT interface for 8080, power supply. System includes 8k bytes of RAM for BASIC-8, 12k bytes of RAM for Extended BASIC-8; built-in audio-cassette interface (two cassette recorders may be used to give read/write capability); memory expandable to 64k bytes (32k internally, 32k externally). BASIC-8 uses a calculator chip as a floating-point processor for high speed in calculation-oriented programs and to provide complete set of trig functions; uses scientific notation with 10 digits of precision and nearly 200 orders of magnitude of the exponent. Size 22"D × 17"W × 14"H, weight 35 pounds. BASIC-8, kit/assembled .... $1695/$1995.00
Extended BASIC-8 Option $295.00
Numeric Keypad $19.50

MITS

Altair 8800b

Second-generation Altair 8800. New version compatible with Altair 8800 hardware and software. Features include redesigned front panel, new CPU board, power supply, and 18-slot motherboard. New CPU board includes 8224 clock generator, 8216 bus drivers; clock-pulse widths/phasing/frequency are crystal-controlled. New front panel with multi-color graphics, longer and flat toggle switches. Five new functions in front-panel PROM: Display Accumulator (displays contents of accumulator), Load Accumulator (loads contents of 8 data switches into accumulator), Output Accumulator (outputs contents of accumulator to I/O device addressed by



upper 8 address switches), Input Accumulator (inputs to the accumulator from the I/O device), and Slow (executes program at about 5 Hz for debugging). Front-panel/CPU interface via two 34-conductor ribbon cables connected to new front-panel interface board. Heavy-duty power supply has +8 volts at 18 amperes, +18V/2A, −18V/2A .... Kit $840.00
Altair 8800b assembled $1100.00
88-1NMCS. 1k static memory, kit/assembled .... $115/$160.00
88-4MCS. 4k static memory, kit/assembled .... $167/$325.00
88-16MCS. 16k static memory, kit/assembled .... $765/$945.00
88-4MCD. 4k dynamic memory, kit/assembled .... $195/$295.00
88-4PIO. Parallel I/O board with one port, kit/assembled .... $105/$130.00
88-PP. Extra port for 4PIO—add up to 3, kit/assembled .... $38/$55.00
88-2SIO. Serial I/O board with one port, kit/assembled .... $148/$180.00
88-SP. Extra port for 2SIO, kit/assembled .... $38/$50.00
88-ACR. Audio cassette record interface, kit/assembled .... $138/$195.00
88-VI. Vectored interrupt, kit/assembled .... $138/$185.00
88-RTC. Real-time clock, kit/assembled .... $53/$84.00
88-PMC. PROM memory card (holds 2k bytes), kit/assembled .... $85/$125.00
PROM. PROM, 256 × 8 bytes, for 88-PMC, kit/assembled .... $30/$42.00

Altair 680b

Second-generation Altair 680. New version features a 256-byte PROM monitor so that paper tape can be loaded immediately, and an Asynchronous Communication Interface Adapter (ACIA) that allows the machine to transmit and receive a character at a time rather than one bit.

The MPU is a Motorola M6800, an 8-bit parallel processor with 16-bit address bus, can address 65k bytes of memory, has 72 basic instructions. Measures 11" wide, 11" deep, 5" high. Comes with power supply, front-panel control board, CPU board with 1k RAM, provisions for 768 bytes of additional PROM or ROM, and built-in I/O that can be configured for RS-232 or Teletype. A five-level Baudot interface option is available, as is a turnkey model without the front-panel switches or lights. Three additional circuit boards can be plugged inside the case. .... Kit $466.00
Altair 680b assembled $625.00
Altair 680b with Baudot option, kit/assembled .... $508/$667.00
Altair 680T. Turnkey model, kit/assembled .... $395/$550.00
680-BSM. 16k static memory, kit/assembled .... $685/$865.00

MOS TECHNOLOGY

KIM-1

Based on 6502 MPU (13 addressing modes); 23-key keyboard (hex and control keys) plus single-step switch; 6-digit segmented LED display; two 6530 arrays include 2k 8-bit ROM bytes storing the monitor and operating programs, plus 128 RAM bytes; 1k bytes of static RAM (expandable to 65k); interface and control for audio cassette and TTY; crystal-controlled clock. Requires +5 V at 1.2 A, +12 V at 0.1 A. Documentation includes user manual, hardware manual, programming manual, programmers reference card $245.00
KIM-2. 4k static RAM board $179.00
KIM-3. 8k static RAM board $298.00

NATIONAL SEMICONDUCTOR

SC/MP

Uses SC/MP MPU: 46 instructions, single-byte and double-byte operation, software-controlled interrupts, built-in serial I/O ports, bidirectional 8-bit tri-state parallel data port, latched 12-bit tri-state address port. Includes 512-byte (8-bit) ROM with Kitbug monitor and debug program; 256-byte RAM; 8-bit data buffer; timing crystal; TTY 20-mA current-loop interface; 72-pin edge connector .... Kit $99.00

OSI

400 SYSTEM

Based on 6502 MPU. CPU board comes with monitor in PROM, 1k RAM, 6850 ACIA, all parts to interface with TTY (less power supply) . $139.00
413A. Same using 6800 MPU $159.00
410Z. Same using Z-80 MPU, unpopulated $29.00
420. Memory board, unpopulated $29.00
430. Super I/O board, A/D, D/A, unpopulated $29.00
440. Video graphics board, unpopulated $29.00
480. Backplane board $39.00
460. PDP-8 emulator board, unpopulated $29.00

300 TRAINER

Basic training package, featuring 6502 MPU; 128 words of RAM; input port and output latch; laboratory manual $109.00
Battery Eliminator $16.00

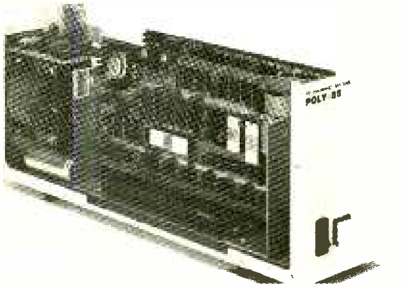
315 PLAN
For $129 you get a 300 Computer Trainer (see above), including 20-experiment lab manual, spec sheets on 6502, Motorola book "Introduction to Microprocessors." Return the 315 to OSI and receive a 400 Superboard, 430 Super I/O board, 440 Super video board, plus TV typewriter and audio-cassette monitor software (total value $110) at no extra charge $129.00

