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(SHUTS A.C. POWER WHEN AUDIO ENDS)
- ADJUSTABLE TIME DELAY
- CONVENTIONAL TIMER USE

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- Stereo Equalizer
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MEASURE LOW MILLIVOLTS WITH A MULTIMETER .......... John F. Hollabaugh 11
   Range expander increases sensitivity of a VOM by ×10 or ×100
MAKING NOISES WITH THE 555 IC TIMER ......................... Michael S. Robbins 20
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   You can experiment with a young science and have fun at your parties with it too!
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   If you add this low-cost accessory to your shortwave receiver, you can enjoy more stations with greater clarity.
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**COLOR BAND SYSTEM**

1st Significant Digit

2nd Figures

Multiplier

Tolerance

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.

**DISC CERAMICS (5-DOT SYSTEM)**

1st Significant Digit

2nd Figures

Multiplier

Tolerance Temperature Coefficient

**DISC CERAMICS (3-DOT SYSTEM)**

1st Significant Digit

2nd Figures

Multiplier

**MOLDED INSULATED AXIAL LEAD CERAMICS**

1st Significant Digit

2nd Figures

Multiplier

Tolerance Temperature Coefficient

**MOLDED CERAMICS**

Using Standard Resistor Color-Code

1st Significant Digit

2nd Figures

Multiplier

Tolerance

Distinguishes Capacitor From Resistor

**MOLDED MICA CAPACITOR CODES**

(Capacitance Given In pF)

<table>
<thead>
<tr>
<th>COLOR</th>
<th>DIGIT</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
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<tr>
<td>BLACK</td>
<td>0-9</td>
<td>10</td>
<td>±5%</td>
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<tr>
<td>RED</td>
<td>1</td>
<td>100</td>
<td>±1%</td>
</tr>
<tr>
<td>ORANGE</td>
<td>2</td>
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<tr>
<td>GREEN</td>
<td>3</td>
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<td>±1%</td>
</tr>
<tr>
<td>BLUE</td>
<td>4</td>
<td>100000</td>
<td>±5%</td>
</tr>
<tr>
<td>VIOLET</td>
<td>5</td>
<td>1000000</td>
<td>±1%</td>
</tr>
<tr>
<td>WHITE</td>
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<tr>
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<td>7</td>
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<tr>
<td>GOLD</td>
<td>8</td>
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</tr>
<tr>
<td>NO COLOR</td>
<td>9</td>
<td>01</td>
<td>±1%</td>
</tr>
</tbody>
</table>

*GMV guaranteed minimum value, or -0.1% tolerance.
*5, 6, 12, 1/2, and 30% are ASA 40, 20, 10, and 5 step tolerances.

**RESISTOR CODES** (Resistance Given In Ohms)

<table>
<thead>
<tr>
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<th>DIGIT</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10</td>
<td>±5%</td>
</tr>
<tr>
<td>RED</td>
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<td>100</td>
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</tr>
<tr>
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<tr>
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<td>5</td>
<td>100000</td>
<td>±5%</td>
</tr>
<tr>
<td>BLUE</td>
<td>6</td>
<td>1000000</td>
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</tr>
<tr>
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<td>±1%</td>
</tr>
<tr>
<td>SILVER</td>
<td>9</td>
<td>10</td>
<td>±5%</td>
</tr>
</tbody>
</table>

**CERAMIC CAPACITOR CODES** (Capacity Given In pF)

<table>
<thead>
<tr>
<th>COLOR</th>
<th>DIGIT</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
<th>TEMPERATURE COEFFICIENT</th>
<th>EXTENDED RANGE</th>
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<td>±2.5%</td>
<td>-150115</td>
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<td>±5%</td>
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<td>100000</td>
<td>±1%</td>
<td>-220120</td>
<td>2.2</td>
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<tr>
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<td>±5%</td>
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<td>±1%</td>
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<td>10</td>
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<tr>
<td>GOLD</td>
<td>9</td>
<td>10</td>
<td>±5%</td>
<td>-201700</td>
<td>10</td>
</tr>
</tbody>
</table>

**TYPographically Marked CERAMICS**

Temperature Coefficient Capacity Tolerance

**BUTTON CERAMICS**

1st Significant Digit

2nd Figures

Multiplier

**STAND-OFF CERAMICS**

Temperature Coefficient Tolerance

**FEED-THRU CERAMICS**

Temperature Coefficient Tolerance

**MOLDED PAPER CAPACITOR CODES** (Capacity Given In pF)

<table>
<thead>
<tr>
<th>COLOR</th>
<th>DIGIT</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
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</thead>
<tbody>
<tr>
<td>BLACK</td>
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<tr>
<td>YELLOW</td>
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</tr>
<tr>
<td>SILVER</td>
<td>9</td>
<td>10</td>
<td>±5%</td>
</tr>
</tbody>
</table>

*For ≤10 pF without greater.

**CURRENT STANDARD JAN AND EIA CODE**

<table>
<thead>
<tr>
<th>BUTTON SILVER MICA</th>
<th>DIGIT</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 1</td>
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<tr>
<td>TYPE 2</td>
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</tr>
<tr>
<td>TYPE 3</td>
<td>5</td>
<td>±10%</td>
</tr>
</tbody>
</table>

**MOLDED FLAT PAPER CAPACITORS**

Commercial Code

Voltage

**MOLDED FLAT PAPER CAPACITORS JAN CODE**

Silver

Tolerance Characteristic

**BODy-END-Dot SYSTEM**

1st Significant Digit

2nd Figures

Multiplier

Tolerance

**BODy-END BAND SYSTEM**

1st Significant Digit

2nd Figures

Multiplier

Tolerance

**HIGH CAPACITY TUBULAR CERAMIC INSULATED OR NON-INSULATED**

Using Standard Resistor Color-Code

1st Significant Digit

2nd Figures

Multiplier

Tolerance

**TEMPERATURE COMPENSATING TUBULAR CERAMICS**

Temperature Coefficient Tolerance

**ENTENDED RANGE TUBULAR CERAMICS**

Temperature Coefficient Tolerance

**FEED-THRU CERAMICS**

Voltage

*Voltage ratings are standard 300 volts for some manufacturers, but 1000 volts for other companies.

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.

