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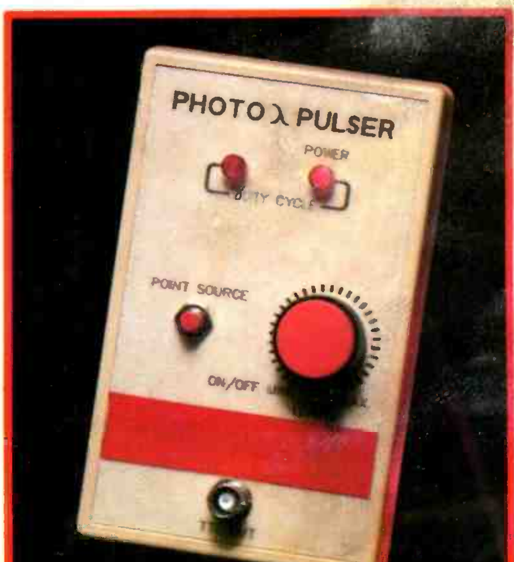
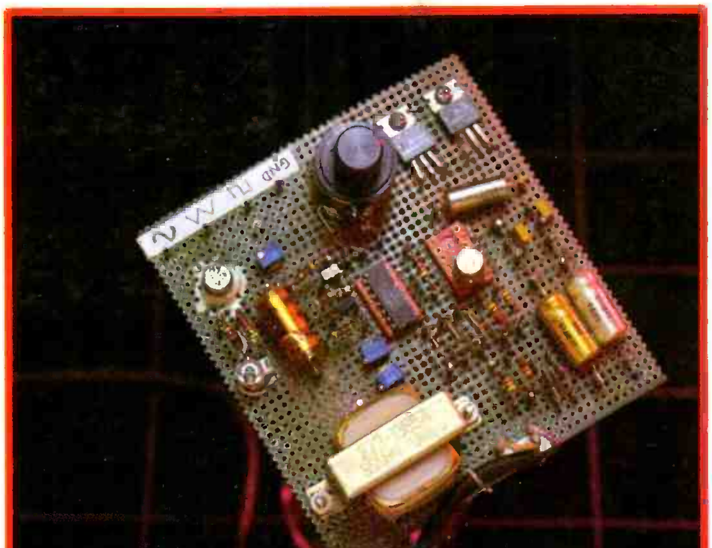


A Phototachometer for Frequency Counters (p. 32)

Delayed Trigger for Oscilloscopes (p. 18)



Low-Cost Function Generator (p. 54)

New Monthly Columns: ■ Solid-State Devices ■ Computer Capers

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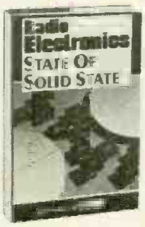

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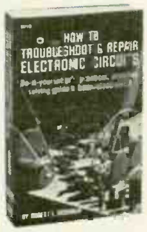

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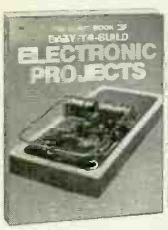

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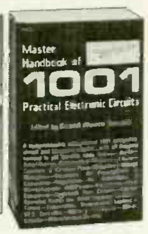

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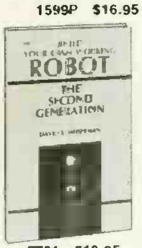

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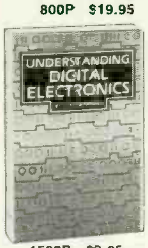

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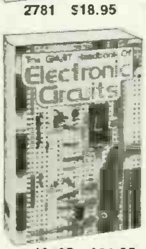

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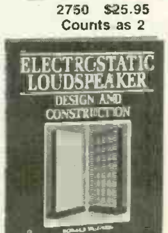

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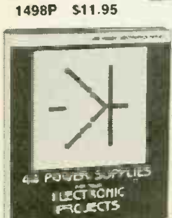

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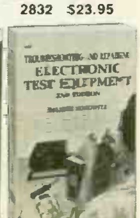

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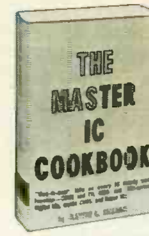

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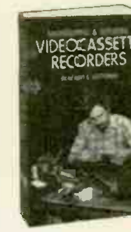

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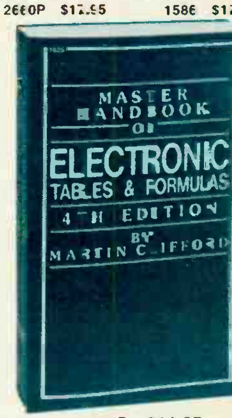

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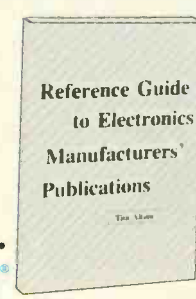

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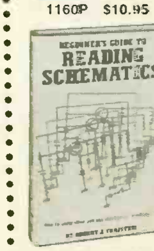

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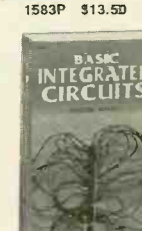

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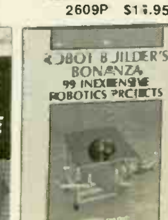

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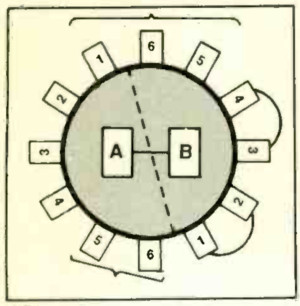
JANUARY 1988