PCM

PCM-12
Software-compatible with DEC PDP-8 family. The CPU module includes an IM6100 MPU, crystal-controlled baud-rate generator, line drivers, interfaces. Front panel contains one PC board with the electronics, control,and indicators to implement the PDP-8 style, 27 toggle switches, 28 LEDs. Contains built-in binary bootstrap loader; DECrement ADDress function added. Backplane bus has positions for 15 plug-in cards in 80-pin connectors. Bus has 79 parallel lines, one serial interrupt-priority line. Basic memory element is a 4k static module; system will accomodate eight modules for 32k capacity; 1k words of RAM provided. heavy-duty regulated power supply can accomodate 16k memory and/or three or four peripheral interfaces. Cabinet is 19"D × 17"W × 7"H, has built-in card cage for 15 modules. Kit/assembled ....$799/$1224.00
12020. 4k static memory. Kit/assembled ....$245/$355.00
12060. TTY/CRT interface. Kit/assembled ....$97/$177.00
12080. Audio cassette interface. Kit/assembled ....$117/$197.00
12210. 4k CMOS memory. Kit/assembled ....$645/$775.00
12310. Parallel I/O interface. Kit/assembled ....$152/$242.00

POLYMORPHIC

POLY-88
CPU board includes 8080A MPU, 500 bytes of static RAM, 1k bytes of monitor ROM, room for 2k more ROM, 8-level priority vectored interrupt, real-time clock, Altair/Imsai-compatible bus. Chassis and backplane/motherboard holds five cards. Video-terminal interface generates 16 lines of 32 or 64 characters (depending on option) on video monitor or modified TV set. Cassette and serial interfaces are mini-cards; up to



two mini-cards plug into CPU board. Prototyping board includes 25 wirewrap terminals. Basic system includes CPU board, video-terminal interface card, power supply, backplane, cabinet. Kit/assembled ....$595/$795.00
CPU/8. CPU board. Kit/assembled .$215/$275.00
VTI/32. Video terminal interface, 32-character ....Kit $185.00
VTI/64. Same except 64-character. Kit/assembled ....$210/$280.00
SER/8. Serial interface. Kit/assembled $45/$60.00
CAS/2. Cassette interface. Kit/assembled ....$45/$65.00
ADA/1. Analog interface, 1-channel, unipolar Kit $145.00
ADA/2. Analog interface, 2-channel, unipolar Kit ....$185 .00
ADA/1B. Analog interface, 1-channel, bipolar Kit $155.00
ADA/2B. Analog interface, 2-channel, bipolar. Kit/assembled ....$195/$245.00
PROTO/1. Prototyping board $55.00

PRONETICS

PS-810
Computer on a PC card uses F8 MPU: 76 instructions, 2-μs execution cycle time. 64 RAM scratchpad registers on the MPU, indirect addressing modes, two external interrupt inputs, two programmable timers. Includes F8, 1k bytes of RAM, 1k-byte resident monitor-debug, 32 bidirectional latched I/O ports, RS-232 and 20-mA current-loop interfaces $179.00

SOUTHWEST TECH. PRODUCTS

6800
Based on Motorola 6800 MPU and its family of support devices. Chassis; motherboard; memory card with 2k bytes of 8-bit static RAM; serial 20-mA TTY/RS-232 interface card; power supply; crystal-controlled clock for baud rates from 110 to 1200; 6820 peripheral interface adapter (PIA); ROM-stored mini-operating system features tape load/dump routine, memory and register examine and/or change function, and execute user's program command. Documentation package includes Motorola 6800 Programming Manual plus SWTP 200-page notebook, diagnostic and game programs, and application to join

Motorola 6800 User Group. All boards are "plug in" type and contain on-board voltage regulators. Any combination of up to 7 serial/parallel interface boards may be plugged in. ....Kit $395.00
MP-MX. Memory expansion. from 2k to 4k. $45.00
MP-L. General-purpose parallel interface $35.00
MP-S. General-purpose serial interface .$35.00

SPHERE

SYSTEM 310
Consists of CPU with 6800. 1k PROM, 4k dynamic RAM, 8 I/O lines, 2 interrupt lines, RS-232/20-mA serial interface, real-time clock, power-on reset. The CRT module displays 16 lines of 32 characters with a 5 × 7 matrix; 512-character memory; up to 8 modules may be used in a single system.

Keyboard is 63-character ASCII with mechanical shift lock. Metal base, low-profile cover, power supply. Assembled systems come with 9" CRT installed; kits do not include one. Kit/assembled .... $1019/$1590.00

SYSTEM 320
CPU, CRT module, keyboard, power supply. Includes SIM module for serial interface with several configurations: dual cassette, cassette and serial, cassette and modem, modem alone, serial alone, single cassette. Metal base includes desktop chassis with card rack. Kit/assembled $1190/$1769.00

SYSTEM 330
Same as System 320, with 16k more memory (total 20k). BASIC on cassette tape. Kit/assembled .... $1925/$2579.00

SYSTEM 340
Same as System 310, plus line printer with 80 columns, 100 characters per second; dual floppy-disk memory (256k bytes on each disk); disk operating system; BASIC; 16k more memory (20k total), printer interface, floppy-disk interface. Kit/assembled .... $6100/$7995.00

WAVE MATE

JUPITER II
The CPU-125 module contains the 6800 MPU plus support electronics; clock is 1 μs, but may vary depending on device being addressed; seven vectored interrupt levels; DMA; 30-μs refresh clock; automatic reset on power-up. The debugger and monitor is on up to three 1024-byte EPROMs (priced separately), includes 16-line address breakpoint comparator, and logic for executing any single instruction at a time. Front panel has 3 operation switches, 4-digit hex display, 2 status lights. No wiring required with backplane motherboard.
CPU-125. CPU module. Kit/assembled .... $179.95/$280.00
SMC-125. System module cage. Kit/assembled .... $189.95/$260.00
CPS-125. Power supply. Kit/assembled .... $149.95/$180.00
CFP-125. Front panel. Kit/assembled .... $89.95/$130.00
SDM-125. Software debugger and monitor. Kit/assembled .... $109.95/$205.00
SDM Control EPROMs. 2k for serial devices $200.00
DMM-125-4. 4k dynamic memory. Kit/assembled .... $219.95/$325.00
DMM-125-8. 8k dynamic memory. Kit/assembled .... $329.95/$435.00
SDI-125. Serial interface. Kit/assembled .... $99.95/$145.00
PDI-125. Parallel interface. Kit/assembled .... $84.95/$130.00
BSM-125. Basic system, with SMC, CPS, CPU, CFP, SDM, EXC-125 extension card. Kit/assembled .... $699.95/$995.00