*For ≤10 pF without greater.
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ELECTRONIC EXPERIMENTER'S HANDBOOK
BUILD THE HI-FI/TV AUDIO-MINDER

- SHUTS AC 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, C10-0.047 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-JM3900 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-Q5-2N6463
- Q5-Triac, 20-A, 200 PIV
- R1, R2, R6-1000-ohm resistor
- R3-68,000-ohm resistor
- R4-4700-ohm resistor
- R5, R6, R26-2000-ohm resistor
- R7-270,000-ohm resistor
- R8-12,000-ohm resistor
- R9-1000-ohm resistor
- R10, R22-1-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')
- R19-130,000-ohm resistor
- R21-33,000-ohm resistor
- R22, R23, R28-82,000-ohm resistor
- R26, R29, R30-10,000-ohm resistor
- R27-3300-ohm resistor
- R31-100-ohm resistor
- R32-470-ohm, 1/2-watt resistor
- S1-Pushbutton switch, momentary contact, normally open ('Reset')
- S2-Spdt switch ('Power')
- S3-Dpdt switch ('Normal/Timer')
- S01 to S04-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 $10.95; PC board (SO-2) at $4.00; metal case (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 (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 gate formed by IC1D which, in turn, causes Q4 to saturate and drain 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 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 deenergized only after the selected time interval has been reached. This mode is used to turn off any appliances or TV receiver automatically.
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<table>
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<th>Model</th>
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<th>Terminals</th>
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*U.S. Pat. No. 235,554  All Prices Shown Are Manufacturer’s Recommended List. Prices and Specifications Subject to Change Without Notice.

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IC2—741 operational amplifier  
J1, J2—Phono jack  
R1—3900-ohm, 1/4-watt resistor  
R2—37-ohm, 1/2-watt resistor  
R3—1500-ohm, 1/2-watt resistor  
R4, R11—1-Megohm, 1/4-watt resistor  
R5, R6—10,000-ohm, 1/4-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 DR 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 2 3/4 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. 

**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.
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 physiological 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.
**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

---

**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.
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 pushbutton 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

---

**PARTS LIST**

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1, B2</td>
<td>9-volt battery</td>
</tr>
<tr>
<td>C1-C3</td>
<td>0.001-μF, 20% Mylar or ceramic capacitor</td>
</tr>
<tr>
<td>C3-C5</td>
<td>0.1-μF, 20% Mylar or ceramic capacitor</td>
</tr>
<tr>
<td>IC1</td>
<td>4013 CMOS dual-D flip-flop</td>
</tr>
<tr>
<td>IC2, IC4</td>
<td>4011 CMOS quad 2-input NAND</td>
</tr>
<tr>
<td>IC3, IC5</td>
<td>4001 CMOS quad 2-input NOR</td>
</tr>
<tr>
<td>IC4</td>
<td>4055 CMOS 7-segment decoder/driver</td>
</tr>
<tr>
<td>IC6</td>
<td>4016 CMOS quad bilateral switch</td>
</tr>
<tr>
<td>IC7</td>
<td>4012 CMOS dual 4-input NAND</td>
</tr>
<tr>
<td>LED1, LED4</td>
<td>Light-emitting diodes (Monsanto MV-5024 or similar)</td>
</tr>
<tr>
<td>Q1</td>
<td>2N2905 transistor</td>
</tr>
<tr>
<td>R1, R2, R4, R6, R8, R10, R11</td>
<td>560-ohm, 1/4-watt, 10% resistor</td>
</tr>
<tr>
<td>R3</td>
<td>3300-ohm, 1/4-watt, 10% resistor</td>
</tr>
<tr>
<td>R5-R7, R9, R14-R17</td>
<td>1-megohm, 1/4-watt, 10% resistor</td>
</tr>
<tr>
<td>R12, R18, R19, R21</td>
<td>68,000-ohm, 1/4-watt, 10% resistor</td>
</tr>
<tr>
<td>R13, R20</td>
<td>100,000-ohm, 1/4-watt, 10% resistor</td>
</tr>
<tr>
<td>R10</td>
<td>7-segment LED readout (Litronix D1-707 or similar)</td>
</tr>
<tr>
<td>S1</td>
<td>Spst momentary pushbutton switch (red) (Oak 415-399592-LP or similar)</td>
</tr>
<tr>
<td>S2-S5</td>
<td>Spst momentary pushbutton switch (white) (Oak 415-399596-LP or similar)</td>
</tr>
<tr>
<td>S6</td>
<td>Spst alternate-action rocker switch (Arclectric C-400 or similar)</td>
</tr>
<tr>
<td>Misc.</td>
<td>Case (H.H. Smith 2255), cover (H.H. Smith 2256), plastic for target partition, battery holders (2), battery connectors (2), mounting hardware, etc.</td>
</tr>
</tbody>
</table>

Note 1—The following are available from Paratronics, 150 Tait Ave., Los Gatos, CA 95030: etched and drilled pc board (ESP-IPC) at $11.50; finished and labeled panel, case, and target partition (ESP-IJP) at $10.50; complete kit of parts (less batteries) (ESP-IKN) at $59.50; assembled and tested unit (ESP-IAT) at $69.50. California residents please add 6% sales tax. Add 5% for air shipping inside U.S.: 10% outside U.S.
Fig. 3. Component layout for pc board (above) and full-size foil patterns for construction right and below.

NOTE: LED1-LED4, RO1, B S1-S5 ON SIDE OPPOSITE IC'S
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 1/2 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 feel 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:

2. Turn on the power and press the target select pushbuttons in accordance with the chosen sequence. When the last number is entered, your 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.

Performance Chart

<table>
<thead>
<tr>
<th>No. of Runs</th>
<th>Chance Score</th>
<th>Good Score (Odds 20:1)</th>
<th>Excellent Score (Odds 100:1)</th>
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<tbody>
<tr>
<td>10</td>
<td>25</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td>62</td>
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<tr>
<td>30</td>
<td>75</td>
<td>90</td>
<td>94</td>
</tr>
</tbody>
</table>

*10 trials in each run.

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

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.
### Consumer Electronics

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- Handball

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- Built-in self-test for CMOS TTL devices.
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- Bailing mechanism allows for easy retrieval of scores when playing against each other.