JUPITER IIC
Similar to Jupiter II; includes 6800 MPU; 8k dynamic RAM; 3k ROM; 1k dual-port static RAM; keyboard with 128-character ASCII set; dual audio-cassette interface with start/stop motor control, 300, 600 or 1200 baud rate, and error correction. Video-terminal interface features upper/lower case, Greek characters, dot graphics; 64 characters by 16 lines (32 lines optional); 7 × 12 dot format; graphics use 128-dot horizontal by 48-dot vertical (96-dot option). Monitor/debugger includes interrupt system and I/O monitor call instructions. Programmable macro editor and expanded assembled included, along with proposed ANSI standard BASIC. Assembled unit includes two audio-cassette units and 12" B&W TV set. Kit/assembled .... $2200/$3200.00

COMPUTER PERIPHERALS

ELECTRONIC PRODUCT ASSOC.

EPA PRINTER
Prints 100 characters per second bi-directionally; 40 columns; dot-matrix. Complete with drive electronics, interface for 6800 microcomputer, power supply, hardwood and plastic cabinet $450.00

HAL

DS-3000 VIDEO DISPLAY TERMINAL
Keyboard send/receive (KSR) and read-only (RO) versions. Choice of 5-level Baudot or 8-level ASCII data. Uses 8080A for full cursor positioning and editing capability (KSR), display 1152 characters in 16 lines of 72. Has RS-232 and current-loop ports; Baudot from 45 baud (60 wpm) to 100 baud (132 wpm), ASCII from 110 to 1200 baud. Has 6.1-MHz bandwidth, 1-volt EIA video output. CRT with 11" diagonal, 5 × 7 dot matrix. Keyboard: 52-key ASCII, shift, control,

n-rollover, Quick Brown Fox test message, programmable character string to 255 characters. Bell tone provided. Scrolls from top down, full cursor control, word wrap-around.
DS-3000 KSR Baudot $1275.00
DS-3000 KSR ASCII/Baudot $1475.00
DS-3000 RO Baudot $975.00
DS-3000 RO ASCII/Baudot $1075.00

DS-4000 VIDEO DISPLAY TERMINAL
Serial ASCII (8-level) code. Has RS-232 and current-loop ports; KSR version 110 to 1200 baud, 150 baud available on RO model. Word format is ASCII 10 or 11-unit code, parity odd, even or mark. Video 1-volt, neg. sync, 6.1-MHz bandwidth, timing is crystal-controlled. Display is 1280 characters in 5 × 7 dot format, 16 lines by 80 characters per line, 11" CRT. Has 8080A processor for full cursor control and text editing. Transmission modes are character by character, line, block, all switchable. Printer interface is RS-232 level. Bell tone is provided. Keyboard is 52-key standard ASCII with shift, control, n-rollover.

DS-4000 KSR (ASCII) $1275.00
DS-4000 RO (ASCII) $975.00

RVD-2110 MONITOR/TV
Solid-state, 9"-diagonal screen, BNC connector for 75-ohm video input. As TV, operates on all channels $150.00

RVD-910 VIDEO MONITOR
Solid-state, 9"-diagonal screen. Front panel includes brightness, focus, on/off, contrast, vertical hold/size, horizontal size/reduce size. Rear apron has horizontal size, two video inputs, int/ext sync, two ext sync inputs, 75-ohm termination. Bandwidth to 15 MHz. Linearity better than 2% overall. Resolution greater than 1000 lines in central 80% of screen $150.00

RVD-1005 VIDEO DISPLAY UNIT
Provides electronic display of Baudot 5-level code on external video monitor. Has RS-232 and current-loop ports; TTL compatible, 45 baud (60 wpm) to 74 baud (100 wpm), optional to 400 baud. Video output is RS-170 standard, interlaced, crystal-controlled, 1-volt, neg sync, 75-ohm output, 3.1-MHz bandwidth. Display is 1000 characters on 5 × 7 dot matrix, 25 lines at 40 characters per line; 26 alphabetic, 10 numeric, 16 punctuation characters displayed $375.00
RVD-1005A ASCII version $375.00
RVD-1005A current-loop option ... $25.00
RVD-1005A with keyboard $475.00

INFO-TECH

66C TERMINAL KEYBOARD
Keyboard with 53 keys, ASR33 format, generates 102 ASCII characters; video display 32 characters on 16 lines with 5×7 dot matrix, 64-character repertoire, scrolling. 14"W × 12"D × 3½"H $400.00
66d. Same with 64 characters per line . $475.00

INTELLIGENT SYSTEMS

INTECOLOR 8001 COLOR TERMINAL
Intelligent terminal, full color display on 19" diagional CRT screen; 80 characters per line, 25 lines per page, 64 ASCII characters, 5 × 7 dot matrix; white blinking overscore and underscore cursor, non-destructive; eight color levels (red, green, blue, magenta, cyan, yellow, white, black); seven

bit-transfer rates, from 100 to 9600 baud, keyboard selectable. MPU is 8080; 4096 bytes of EPROM (not included) in 1024-byte increments; 4096 bytes of RAM for screen refresh; RS-232C I/O; keyboard has color-coded keys. Editing capability includes tab, erase page, erase line, blink, color selection, cursor up/down/right/left/home, cursor XY positioning, page-mode operation, transmit. Many options available. Basic terminal $1395.00
Option 16. 80-character/48-line $250.00
Option 17. 64 special characters $66.00
Option 01. Limited graphics mode .. $33.00
Option 02. Expanded graphics mode $33.00
Option 09. Additional 4k RAM $90.00
Option 25. Additional 8k RAM card ... $270.00
Option 05. Insert/delete editing $20.00
Option 15. Page roll-up $33.00
Option 34. 8001 OS and debug ROM . $135.00
Option 40. Text editor and assembler . $135.00
Option 42. BASIC ROM $338.00

LEAR SIEGLER

ADM-3 VIDEO DISPLAY TERMINAL
Kit version of $1280 commercial ADM-3 "Dumb Terminal." Displays 1920 characters at 80 per line, 24 lines, on a 12-inch (diagonal) screen, with a standard set of 64 ASCII characters, upper case, 5 × 7 dot matrix. The CRT section is premounted in the cabinet; the keyboard control and power supply are premounted in the display electronics section. Can be connected to a minicomputer or a microcomputer; with an acoustic coupler the user can time-share with a remote computer. Will directly replace a TTY; has a switch-selectable 20-mA current-loop interface and RS-232C interface. An auxiliary RS-232C port is optional for interface with a tape recorder, printer, etc. Speeds range from 75 to 19,200 baud; word format can be chosen from 9-, 10-, or 11-bit words with odd, even or no parity, plus one or two stop bits. Size 19"D × 15.5"W × 12.5"H, weight 25 pounds .... Kit $875.00

M&R

PENNYWHISTLE 103 MODEM
May be used as acoustic coupler (with telephone handset) or wired directly into the telephone via a direct-access adapter. Operates in both half-duplex (unidirectional) or full-duplex (bidirec-

tional) modes. Records data to and from audio tape; communicates directly with another modem and terminal; can record data from a remote source over the phone line and enter the data into the memory of a computer. Kit $109.95

MICRO PERIPHERALS

MP-40 PRINTER
Impact printer for microsystems; 5 × 7 dot matrix; 75 lines per minute, 40 columns. Software control permits printing at standard width (12 characters per inch) or extended width (6 per inch); 64-character ASCII set; 6 lines per inch vertically. Paper guides adjustable for paper widths from 2¾" to 4". A TTL 8-bit parallel "handshake" interface is compatible with most parallel I/O ports, provides for optional line-termination resistors when long cables used. Self-test feature in interface design aids in system debug operations. Requires 115 volts a.c. Size 13"W × 13"D × 6.5"H, weight 6 pounds $425.00

MIKRA-D

VT-1920 VIDEO TERMINAL
Consists of display CRT, 55-key keyboard with 64-character ASCII-compatible set, housing, CRT interface for 8080 and power supply. Display format 80 characters by 24 lines; 1920-character capacity. Can be updated to MTS-8 terminal or BASIC-8 system at any time. Not a free-standing "TV typewriter," must be used with a microprocessor. Size 22"D × 17"W × 14"H, weight 35 pounds. Kit/assembled .... $695/$895.00
Numeric Keypad $20.00
Upper/Lower-Case Option $50.00
MTS-8A. Update to MTS-8. Kit/assembled .... $535/$635.00

MTS-8 INTELLIGENT TERMINAL
Consists of VT-1920 video terminal plus 8080 microprocessor, 1k bytes of ROM, 4k bytes of RAM, cassette program loader, assembler, editor and debug software, built-in cassette/serial interface. Can be updated to BASIC-8 system at any time with add-on option. Kit/assembled .... $1195/$1495.00
BASIC-8A. Update to BASIC-8. Kit/assembled .... $535/$635.00

MITS

ALTAIR FLOPPY DISK SYSTEM
Nonvolatile fast-access memory, stores over 300,000 bytes per disk, 4k bits on each of 77 tracks. Average read/write time 400 ms; data transfer rate 250k bits per second. Disc controller consists of two PC boards that fit the Altair/Imsai, connects to the disk drive via a 37-pin connector. The 88-DCDD consists of the disk controller and one disk drive. Kit/assembled . . . $1480/$1980.00
88-DISC. Additional disk drive, in cabinet . . . . $1180/$1600.00

ALTAIR 110 LINE PRINTER
Desktop line printer, produces 80 columns of 5 × 7 dot-matrix characters at 100 cps (70 lines per minute). Control electronics are on a PC card that fits the Altair/Imsai bus. Kit/assembled . . . . $1950/$2125.00
Same with pin-feed option. Kit/assembled . . . . $2200/$2375.00

COMTER II TERMINAL
Displays one line of 32 dot-matrix characters, upper case only. Features audio cassette interface, RS-232 data interface, 256-character memory (not expandable) ASCII keyboard, cursor control for moving data in and out of display from memory, auto transmit for on-line transmitting data from memory or for editing programs. No interface required for use with Altair 680b; 88-SIO required for use with Altair 8800b. Display case is connected by cable to separate keyboard case. Display: 14"W × 11½"D × 5"H; keyboard 14"W × 7½"D × 2½"H. Kit/assembled . . . . $890/$1050.00

MITS COMTER 256 TERMINAL
Same as Comter II except without audio cassette interface but with acoustic coupler; memory 256 characters expandable to 1024. Kit/assembled . . . . $850/$1000.00

NATIONAL MULTIPLEX

CC-7A DIGITAL DATA RECORDER
Digital recorder for computer or Teletype use (no voice capability), up to 4800 baud. Recording mode is NRZ tape saturation. Two channels,

clock and data; or 2 channels providing 4 tracks for bi-phase. Accepts TTY, TTL or RS-232 inputs. Two outputs, either TTY, RS-232 or TTL. Erases while recording one track at a time. Interfaces with any UART/ACIA. Loads 8k memory in 17 seconds. Motor speed adjustable, 2000-2500 rpm. Speed regulation 0.5% or better. Tape speeds available (by pulley changes): 2", 3" or 4" per second. Includes prerecorded 8080 software used in factory test $169.95

OLIVER

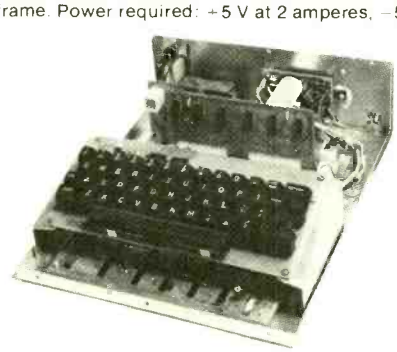
OP-80A PAPER TAPE READER
High-speed optical tape reading, no moving parts, reads punch paper tape up to 5000 cps. Includes optical sensor array, high-speed data buffers, handshake logic for interfacing with any microprocessor parallel I/O port. Kit/assembled . . . . $74.50/$95.00

OSI

470 FLOPPY DISK SYSTEM
Floppy-disk drive, completely assembled including read/write electronics; interface board, and simple sector-per-track operating system for 6502 or 6800-based system. Minimum storage capacity 256k bytes; average access time 84 ms $649.00