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- 1000: 1¢

#### Display LEDs Super Savings!

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- MAN 7: $99
- DL338: $99

### Ic Sockets

#### IC Solder Tail - Low Profile (TIN) Sockets

<table>
<thead>
<tr>
<th>Type</th>
<th>Polarity</th>
<th>Type</th>
<th>Polarity</th>
<th>Material</th>
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<tr>
<td>AM206</td>
<td>Amount</td>
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### Zeners, Diodes, Rectifiers

#### Zeners

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<tr>
<td>Z100</td>
<td>0.1V</td>
<td>100</td>
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</tr>
<tr>
<td>Z200</td>
<td>0.2V</td>
<td>200</td>
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### Capacitors

#### Aluminum Electrolytic

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<tr>
<td>C101</td>
<td>1µF</td>
<td>100</td>
<td>0.50</td>
</tr>
<tr>
<td>C102</td>
<td>2µF</td>
<td>200</td>
<td>1.00</td>
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#### Molex Pins

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<th>Type</th>
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<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 per strip</td>
<td>1000/10000</td>
<td>$2.25</td>
</tr>
</tbody>
</table>

#### Single Turn 1/4 Ceramic Potentiometer

- Resistance Tolerance: ±5%
- High Power: 0.5 watt at 70°C
- Minimum Operating Temp: -55°C to +125°C

#### Standard Resistance Values

- 50Ω 100Ω 500Ω 1kΩ 5kΩ 10kΩ 50kΩ 100kΩ 200kΩ 500kΩ 1MΩ

#### Zener Diodes

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
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<th>Price</th>
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</thead>
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<tr>
<td>Z100</td>
<td>0.1V</td>
<td>100</td>
<td>0.25</td>
</tr>
<tr>
<td>Z200</td>
<td>0.2V</td>
<td>200</td>
<td>0.50</td>
</tr>
</tbody>
</table>

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**CIRCLE NO. 15 ON FREE INFORMATION CARD**

**Electronic Experimenter's Handbook**
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.

![Figure 1. Charger can be used for one to four C cells with cells in clips or connected to binding posts.](image)

### PARTS LIST

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

---

Build your own TTL-5 Power Supply

The fast, easy way to build a TTL-5 Power Supply that provides the rigid power requirements of the TTL (Transistor-Transistor Logic) and C-MOS digital circuits. Comes complete with all necessary parts for assembly and illustrated, step-by-step instruction booklet. See the TTL-5 Power Supply, Motor Speed Control, Ditigal Clock, DC Regulated Power Supply and Burglar Alarm kits at Calestro dealers everywhere.

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GC ELECTRONICS
DIVISION OF HYDROMETALS, INC.
ROCKFORD, ILLINOIS 61101 U.S.A.
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.

**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

---

**PARTS LIST**

- R1—500,000-ohm trimmer potentiometer (CTS X-201 or similar)
- R2—1000-ohm, 1/2-watt resistor
- R3—100,000-ohm, 1/2-watt resistor
- R4—15,000-ohm, 1/2-watt resistor
- R5—33,000-ohm, 1/2-watt resistor
- R6—22,000-ohm, 1/2-watt resistor
- C1—0.01-µF disc capacitor
- IC1—CA3089E
- L1—1000-µH, 5% inductor (Nryonic WEE 1000 or similar)
- L2—10,000-µH, 10% inductor (Nryonic WEE 10,000 or similar)
- Q1—2N2222

---
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.

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.

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 $10^8(4n^2)$; and for C8, use $10^8/(4n^2)$—70; where C is in picofarads and f is in kilohertz.
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_c. As the frequency increases, a transistor's amplifying capability drops rapidly. Above f_c, there is no gain at all, and the transistor just doesn't work. You can check your transistors' f_c 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_c, see the box on page 59.)

**How It Works.** The circuit is essentially an emitter-follower amplifier whose input impedance varies with the f_c 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_c.

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_m, 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_c of 17 MHz is checked on the 1-MHz range, it will have a beta of f_c/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.

**R-F TRANSISTOR TESTER**

**Checks upper frequency limit of bipolar transistors**

**BY DANIEL METZGER**
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 fT 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 not be encountered.

**WHAT IS fT?**

The cutoff frequency (sometimes also called gain-bandwidth product) is the frequency at which the current gain (hβ) drops to unity. For frequencies lower than fT, hβ 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 (βο) is reached at the beta cutoff frequency (fBO) as shown in the diagram. Notice that, for any frequency above fBO, the product of current gain and operating frequency is constant and equal to fT. Hence, the name gain-bandwidth product for fT.

Calculating hβ at any frequency when fT is known is a simple matter. If this relationship is kept in mind. For example, if a transistor having an fT of 200 MHz is to be used in a 27-MHz amplifier, its effective beta is fT 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.
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 \textit{f}_\text{i} scale.

To calibrate the instrument, a high-beta transistor with an \textit{f}_\text{i} specification above 250 MHz is inserted in test socket 50 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 \textit{I}_\text{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 \textit{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 \textit{R4} and \textit{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 (\textit{RQ}) across \textit{L1} or \textit{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 \textit{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.

\textbf{FIG. 2. SAMPLE CALIBRATION CHART}

\begin{tabular}{|c|c|c|c|c|c|}
\hline
\textit{f}_\text{i} & \beta & \textit{r}_\text{i} & \textit{V}_\text{r} & \textit{V}_{\text{C10}} & \textit{I}_\text{m} \\
MHz & & Ohms & Volts (p-p) & Volts & mA \\
\hline
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 \\
\hline
\end{tabular}

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

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 1/2 of Vcc, C1 discharges rapidly through R1 and the internal circuit of the IC to 1/3 of Vcc, 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.

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.
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\textsubscript{IN} is the positive supply and V\textsubscript{SC}, 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\textsubscript{IN}, 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 \(\frac{1}{2}V\textsubscript{IN}\), 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.

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
Suppose there is an increase in the input voltage—approaching $V_{\text{in}}$. 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 $V_{\text{in}}$, 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 $V_{\text{in}}$, since it simply looks like a 500-ohm resistor to $V_{\text{in}}$. So the high logic level of CMOS is essentially equal to $V_{\text{in}}$. 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 $V_{\text{in}}$ 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 $\frac{1}{2}V_{\text{in}}$ and for digital use, this means that above or below the balance point, the output will go toward its low or high state.
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 $\frac{1}{2}$ 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 CD4007A 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
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 don’ts and don’ts 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 VDD and greater than or equal to VSS (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 VDD and VSS, respectively (for example, 2 and 11 to 14 or 9 to 7).

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

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.

CMOS MANUFACTURERS

RCA Solid State Division
Box 3200
Somerville, N.J. 08876
Motorola Semiconductor Products
Box 20912
Phoenix, AZ 85036
National Semiconductor
2900 Semiconductor Dr.
Santa Clara, CA 95051
Harris Semiconductor
1000, 54/74C
Box 983
Melbourne, FL 32901
Fairchild Semiconductor
313 Fairchild Dr.
Mountainview, CA 94040
Solid State Scientific Inc.
2400 North, 400B
Montgomeryville, PA 19463
Teledyne Semiconductor
1300 Terra Bella Ave.
Mountain View, CA 94043

ELECTRONIC EXPERIMENTER'S HANDBOOK
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\text{in}, 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.