SOUTHWEST TECH. PRODUCTS

CT-1024 ALPHANUMERIC VIDEO TERMINAL
Alphanumeric terminal (also known as TV Typewriter II); 16 lines of 32 characters per line; 2 pages; 64-character ASCII set (upper case only); static 1024-character RAM memory; 512 characters stored, 512 displayed. Hardware and software carriage-return and line-feed. Cursor control for home, erase to end-of-line, end-of-frame. Power required: +5 V at 2 amperes, −5 V



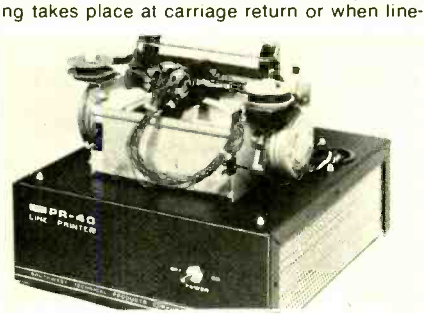
at 20 mA, −12 V at 20 mA, 6 V ac at 20 mA. Dimensions with plug-in boards, 12"D × 9½"W × 4½"H. Cabinet, keyboard, video monitor not supplied . . . . Kit $175.00
KBD-5. ASCII keyboard and encoder, 56 keys . . . . Kit $49.95
CT-P. Power supply . . . . Kit $15.50
CT-S. Serial interface (110 baud) . . . . Kit $39.95

CT-SO. Baud-rate extension (150, 300, 600, 1200 baud) .... Kit $14.75
CT-CA. Computer-controlled cursor . Kit $15.50
CT-L. Parallel interface .... Kit $29.95
CT-E. Screen-read board, transmits screen data to computer .... Kit $17.50
Package: CT-1024, KBD-5, CT-P, CT-S, CT-CA .... Kit $275.00

GT-6144 GRAPHICS TERMINAL
Cell array is 64 wide by 96 high; each cell addressable by computer; programming allows fixed or moving images. Data can be loaded in less than 2 µs. Image reversal for white on black or reverse; standard 525-line format; 6144-bit static RAM. Operates with any computer whose parallel interface outputs an 8-bit word and data-ready strobe; this includes any 8080 or 6800 machine. Does not include chassis or video monitor. Programming allows display of graphics, CT-1024 alphanumerics, or combination of both .... Kit $98.50
CT-P. Power supply .... Kit $15.50
MP-L. Interface for SWTP 6800 computer .... Kit $35.00

AC-30 AUDIO CASSETTE INTERFACE
Interfaces RS-232 with terminals or computer systems, using UART and accessible 16x 300-baud clocks. In addition to manual cassette-recorder controls, the automatic record, play, and even motor controls may be picked off adjoining terminal's control-character decoder. Provides independent control for two separate recorders (not included with kit). One recorder can be read while other is generating updated data. Control-panel switches select correct audio/motor controls for each recorder; LED indicators display record/read status and data flow. Local/remote switch permits using recorder from terminal without computer. Size 12¾"W × 12½"D × 3"H. Kansas City standard (1200/2400 Hz) at 300 baud .... Kit $79.50

PR-40 ALPHANUMERIC PRINTER
Alphanumeric printer with 64 upper-case characters, 40 characters per line, 75 lines per minute. Uses standard 3⅞" adding-machine paper. Has internal 40-character line-buffer memory; printing takes place at carriage return or when line-



buffer memory is filled; 5 × 7 dot-matrix impact printing. Accepts data up to one character per microsecond or slower; 7 parallel data lines are TTL-compatible and enabled by data-ready signal. Used with any computer having 8-bit parallel interface, including 8080 and 6800 machines. Internal power supply. Size 10½"D × 9⅝"W × 8¾"H .... Kit $250.00
PR-4L. Extra ribbon $5.00
MP-L. Interface for SWTP 6800 computer . $35.00

WINTEK

B-R-B VIDEO TERMINAL
Character set is standard 64-character ASCII (upper case) plus CR, LF, BS and bell. Parity odd, even, marking or spacing; selectable. Logic levels: RS-232 (20-mA optional); transmission rate is serial, asynchronous, half/full duplex selectable, standard baud rates from 110 to 9600, one or two stop-bits selectable. Characters are 5 × 7 dot matrix; screen size is 9" diagonal; 16 rows of 80 characters; scrolling; cursor is solid, non-blinking. Keyboard cabinet size is 13"W × 10"D × 3½"H; monitor cabinet is 13"H × 10"W × 10"D $875.00
B-R-B Board. Assembled $495.00

COMPUTER MODULE BOARDS

CROMEMCO

BYTESAVER MEMORY BOARD
8k PROM board uses 2704 and 2708 ultraviolet-erasable PROMs on an Altair-8800/Imsai-8080 bus compatible board. Stores programs up to 8k, including 8k BASIC; provides independence from power turnoff; takes 500 mA from 8-volt line; no keyboard needed with special 2704 PROM that transfers contents of RAM into Bytesaver. 8KBS-K kit/8KBS-W assembled ... $195/$295.00

TV DAZZLER
Computer/TV interface to color-TV receiver, Altair-8800/Imsai-8080 bus-compatible board: alphanumerics and graphics; DMA; 2k memory produces 128 × 128-element picture; 512 bytes provide a 32 × 32 picture; output is video; all colors can be controlled. Software: three full-color programs on punched paper tape, with documentation; Dazzle-Writer provides alphanumeric displays in color. TV Dazzler, kit-/assembled .... $215/$350.00
Life software $15.00
Kaleidoscope software $15.00
Dazzle-Writer software $15.00

D+7A INTERFACE FOR D/A & A/D
Multichannel converter has 7 channels of 8-bit analog-to-digital conversion for input to computer; 7 channels of digital-to-analog conversion

for computer output; one 8-bit parallel I/O port. Plugs into Altair/Imsai data bus. Applications include interfacing analog controls such as potentiometers or joysticks to computers or using a computer as a music synthesizer $245.00

DIGITAL GROUP

Z-80 CPU CARD
Based on Zilog Z-80 MPU, compatible with 8080A instruction set, includes 80 new instructions for total of 158; 16-bit arithmetic; 3 interrupt modes; built-in automatic dynamic-memory refresh; 11 addressing modes; 22 registers (16 general-purpose); 1, 4, 8 and 16-bit operations. Z-80 CPU card includes 2k bytes static RAM, 256 bytes EPROM bootstrap loader, 2 DMA channels, hardware interrupt controller. Interchangeable with other CPU cards in Digital Group system. Kit/assembled .... $295/$395.00

DUTRONICS

8KLST 8K MEMORY
8k memory for Altair-8800/Imsai-8080 bus; uses 500-ns static n-channel RAM ICs; power requirement is less than 225 mA per 1k words, worst case is 250 mA per 1k words; low-profile sockets included $285.00
4KLST. 4k memory, expandable to 8k with 4 KXST $159.00
4KXST. 4k expansion kit to 4KLST ... $139.00
50/50A. 100-pin connector $9.50

ELECTRONIC CONTROL TECH.