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\text{in}. 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\text{in} 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.

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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Tie Point Blocks

Tie Point Blocks are four-tie-point terminal groups that include solder tails and press-fit mounting legs for no-hardware installation. 20 to a package. Also available is a special LED mounting block (less LED) with an integral tie point.

Tie Point Blocks (20/pk)

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Terminal and Distribution Strips

Terminal Strips offer groups of four-tie-point or five-tie-point terminals in smaller solderless breadboard packages. Distribution Strips carry buses in groups of connected 4-tie-point terminals.

Terminal Strips

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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 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; the CD4012AE is a dual four- and the CD4023 has triple, three-input capability.

While the 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 design 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 CD4066A.

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 CD4013A as shown in Fig. 12.
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.

**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 CMOS 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...
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.

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**BY L. GEORGE LAWRENCE**

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*Probe magnetic fields with this home-built instrument.*

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**HALL-EFFECT**
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.

![Hall generator diagram](image)

**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.

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...
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 1/4-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 R1 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.

**Parts List**

- B1, B2—1.5-volt D cell
- B3, B4—9-volt battery
- Hall Generator—BH-702 (F.W. Bell)*
- IC1—741 op amp
- M1—1-mA meter (Calevo D1-912 or similar)
- PI—4-pin plug with attached color-coded leads (see text)
- Q1—HEP-51 transistor
- R1, R2—2700-ohm, 1/2-watt resistor
- R3—580,000-ohm linear potentiometer
- R4—1500-ohm, 1-watt resistor
- R5—10,000-ohm linear potentiometer
- R6—3300-ohm, 1/2-watt resistor
- R7—100-ohm, 1-watt resistor (adjusted for recommended Hall-element current)
- R8—10,000-ohm, 1/2-watt resistor
- S1, S2—Dpst switch
- S3—Dps switch
- S01—4-pin socket to match PI
- 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., 3999 Freeway Drive East, Columbus, Ohio 43229; and Ohio Semitronics, Inc., 1205 Chesapeake Ave., Columbus, Ohio, 43212.
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 1/8 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 tube plate, being small, can be bonded to a glass or non-magnetic mount with epoxy cement to form a filament 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-PC4F385 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.
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.
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.

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

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

**Fig. 4.** How to connect the Q multiplier into your receiver using connx.
UNDERSTANDING YOUR TRIGGERED SWEEP SCOPE

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.

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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.
A N 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.

BUILD 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
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 level 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 6dB/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, of course). 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.

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**PARTS LIST**

For equalizer boards (1 of each for each board):

C1, C21—0.1µF, 50 volt electrolytic capacitor
C2, C11—0.022µF capacitor
C3, C12—0.12µF capacitor
C4, C13—0.056µF 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—10µF, 60 volt electrolytic capacitor
IC1, IC6—555 opt amp IC
J1, J2—Audio connector

Unless otherwise noted, resistors are 1/4-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—3900-ohm
R45, R56—680-ohm
R57—100-ohm

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—3900-ohm
R45, R56—680-ohm
R57—100-ohm

Followings components on right board only:

C23—0.047-µF capacitor
T1—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—IN5040 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.
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).

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 +Vcc 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 DI1 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—40-μF tantalum capacitor
C6—0.1-μF ceramic capacitor
C7—1-μF tantalum capacitor
D1—IN914 diode
D2—IN914 diode
D3—See text
D15—Bar indicator light (see note)
IC1—558 dual op amp
IC2, IC3, IC4—LM339 quad comparator (National)
IC5—555 timer
IC6—Phono connector
Q1—2N2222 transistor (or similar)
R1—10,000-ohm potentiometer
R2—R4, R5, R9, R12, R26, R29, R30, R32, R34, R36, R38, R40—2000-ohm, 5% resistor
R4—1000-ohm, 5% resistor
R5—1000-ohm, 5% resistor
R6—20,000-ohm, 5% resistor
R7—10,000-ohm, 5% resistor
R8—1000-ohm, 5% resistor
R9—1000-ohm, 5% resistor
R10—1470-ohm, 5% resistor
R11—1000-ohm, 5% resistor
R12—1470-ohm, 5% resistor
R13—150,000-ohm, 5% resistor
R14—150,000-ohm, 5% resistor
R15—150,000-ohm, 5% resistor
R16—150,000-ohm, 5% resistor
R17—150,000-ohm, 5% resistor
R18—150,000-ohm, 5% resistor
R19—150,000-ohm, 5% resistor
R20—150,000-ohm, 5% resistor
R21—150,000-ohm, 5% resistor
R22—150,000-ohm, 5% resistor
R23—150,000-ohm, 5% resistor
R24—150,000-ohm, 5% resistor
R25—150,000-ohm, 5% resistor
R26—150,000-ohm, 5% resistor
R27—150,000-ohm, 5% resistor
R28—150,000-ohm, 5% resistor
R29—150,000-ohm, 5% resistor
R30—150,000-ohm, 5% resistor
R31—150,000-ohm, 5% resistor
R32—150,000-ohm, 5% resistor
R33—150,000-ohm, 5% resistor
R34—150,000-ohm, 5% resistor
R35—150,000-ohm, 5% resistor
R36—150,000-ohm, 5% resistor
R37—150,000-ohm, 5% resistor
R38—150,000-ohm, 5% resistor
R39—150,000-ohm, 5% resistor
R40—150,000-ohm, 5% resistor
R41—150,000-ohm, 5% resistor
R42—150,000-ohm, 5% resistor
R43—150,000-ohm, 5% resistor
R44—150,000-ohm, 5% resistor
R45—150,000-ohm, 5% resistor
Misc.—IC sockets (6), transparent filler, cement, mounting hardware, power supply.

Note—Bar indicator (30150) is available from Readouts, Inc., Box 149, Del Mar, CA 92014, for $4.25, plus postage.

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.
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 IC7 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

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**FLIP**

**A CMOS GAME COMPUTER**

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

BY JOSEPH A. WEISBECKER
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 board, some short cuts have been taken. Note that C1 through C10, R1 through R10, 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
The 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 properly. 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.

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**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 pre-sensitized pc blanks. (The so-called "photo" process is the only practical way of making complicated pc boards.)
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.

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

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 feed-throughs 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-

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-IC8 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.

NOTE: ALL LEDS CONNECT TO BOARD VIA CATHODES.
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-lit area.

Measure the length and width of your pencil layout, and divide these two 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.

Paste 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., Simi Valley, CA 91342): Direct positive photoresist kits, double-clad pc blanks, drafting aids, chemicals.
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 ¼ 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 feed-throughs. 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 Solderscons.)*

You have now designed and fabricated your own double-sided pc board. Good luck on your project.
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 between 10 and 100,000 microfarads and indicates leakage.
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 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.

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**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.

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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 biasing 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—IN4001 silicon diode
- J1—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, 1/2-watt resistor
- R2, R5, R8, R14, R15—10,000-ohm, 1/2-watt resistor
- R3, R6, R9—5800-ohm, 1/2-watt resistor
- R10, R12—5000-ohm linear-taper potentiometer
- R11, R13—1000-ohm, 1/2-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, 2 1/4-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.

**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."
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 binary digits), 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.

BY FORREST M. MIMS
**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:

\[
1100 \\
+ 1001
\]

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:

\[
10101
\]

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 = 10000.

**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:

\[
\begin{array}{c|c|c|c|c|c|c}
   & 10^2 & 10^1 & 10^0 & 6 & 4 & 2 \\
\mid & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\
\mid & 10^2 & 10^1 & 10^0 & 6 & 4 & 2 \\
\mid & 6 \times 10^0 & = & 6 & 4 \times 10^2 & = & 40 \text{ (add)} \\
\mid & 8 \times 10^2 & = & 800 & & & \\
\mid & & & & & & 846 \\
\end{array}
\]

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:

\[
\begin{array}{c|c|c|c|c|c|c|c}
   & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 & 1 & 0 \mid 1 & 1 \\
\mid & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\
\mid & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 & 1 & 0 \mid 1 & 1 \\
\mid & 1 \times 2^0 & = & 1 & 1 \times 2^1 & = & 2 & 1 \times 2^2 & = & 4 \text{ (add)} \\
\mid & 1 \times 2^3 & = & 8 & 0 \times 2^2 & = & 0 & 1 \times 2^4 & = & 16 \text{ (23)} \\
\mid & & & & & & & & & 10 \\
\end{array}
\]

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:

\[
\begin{array}{c|c|c|c|c|c}
   & 1 & 0 & 0 & 1 & 1 \\
\mid & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\
\mid & 1 & 0 & 0 & 1 & 1 \\
\mid & 16 + 0 + 0 + 2 + 1 & = & (19)_{10} \\
\end{array}
\]

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 binary 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:

\[
1 1 0 1 1 0 0 1 1 0 1 1
\]

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

\[
\begin{array}{c|c|c|c|c}
\text{Decimal} & \text{Binary} & \text{Octal} \\
\hline
0 & 0 & 0 \\
1 & 1 & 1 \\
2 & 10 & 2 \\
3 & 11 & 3 \\
4 & 100 & 4 \\
5 & 101 & 5 \\
6 & 110 & 6 \\
7 & 111 & 7 \\
8 & 1000 & 10 \\
9 & 1001 & 11 \\
10 & 1010 & 12 \\
11 & 1011 & 13 \\
12 & 1100 & 14 \\
13 & 1101 & 15 \\
14 & 1110 & 16 \\
15 & 1111 & 17 \\
16 & 10000 & 20 \\
17 & 10001 & 21 \\
18 & 10010 & 22 \\
19 & 10011 & 23 \\
20 & 10100 & 24 \\
\end{array}
\]

Hence, \(11101100001101_2\) equals \(35415_8\). 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
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.

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.

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:

\[ A + B = A \times B. \]
\[ A \times B = A + B. \]

The arithmetic symbols + and \( \times \) 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. 1. Switches are arranged to illustrate three basic digital electronic functions.

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.

Fig. 4. Logic array for XOR circuit.
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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 (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 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, Q will be at 1.

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-
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 of its inputs are a logic 1.) Keyboard output lines B0, B1, and B2 then have the following conditions:

\[
B_0 = 1, 
B_1 = 0, 
B_2 = 1 
\]

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
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
D1S thru D1S3-7-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 hex inverter 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, IC17-7477 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, 1/4-watt resistor
R15 thru R22-360-ohm, 1/4-watt resistor
R23, R24, R27-10.000-ohm, 1/4-watt resistor
R25-15-ohm, 1/2-watt resistor
R26-47-ohm, 1/4-watt resistor
R28-100-ohm, 1/4-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.

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 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 keys were 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 long 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

Output Register. The output register consists of FF3 through FF10. These eight flip-flops store data until the three key entry sequences are completed.

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 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 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.
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 bias 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 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 Q1. 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 0.6 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 connections leads or sharp risetime pulses are used.

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

<table>
<thead>
<tr>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

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.

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

Fig. 9. Schematic of power supply (A) and "ready" circuits to be used when terminal feeds a computer (B).
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 60-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 7 1/2 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 circuits (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 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 hexadecimal. 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 computerese, 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 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 MPU 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 its 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 0. RAM's are usually organized into words. They come in all sizes, identified as "x-number of bits" or "x-number of bits." For example, the popular 2102 RAM is organized as 1024 x 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 descrip-
tions 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 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 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.)

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

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
- DI1—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)
- I—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 Numatron (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 output of the AND gate goes high, and SCR1 is triggered. Once SCR1 is on, the Sonaalert 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 (6½" × 3" × 2") with an aluminum cover panel. A 3/4" square hole was cut out of the panel for the display, and a bracket made from scrap aluminum was used to hold the Numatron 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 it corrects 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

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
PARTS LIST

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%, 1/4-watt resistor
R2, R3—5000-ohm miniature trimmer potentiometer
R3—50,000-ohm miniature trimmer potentiometer
R4, R7—1500-ohm, 1/4-watt resistor
R5—50,000-ohm, 1/4-watt resistor
R6—20,000-ohm, 1/4-watt resistor
R8—R21—100-ohm, 5% 1/4-watt resistor
R22—22,000-ohm, 5% 1/4-watt resistor
TDR1—1000-ohm, negative coefficient thermistor (USI 40003, 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.

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**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 R1 and any alarm or circuit connected to it can be made to trip at any temperature selected by switches S7 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 off 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.

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**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—7455 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 spst contacts
- Q5—2N388 (or similar) transistor
- R24—100-ohm, ½-watt resistor
- S1,S8—Spst switch
- T1—12.6-volt, 1-ampere filament transformer

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**Fig. 2. Three typical power sources for thermometer. Top is for line power, other two are for mobile operation.**
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 $3\frac{3}{8}$" wide, 6" long, and $1\frac{1}{2}$" 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 (171.16387E8).

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 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 portion 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 sleeveings that extend beyond the bodies of the batteries. The sleeveings 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.
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-screens.

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 interface is to confine the 30-Hz flicker, which would otherwise be objectionable, to the space between alternate scan lines.