8KM STATIC MEMORY BOARD
Has 8k 8-bit words of static RAM memory with 215-ns access time. Plug-compatible with Altair 8800 and Imsai 8080, draws 150 mA (typically) from the 5-V supply. Static memory, requires no refresh or wait states; can be powered by standby batteries to retain data during power interruptions or for extended periods of time . Kit $350.00

NOTICE TO READERS

We consider it a valuable service to our readers to continue, as we have in previous editions of this guide, to print the price set by the manufacturer or distributor for each item described as available at presstime. However, almost all manufacturers and distributors provide that prices are subject to change without notice.

We would like to call our readers attention to the fact that during recent years the Federal Trade Commission of the U.S. Government has conducted investigations of the practices of certain industries, in fixing and advertising list prices. It is the position of the Federal Trade Commission that it is deceptive to the public, and against the law, for list prices of any product to be specified or advertised in a trade area, if the majority of sales of that product in that trade area are made at less than the list prices.

It is obvious that our publication cannot quote the sales price applicable to each trading area in the United States. Accordingly, prices are listed as furnished to us by the manufacturer or distributor. It may be possible to purchase some items in your trading area at a price that differs from the price that is reported in this edition.

The Publisher

GODBOUT

ECONORAM 4K MEMORY BOARD
Altair/Imsai-compatible 4k RAM board; current drain 0.75 A max; 0.6 A typical; buffers on address lines, data lines, outputs; sockets for all ICs . Kit $99.95

MIKRA-D

MD-2046-4 STATIC RAM CARD
Altair/Imsai plug-in compatible, 4k on a 16k board, permits 16k total in one motherboard slot $175.00
MD-2046-8. Same with 8k $315.00
MD-2046-12. Same with 12k $455.00
MD-2046-16. Same with 16k $595.00
Expansion Kit $140.00

NATIONAL MULTIPLEX

2SIO(R) I/O BOARD WITH MONITOR
Plug-in for Altair/Imsai computers; compatible with any 8080 system. I/O board contains all bootstraps, loads, dumps, and edits in a 512-byte ROM Monitor. A UART interfaces with a terminal; a USART interfaces with one or two cassette recorders. Accepts any of 8 commands to: load octal from any address, load hex from any address, load BASIC, examine an address and correct the data, dump in hex, save on cassette (with parity check), load from cassette (with parity check), go to an address and run. Automatic cassette on/off. Runs at two different baud rates. Kit/assembled .... $140/$170.00

PROCESSOR TECHNOLOGY

VDM-1 VIDEO DISPLAY MODULE
Altair-8800/Imsai 8080 bus compatible; 16 lines of 64 characters; upper/lower case; black on white or white on black; 1024 bytes of on-card RAM memory. Various screen-blanking modes available: during processor access cycle; from vertical sync to beginning of text; from CR to end of line; from VT character to bottom of display. Solid video inversion cursor can be blinked at 0.5-second intervals. Output is EIA composite video 1-V p/p, 75 ohms, 6.7-MHz bandwidth. Display can be scrolled up or down. Any Ik page may be selected for memory address if two low-order bits are 00. Multiple programmable cursors are built in, and all 1024 can be displayed at one time or begin anywhere on screen, so video games are possible. Text-editing software and games packages available. Kit/wired .... $199/$245.00

8KRA 8K STATIC MEMORY MODULE
Static RAMs; fully buffered address and data lines; noise-immunity circuits; dual in-line switch for address selection; battery back-up option; low-profile IC sockets; 520-ns cycle time; fits Altair/Imsai bus. Kit/wired .... $295/$359.00
4KRA. 4k static memory module. Kit-/wired .... $139/$195.00

3P · S INPUT/OUTPUT MODULE
Altair/Imsai-compatible board. Two 8-bit parallel ports, standard TTL level; one Teletype 20-mA port; four RS-232C ports; one peripheral 50-mA current driver for paper-tape-reader control or cassette-recorder control. Baud-rate control for 35 to 9600 baud and/or EIA control outputs. Can be used with 1.5 stop bits (older Teletypes). Low-profile IC sockets. Kit/wired .. $135/$175.00

2KRO MEMORY MODULE
Accepts up to 8 EPROMs (1720A or 5203) to provide 2048 8-bit words of non-volatile storage. Static operating mode; access and cycle times depend on EPROM used; will work from 30 to 2500 ns; Altair/Imsai compatible; wait-state selection; low-profile sockets. Kit/wired .... $65/$89.00

ALS-8 FIRMWARE MODULE
Assembly-language operating system enables "turn of the switch" operation. You can write, edit, assemble, debug and run programs. Up to 20 custom commands. Requires 2k RAM for symbol tables and system global area. Six source programs can be stored and called, edited, assembled, or simulated; any selected input device can be used; files can be appended, moved, renumbered, taken apart, or linked together, and crashed files can be restored. Assembler includes labels, comments, expressions, relative symbolic addressing, and error messages. Can handle many different I/O configurations. Can be used with TXT-2 (below) $325.00

TXT-2 TEXT EDITING FIRMWARE
User can insert, delete, move single characters, entire lines, or portions of lines. Text files scanned up to 1000 lines per minute when used with VDM-1 .... $95.00

SCIENTIFIC RESEARCH INSTR.