**Bits to Dots.**

How digital information is transformed into video displays.

BY LEE FELSENSTEIN

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 interface 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 interface.

**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 TV! 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 take 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.

**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 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-numeric and graphics. These devices use a character generator for the alphanumeric 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.

**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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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, 1k 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 x 12.5"D x 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

1306. EEAROM ............................ $125.00

1406. 8080A CPU module ................. $165.00

1407. 8080A CPU with 1k RAM .......... $245.00

1408. 8000 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 I/O 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 of GNAT 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 GNAT 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 GNAT serial and parallel interfaces for RS-232/20-ma; PROM programmer for 1702A and 270B; 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-disks and Teletype 40 line-printer; complete front panel; 19" cage, 15 connectors; power supply; rack-mountable cabinet $2955.00

Lear-Siegler ADM-3, CRT terminal $1300.00

Teletype 40, 300-line printer $2000.00

ICOM Dual Floppy-Disk System $3500.00

High-Speed Paper-Tape Reader $525.00

HAL

MC68000
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 hexadecimal files, and dump or display of memory. Sub-routines 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-KBVDU. 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
MCEM-7K RAM-7K. Static RAM expansion board with 7k of RAM. $350.00
MCEM-PROM PROG. PROM programmer for RAM cards. Programs 8704/8708 EPROMs. $350.00
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
MCEM-PS. Power supply. $55.00

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-gauge 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 displays and keyboard terminals, printers, software including bootstrap loaders. 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. $655/$999.00
EXP-22. 22-slot motherboard. $52.00
RAM 4A-4. 4K RAM memory. Kit/wired. $139/$279.00
PROM 4-4. 4K PROM module. Kit/wired. $399/$579.00
PIO 4-4. 4-port parallel I/O module. Kit/wired. $156/$299.00
FDD. Floppy-disk drive. $1095.00
CRT-2400A. 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 hexadecimal display address, memory contents, port control, front-panel control of interrupt. DMA, I/O, I/O: 256-byte RAM expandable to 65k bytes of RAM. ROM internally; crystal-controlled clock, parallel data interface 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
"INTERCEPT JR." MICROCOMPUTER
Tutorial microcomputer system using Intersil's IMS100 CMOS microprocessor and related CMOS devices. Recognizes DEC PDP-8/E instruction set. Multi-function alphanumeric keyboard, two-digit LED displays, resident micro-interpreter, battery-powered. A non-volatile CMOS RAM permits extending memory up to 128K. IMS100 has two modes: read-only, read-write. $595.00
Option 010. Front-panel control board includes memory for up to 2K words of user program. Optional serial I/O for both RS-232C and TTY. Terminal is 24-character memory. In addition, 10 external I/O lines. $74.65
I/O Module. $58.70

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 of seven-segment LED displays read out time in

MARTIN RESEARCH
MIKE 3 (AT1813)
Three-board system with 8080A MPU, crystal-controlled clock, 50-pin bus structure. Console board uses calculator-type keyboard and

MICROCOMPUTER ASSOCIATES
JOLT
Modular system, uses 6502 MPU, internal clock; can address 65k of memory directly. Two registers: 17 instructions; 11 'true' addressing modes, two interrupts, both single-step and address-halt capabilities. A 1k ROM debug monitor self-adapts to any address speed from 10 to 300 (100 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 BNF 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, dual full-duplex, high-speed reader interface lines and 24 fully programmable bidirectional I/O lines plus two bit-slice I/O lines. Kit/assmbled. $159/$249.00
RAM Card. Static 4k bytes. Kit/assmbled. $199/$285.00
I/O Card. Two PIA/Cs, 32 I/O lines. Kit/assmbled. $96/$140.00
Power Supply. Kit/assmbled. $99/$145.00
Power Supply Booster. For memory expansion. $25.00
Complete JOLT 4K System. Kit/assmbled. $339.50/$509.50
Power JOLT 4K System. Kit/assmbled. $429.50/$644.50
Complete JOLT 8K System. Kit/assmbled. $499.50/$749.50
Power JOLT 8K System. Kit/assmbled. $599.50/$889.50
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).

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MIKRA-D
BASIC-8 SYSTEM
Consists of MTS-8 intelligent terminal plus BASIC software and special hardware. Fully Altair/MITS bus compatible, display format 60 characters by 24 lines, 1600-character capacity. Terminal consists of display CRT, 55-key keyboard with 64-character ASCII-compatible set, housing, CRT interface for 6800, power supply. System includes RAM for BASIC-8, 12k bytes of RAM for Extended BASIC-8; built-in audio-cassette interface (two cassette recorders may be used to 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 x 17"W x 14"H, weight 35 pounds. BASIC-8. kit/associated...

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 flatter 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/CP 0 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/5A. Kit $849.00

Altair 8800b assembled
88-INMCS. 1k static memory, kit/ assembled $115/$60.00
88-ACMS. 4k static memory, kit/ assembled $167/$225.00
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 $36/$55.00
88-2SIO. Serial I/O board with one port, kit/ assembled $148/$180.00
88-SP. Extra port for 2SIO—add up to 3, kit/ assembled $138/$185.00
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...

88-PMC. PROM memory card (hex 2k bytes), kit/ assembled...

88-PROM. PROM, 256 x 8 bytes, for 88-PMC, kit/ assembled...

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 1" wide, 1" 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 live-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...

Altair 680b with Baudot option, kit/ assembled...

Altair 680T. Turnkey model, kit/ assembled...

680-BSM. 1k static memory, kit/ assembled...

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...

KIM-2. 4k static RAM board...

KIM-3. 8k static RAM board...

NATIONAL SEMICONDUCTOR

SCI-6. Use 80C M6502 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 128-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...

OSI

400 SYSTEM
Based on 6502 MPU. CPU board comes with monitor in PROM. 1k RAM, 6850 ACIA, all ports to interface with TTY (less power supply)...

413A. Same using 6800 MPU...

410Z. Same using Z-80 MPU, populated...

420. Memory board, unpopulated...

430. Super I/O board, A/D, unpopulated...

440. Video graphics board, unpopulated...

480. Backplane board...

460. POP-8 emulator board, unpopulated...

300 TRAINER
Basic training package, featuring 6502 MPU: 128 words of RAM: input port and output latch; laboratory manual...

Battery Eliminator...

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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. Kit $39.00
MP-S. General-purpose serial interface. Kit $35.00

SYSTEM 310
Consists of CPU with 6800, 1k PROM, 4k dynamic RAM, 8/I lines, 2 interrupt lines. RS-232-20mA serial interface, real-time clock, power-on reset. The CRT module displays 16 lines of 32 characters with a 5 x 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

JUPITER II
The CPU-125 module contains the 6800 MPU plus support electronics: clock 1 μs, but may vary depending on device being addressed, seven vectored interrupt levels, DMA 32-bit refresh clock, automatic reset on power-up. The debugger and monitor is on up to three 1024-byte EPROMs (pinned 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. MPU module. Kit assembled. $179.95/$280.00
SMC-125. System module cage Kit assembled. $195.95/$260.00
CPS-125. Power supply. Kit assembled. $149.95/$180.00
CFP-125. Front panel. Kit assembled. $39.95/$52.00
SDM-125. Software debugger and monitor. Kit assembled. $109.95/$205.00
SDM Control EPROMs. 2k for serial devices. Kit assembled. $529.95/$545.00
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 III
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 x 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

HAL

DE-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. Kit assembled. 1552 characters in 16 lines of 72. Has RS-232 and current-loop ports. Baudot from 45 baud (80 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 x 7 dot matrix. Keyboard: 52-key ASCII shift, control.

n-rollerover. Quick Brown Fox test message, programmable character string to 255 characters. Bell tone provided. Scrolls from top down. Full cursor control, word wrap-around, line control, word break. RS-232-D asynchronous interface. Kit assembled. $185.00

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-bit) codec. Has RS-232 and current-loop ports. KSR version 110 to 1200 baud. 150 baud available on RO model. Word format is ASCII 10 character code, parity odd, even or none. Video 1-volt neg sync, 6.1-MHz bandwidth, timing is crystal-controlled. Display is 1280 characters in 5 x 7 dot format. 16 lines by 60 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-D level. Bell tone is provided. Keyboard is 52-key standard ASCII with shift, control, n-rollerover.
for 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, inter-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-voit. neg sync. 75-ohm output. 3.1 MHz bandwidth. Display is 1000 characters on 5 x 7 dot matrix, 25 lines at 40 characters per line, 26 alphabet, 10 numeric, 16 punctuation characters.

$175.00

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. ASCII format, generates 102 ASCII characters. Displays 32 characters on 16 lines with 5 x 7 dot matrix, 64-character repertoire, scrolling. 14 W x 12 D x 31/2" H $400.00

66d. Same with 64 characters per line. $475.00

INTELCOLOR 8001 COLOR TERMINAL
Intelligent terminal, full color display on 19 diagonal CRT screen. 80 characters per line, 25 lines per page. 64 ASCII characters, 5 x 7 dot matrix, white blinking underscore and underscore cursor, non-destructive: eight color levels (red, green, blue, magenta, cyan, yellow, white, black), seven

bit-transfer rates, from 10 to 9600 baud, keyboard selectable. MTR is 8080, 4096 bytes of EPROM (0000 to 127F). 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 cursor 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...$60.00

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, B5010 OS and debug ROM...$135.00

Option 40, Text editor and assembler...$135.00

Option 42, BASIC ROM...$339.00

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 x 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-223C interface. An auxiliary RS-223C port is optional for interface with a tape recorder, printer, etc. Speeds range from 7 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 x 15.5" W x 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 to the telephone via a direct-access adapter. Operates in both half-duplex (unidirectional) or full-duplex (bidirectional) 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 x 7 dot matrix, 75 lines per minute, 40 columns. Software control permits printing at standard width (12 characters per inch) or extended width (6 inches). 64-character ASCII set. 6 lines per inch vertically. Paper guides adjustable for paper widths from 214 to 41. A TTL 8-bit parallel "handshake" interface is compatible with most parallel I/O ports. Provides for optional line termination resistors when long cable used. Self-test feature in interface design aids in system development. Requires 115 volts a.c. Size 13" W x 13" D x 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 true-standing terminal type, can be used with a microprocessor. Size 22" D x 17" W x 14" H, weight 35 pounds. Kit assembly $695-$895.00

Numeric Keypad
$20.00

Up/Down Cursor Option
$50

MITS-8A. Update to MTS-8. Kit assembled
$535-$635.00

MITS-8 INTELLIGENT TERMINAL
Consists of VT-1920 video terminal plus 8080 microprocessor, 1x 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

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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 PCB boards that fit the Altair/imsai, connects to the disk drive via a 37-pin connector. The 88-CDDD consists of the disk controller and one disk drive. Kit/assembly $1480/$1960.00

88-DISC. Additional disk drive, in cabinet $1160/$1600.00

ALTAIR 110 LINE PRINTER
Desktop line printer. produces 80 columns of 5 x 7 dot-matrix characters at 100 cps (70 lines per minute). Control electronics are on a PCB card that fits the Altair/imsai bus. Kit/assembly $1950/$2125.00

Same with pin-feed option. Kit/assembly $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 880b. Display case is connected by cable to separate keyboard case. Display: 14 W x 11 1/2 D x 5 H; keyboard: 14 W x 7 1/2 D x 2 1/2 H. Kit/assembly $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/assembly $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/assembly $74.50/$95.00

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 8080-based system. Minimum storage capacity 256 bytes, average access time 84 ms. Kit $694.00

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 x 9 1/2 W x 4 1/2 H. Cabinet: keyboard, video monitor not supplied Kit $175.00

KBD-S. ASCII keyboard and encoder. 56 keys. Kit $49.95

CT-P. Power supply. Kit $19.95

CT-S. Serial interface (110 baud). Kit $39.95

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at 20 mA, 12 V at 20 mA, 6 V ac at 20 mA. Dimensions with plug-in boards, 12 D x 9 1/2 W x 4 1/2 H. Cabinet: keyboard, video monitor not supplied Kit $175.00

KBD-S. ASCII keyboard and encoder. 56 keys. Kit $49.95

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CT-50: 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-S, 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 programmer; computer allows fixed or moving images. Data can be loaded in less than 2 μs. Image reversal for white on black or reverse standard 255-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 8000 or 6800 machine. Does not include chassis or video monitor. Programming allows display of graphics, CT-1024 alphanumeric, 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 16x300-baud clocks. In addition to manual cassette-recorder controls, the automatic record, play, and even motor controls may be picked off ad-joining 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 12 1/2"W x 12 1/2"D x 3 1/2"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 3¾ adding-machine paper. Has internal 40-character line-buffer memory. Printing takes place at carriage return or when line-buffer memory is filled: 5 x 7 dot-matrix impact printing. Accepts data up to one character per millisecond 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 10 1/2"D x 9 1/2"W x 8 1/4"H......................... Kit $250.00
PR-4L: Extra ribbon..................................................................................................... $5.00
MP-L: Interface for SWTP 6800 computer.......................................................... Kit $35.00