REAL-TIME MULTIPLEXER MODULE
Interfaces 16 real-time sensors to computer via single A/D board; module comes with two channels. Unity gain; 10 volts maximum per channel; 50-µs switching time; 10-megohm impedance; less than 50-ohm output impedance . Kit $79.50
Extra input channels (each) ...... kit $14.95
Connector $6.50
80-Pin PC Board for Altair 8800 ...... $21.60
Connector for 80-pin PC board $6.95

REAL-TIME A/D CONVERTER
Uses tracking A/D conversion. Resolution is 10 bits (binary); linearity ½ LSB; input resolution (volts) is maximum output peak-to-peak/256; zero-error scale is 1/10 LSB maximum; SVRR is 0.01% maximum; maximum slew rate (sine) is 0.14 V/µs. Maximum tracking frequency is 4.5 kHz; full scale output (adjustable) 1 to 10 volts; output is 8-bit parallel data .... Kit $89.95

REAL-TIME INPUT MODULE
Used with A/D converter, and a wide variety of sensors. Includes one amplifier, can be expanded to eight. Logarithmic compression for up to 7 octaves. Input sensitivity greater than 10 µV; frequency response, dc to 30 kHz; output voltage, ±5 volts; adjustable gain, −30 to 80 dB; dc drift, less than 4 mV/°C; SVRR, 80 dB ..... Kit $34.95
Sensor amplifiers (each) $16.95
Log compression amplifier (optional) . $5.25

TARBELL

CASSETTE INTERFACE
For Altair/Imsai; speeds up to 540 bytes per second (220 bits per inch), 187 bps for ANSI standard 800 bpi, 30 bps for Kansas City standard. Phase-encoded, self-clocking. Works with most audio cassette units; may be adapted to automatic digital cassette units; will also work with reel-to-reel tape recorders. Tape should be low-noise type. Load time for 8k bytes: 15 s at 540 bps, 43 s at 187 bps, 4 minutes at 30 bps. Device code selected with on-board DIP-switch. Four extra status lines available for input. Four extra control lines available for output; may be used to drive relays for extra cassette units. Comes with I/O subroutines, bootstrap, Kansas City software, and low-noise cassette with test stream. Kit/assembled .... $120/$175.00

VECTOR

8800V UNIVERSAL MICROPROCESSOR BOARD
Board permits Altair and Imsai users to add circuits such as RAM, ROM, PROM, interfaces, A/D or D/A converters, multiplexers and relays. Pre-punched with 0.042" diameter holes on 0.1" centers, so DIPs can be placed in any location. Typically, board holds two 40-pin DIPs, eight 24-pin DIPs and 36 14- or 16-pin DIPs. Space for discrete devices and ribbon-wire connectors. Column and row DIP zone-coordinates, plus column and row-hole designators, etched into the laminate. Power and ground planes on opposite sides of board. Two copper heat-sink positions. Size is 10" × 5.313", with 100 connector fingers (50 each side) spaced on 0.125" centers. One low-profile, finned heat-sink supplied with each board $19.95

DIRECTORY OF MICROCOMPUTER PRODUCTS MANUFACTURERS

If you have any additional questions about products described in this Guide, write direct to the company.

APPLIED MICROTECHNOLOGY
100 N Winchester Blvd . Santa Clara Cal 95050

CROMEMCO
One First Street Los Altos Cal 94022

DIGITAL GROUP, THE
Box 6528 Denver Colo 80206

DUTRONICS
P O Box 9160. Stockton. Cal 95208

E & L INSTRUMENTS INC.
61 First Street Derby Conn 06418

EBKA INDUSTRIES, INC.
6920 Melrose Lane. Oklahoma City Okla 73127

ELECTRONIC CONTROL TECHNOLOGY
P O Box 6 Union N J 07083

ELECTRONIC PRODUCTS ASSOCIATES, INC.
1157 Vega Street. San Diego Cal 92110

ELECTRONIC TOOL CO.
4736 El Segundo Blvd Hawthorne. Cal 90250

GNAT COMPUTERS
8869 Balboa Ave Unit C. San Diego Cal 92123

GODBOUT, BILL ELECTRONICS
Box 2355. Oakland Airport. Cal 94614

HAL COMMUNICATIONS CORP.
P O Box 365. Urbana. Ill 61801

IMS ASSOCIATES, INC.
14860 Wicks Blvd . San Leandro Cal 94577

INFINITE INCORPORATED
P O Box 906. Cape Canaveral. Fla 32920

INTELLIGENT SYSTEMS CORP.
4376 Ridgegate Dr . Duluth Ga 30136

INTERSIL, INCORPORATED
10900 N Tantau Ave . Cupertino. Cal 95014

LEAR SIEGLER INC.
714 N Brookhurst Street. Anaheim Cal 92803

M & R ENTERPRISES
P O Box 1011 Sunnyvale Cal 94088

MARTIN RESEARCH
3336 Commercial Ave . Northbrook Ill 60062

MICROCOMPUTER ASSOCIATES
2589 Scott Blvd . Santa Clara Cal 95050

MICRO PERIPHERALS, INC.
P O Box 22101. Salt Lake City. Utah 84122

MIKRA-D INCORPORATED
30 Main Street. Ashland Mass. 01721

MITS
2450 Alamo SE. Albuquerque N M 87106

MOS TECHNOLOGY, INC.
950 Rittenhouse Rd Norristown. Pa 19401

NATIONAL MULTIPLEX CORPORATION
3474 Rand Ave So Plainfield N J 007080

NATIONAL SEMICONDUCTOR CORP.
2900 Semiconductor Dr Santa Clara. Cal 95051

OHIO SCIENTIFIC INSTRUMENTS
11679 Hayden Street. Hiram Ohio 44234

PCM COMPANY
Box 215 San Ramos. Cal 94583

POLYMORPHIC SYSTEMS
737 S Kellogg. Goleta. Cal 93017

PRONETICS CORPORATION
P O Box 28582. Dallas. Tex 75228

PROCESSOR TECHNOLOGY
6200 Hollis Street. Emeryville. Cal 94608

SCIENTIFIC RESEARCH INSTRUMENTS COMPANY
P O Drawer 2096 Ashland Va 23005

SPHERE CORPORATION
940 North 400 East. North Salt Lake. Utah 84054

SWTP
219 Rhapsody San Antonio Tex 78216

TARBELL ELECTRONICS
144 Miraleste Dr #106. Miraleste Cal 90732

VECTOR ELECTRONIC CO., INC.
12460 Gladstone Ave Sylmar. Cal 91342

WAVE MATE
1015 W 190th Street Gardena. Cal 90248

WINTEK CORP.
902 N 9th Street Lafayette Ind. 47904

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CIRCLE NO 12 ON FREE INFORMATION CARD

1977 ELECTRONIC EXPERIMENTERS HANDBOOK ADVERTISERS INDEX

The chances are excellent that...