WINTEX
B-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

x 7 dot matrix; screen size is 9Ó diagonal; 16 rows of 80 characters; scrolling; cursor is solid, non-blinking. Keyboard cabinet size is 13"W x 10"D x 3 1/2"H; monitor cabinet is 13"H x 10"W x 10"D.......................................................... $875.00
B-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/matsi-8800 bus compatible board. Stores programs up to 8K, including 8K BASIC; provides independence from power turnoffs; takes 500 mA from 8-volt line; no keyboard needed with special 2704 PROM that transfers contents of RAM into ByteSaver. 8KBS-K kit/8KB-S-W assembled.......................................................... $195/$295.00

DAA INTERFACE FOR D 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

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for computer output; one 8-bit parallel I/O port. Plugs into Altair/ImsaI data bus. Applications in-clude interfacing analog controls such as poten-tiometers or joysticks to computers or using a computer as a music synthesizer ...... $245.00

DIGINAL GROUP
280 CPU CARD
Based on Z8028 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. 280-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/$339.00

DUTRONICS
8K/8S 8K MEMORY
8k memory for Altair-8800/ImsaI-8800 bus: uses 500-ns static n-channel RAM IC's; power require-ment is less than 225 mA per 1k words; worst case is 250 mA per 1k words; 9V battery included. includes 25 MCM available from any 8-bit systems: word; low-profile sockets included ............... $285.00
4K/8S. 4k memory, expandable to 8k with 4 KAST $150.00
4K/8K 4K expansion kit to 4K/8S $129.00
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-8800, draws 150 mA (typically) from the 5-V supply. Static memory, requires no refresh or warm start; can be powered by standby batteries to retain data during power interrup-tions or for extended periods of time. Kit $350.00

GOBDOUT
ECORAM 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

MD 2046-4 STATIC RAM CARD
Altair/ImsaI plug-in compatible, 4k on a 16k board, permits 16k total in one motherboard slot. Kit $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
2510(R) 10 BOARD WITH MONITOR
Plug-in for Altair/ImsaI computers; compatible with any 8080 system. I/O board contains all building blocks: loads, dumbs, and end of data format; a UART interfaces with a terminal; a UART interfaces with one or two cassette re-corders. Accepts any of 8 commands to: load ocaT from any address, load hex from any address, load BASIC, examine an address and cor-rect the data, dump in hex, save on cassette (with parity check), load from cassette (with parity check), erase cassette on/off. Runs at different baud rates. Kit/assembled ............... $140/$170.00

PROCESSOR TECHNOLOGY
VDM-1 VIDEO DISPLAY MODULE
Altair-8800/ImsaI-8800 bus compatible. 16 lines of 64 characters, upper-case characters can blink 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 VT character to bottom of display. Solid video inversion cursor can be blinkk at 0.5-second intervals. Output is EIA composite video 1-Vpp, 75 ohms, 6.7-MHz bandwidth. Display can be scrolled up or down. Any k pg may be selected for memory address it 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 .......... $199.250.00

8K/4K 8K STATIC MEMORY MODULE
Static RAM memory board, non-volatile data lines; noise-immunity circuits; dual-line switch for address selection; battery back-up option; low-profile IC sockets; 500-ns cycle time; fits Altair/ImsaI-8800/ImsaI-8800. Kit $295/$359.00
4K/8K 4k static memory module. Kit/wired .......... $139/$150.00

3P - INPUT/OUTPUT MODULE
Altair/ImsaI-compatible board. Two 8-bit parallel ports, standard TTL level, one 4-bit (8-pin) parallel bus. has 8 simultaneous input lines. Kit $199.00

2K Mario MEMORY MODULE
Accepts up to 8 EPROMs (12752 or 5203) to provide 2048 8-bit words of non-volatile storage. Static operating mode; access and cycle times de-pend on EPROM used; will work from 30 to 2500 ns; Altair/ImsaI compatible: wait-state selection; low-profile sockets. Kit/wired .......... $65/$69.00

AL-58/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, assem-bled; or simulated; any selected input device can be used; files can be appended, moved, re-numbered, taken apart, or linked together, and crashed files can be restored. Assembler in-cludes labels, conditional 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 scan-naled up to 1000 lines per minute when used with VDM-1 $95.00

SCIENTIFIC RESEARCH INST.
REAL-TIME MULTIPLEXER MODULE
Interfaces 16 real-time sensors to computer via single I/O port. All channels read, write two chan-nels. Unity gain; 10 volts maximum per channel; 10-µs switching time; ±100-ohm impedance; less than 50-ohm output impedance. Kit $79.50
Extra input channels (each) kit $14.95
Connector $6.50
8-PIN PC Board for Altair 8800 $21.60
Connector for 8-pin PC board $6.50

REAL-TIME A/D CONVERTER
Uses tracking A/D conversion. Resolution is 10 bits (binary). Linearity and resolution (vols) 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/s. Maximum bandwidth 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 ex-panded to eight. Logarithmic compression for up to 7 octaves. Input sensitivity greater than 10 µV; frequency response, 10to 3 KHz; output voltage, ±5 volts; adjustable gain ±50 to 80 dB; drift, less than 4 mV/°C; SVRR, ±0.5%. 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 sec-ond (200 bytes per inch), 187 bps for ANSI standard 800 bpi, 380 bps for Kansas City standard. Phase- encoded, self-clocking. Works with most audio cassette units, may be adapted to automatic digi-tal cassette units, will also work with reel-to-reel tape recorders. Tape should be goold-quality tape. Load time for 8k bytes: 15 s at 540 bps, 43 s at 187 bps, 4 minutes at 380 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/0 subroutines, bootstrap, Kansas City and ASCII 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 converters, multiplexers and relays. Pre-ench-punched with 0.042" diameter holes on 0.1" cen-ters, so DIPs can be placed in any location. Typi-cally, board holds both 40-pin DIPS, eight 24-pin DIPS, or 40 ICs and 40 DIPs. Sockets for discrete devices and ribbon-wire connectors. Column and row DIP zone-ordinates, plus column and row-hole designators, embedded into the laminate. Power and ground planes on opposite sides of board. Two copper heat-sink positions. Size is 10" x 5.313", with 100 connector fingers (50 each side). Two low-profile, finned heat-sink supplied with each board. Kit $19.95

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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 pre-recognised prices. However, almost all manufacturers and dis-tributors 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 Fede-ral Trade Commission of the U.S. Gov-ernment has conducted investigations of the practices of certain industries, in fixing and adjusting prices, and has issued the following statement: 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. Accord-ingly, 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
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