You have a talent other people are willing to pay for!

You're "handy" around your house, have the ability to fix things, and "make them work right"... that's why there may be a rewarding career for you in Electronics.

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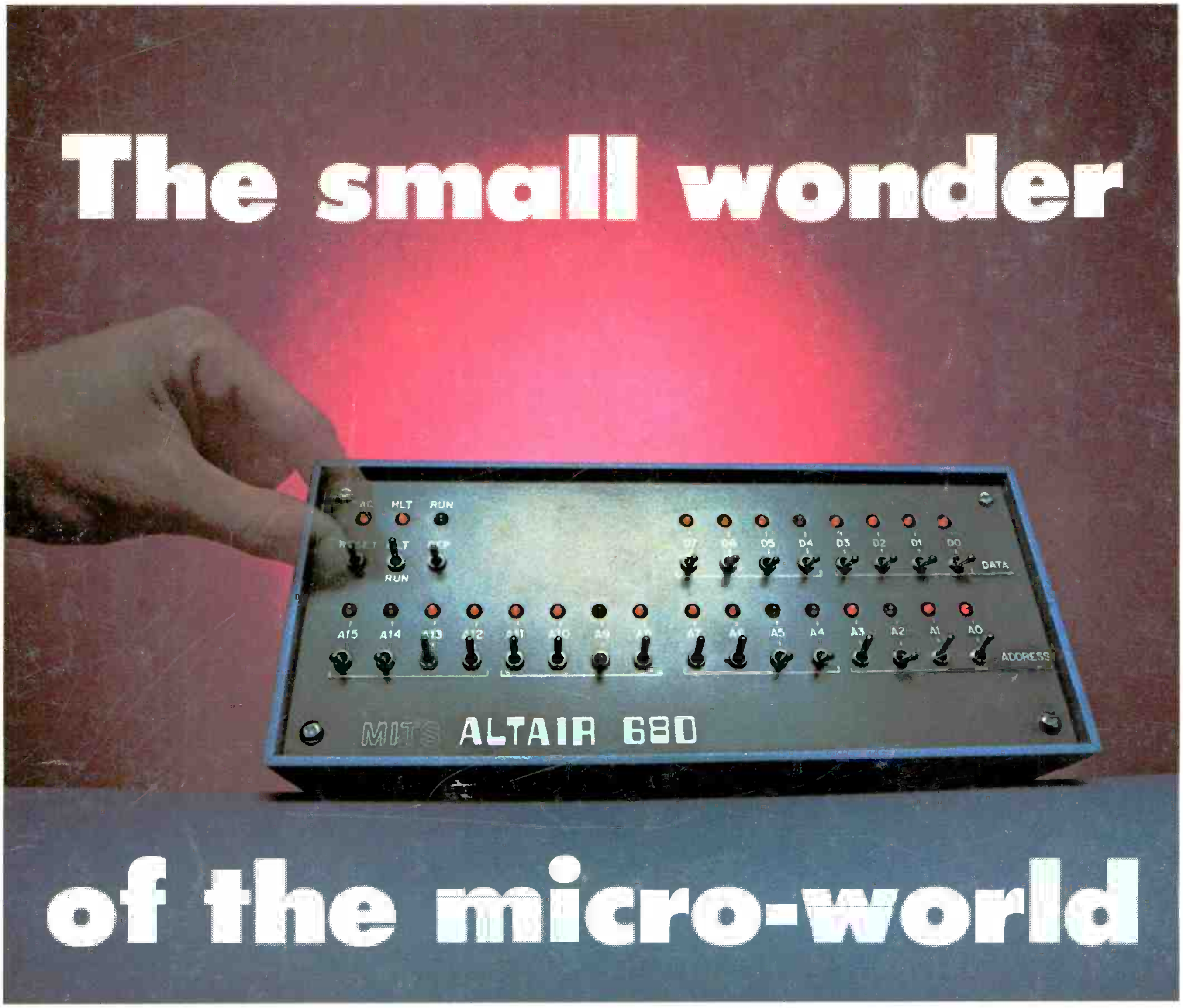

Measuring just 11" wide x 11" deep x 5" high, and weighing a mere 7 pounds, the Altair ™ 680b is a complete, general-purpose computer.

The secret to this revolutionary, small computer is its CPU board. This double-sided board fits along the bottom of the Altair case and plugs directly into the front panel board. It contains the new 6800 microprocessor, 1,024 bytes of RAM memory, a 256 byte PROM monitor, provisions for 768 bytes of additional PROM or ROM, and a single Interface port with a Motorola ACIA serial interface adapter which can be configured either RS-232 or TTY. A five level Baudot interface option is also available.

The Altair 680b can be programmed from front panel switches, or it can be interfaced to a video display terminal, or teletypewriter. Three additional circuit boards can be plugged inside the Altair 680b for further memory and interface expansion. The first of these boards is a 16K static RAM memory board.

Software already developed includes Altair 680 BASIC with all the features of the 8K BASIC previously developed for the Altair 8800. These include Boolean operators, the ability to read or write a byte from any I/O port or memory location, multiple statements per line, and the ability to interrupt program execution and then continue after the examination of variable values. This software takes only 6.8K bytes of memory space and a copy is **included free with the purchase of the Altair 680 16K memory board.**

Other software includes a resident two pass assembler. The Altair 680b is also compatible with Motorola 6800 software.

The Altair 680b is ideal for hobbyists who want a powerful computer system at an economic price. Altair 680b owners qualify for membership in the Altair Users Group, and like other Altair owners, they receive a complimentary subscription to **Computer Notes** and complete factory support.

PRICES:

Altair 680b kit with complete, easy-to-understand assembly manual, operator's manual, and programming manual	$466
Assembled Altair 680b	$625
Altair 680b Turnkey model kit	395
Expander Card 680MB (required to expand 680)	$ 24
Altair 680BSM 16K static RAM board kit with 680 BASIC	$685
Altair 680 BASIC when purchased separately	$200
Baudot option	$ 42

MAIL THIS COUPON TODAY

☐ Enclosed is a check for $________
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☐ Altair 680b ☐ Kit ☐ Assembled ☐ Other (specify)
enclose $8 for postage and handling
☐ Please send free information package

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