VOLUME 5, NUMBER 1



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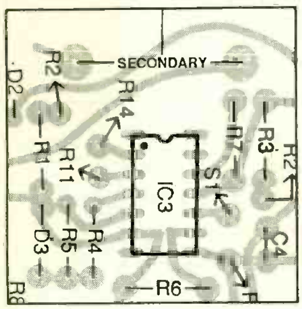

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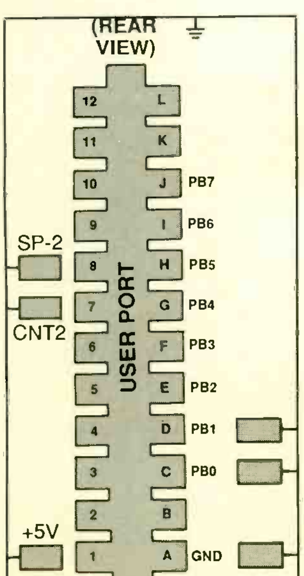

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COLUMNS

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EDITORIAL

Reader Feedback

Editors always relish receiving letters from readers, you should know; good, bad and challenging, it doesn't matter. This keeps us in touch with our readership, which has many mutual benefits.

For example, keen-eyed readers pick up on those tiny glitches in articles—"C1 in the schematic reads 0.1 microfarad, while the Parts List has it as 1.0. Which is correct?"—that somehow escape our proofreaders' (and editors' and authors') eyes from time to time. These reports are always posted in our next available "Letters" department. We thank you thoughtful people for sharing these discoveries with all of us.

Readers' letters also let us know what subjects they'd like us to cover in the future, which articles they liked best, etc. Similarly, advertised and editorialized products circled on the postpaid Free Information Service card bound into every issue point out what product areas are most popular. We get biweekly itemized reports on this, which serves as especially fine guidance from respondents. At the same time, advertisers get mailing labels from us with the names and addresses of readers requesting more information about their products. This eases their mailing chores and speeds data to our readers.

Naturally, we also get letters requesting customized electronic designs for some purpose: "I'd like to build a circuit that would . . . . Could you send me a schematic?" We cannot generally provide such consultation work unless we've published a project that coincidentally meets the need. Nor do authors have the time to do this. We will, however, pass on any inquiries to an author if a stamped, self-addressed envelope is provided. It's up to them whether or not to respond, though. If something relates directly to their project, they often do. But, please, no consulting-design requests.

Requests for parts sources inundate our mail room, as you might imagine. If a stamped, self-addressed envelope is provided, we'll normally respond if it relates to parts from a project we published. Too many such queries concern parts that are not obtainable locally, though. We simply don't know which parts supply stores in one's neighborhood carries what parts. The country's too big for us to help here. The way to go is mail-order, of course. That's why you should scour the parts listings of advertisers in *Modern Electronics*, and why you should gather as many current mail-order company catalogs as possible, getting updated ones from time to time. It was a waste of time for all concerned, for example, to get a batch of reader letters seeking a parts source for two devices in a recent *Modern Electronics* project when one of our advertisers in the same issue, DigiKey, had them listed in its ad.

Finally, we also get lots of letters from readers seeking obscure or hard-to-obtain parts, schematics, a piece of used equipment they'd like to buy, sell or trade, etc. In most cases, we haven't been able to help. Nevertheless, there's obviously an important need here that has not been satisfied. Therefore, starting in the near future, we will publish FREE OF CHARGE non-commercial classified ads, maximum of three lines, for subscribers so that our vast number of readers can help out each other. A recent *Modern Electronics* mailing label must accompany the copy. Such free personal ads will be published on a space-available, first-come/first-served basis.

Let's hear from you soon.

Art Salsberg

Hard At Work

• I enjoyed your review of the "Chessmaster 2000" game program in the December 1987 issue. Your review was right on target from what I have seen of this marvelous game. But you overlooked the most significant feature—at least, from the perspective of the employees in our office. We have found that <Alt–P> is by far the most useful command of this program.

Peter R. O'Dell
St. James, NY

You're right! The hot key instantly substitutes a business-like spreadsheet on the screen.—Ed.

Communications Feedback

• Chuck Steer's "Communications" column in the September 1987 issue was particularly interesting to me, having operated similar transmitters over the past five years. However, there were several shortcomings in the discussion of FCC Regulations, and the collector and emitter of Q2 are shown reversed in the schematic diagram.

Section 15.111 of FCC Rules permits license-free operation over a wide range of the vlf spectrum, but limits field strength to a distance of 300 meters. This limit is less than the 50 microvolts per meter stated for the 1,700-meter band. It poses problems for DX and is hard to measure for purposes of rule compliance. Section 15.112 specifies frequencies from 160 to 190 kHz—not 170 to 190 kHz as stated. The *input* power to the final stage is limited to 1 watt, not the output power. Signals outside the 160-to-190-kHz range must be at least 20 dB below the carrier level, which includes spurious signals, harmonics and sidebands! The choice of operating frequency must take into account the type of modulation used. So 161 to 189 kHz would probably be safe for code, and low-pass-filtered (to 3 kHz) voice could be used with frequencies of 163 to 187 kHz. However, unfiltered voice and music would require a carrier frequency close to the center of the band to prevent out-of-band emissions.

Overall, this was a fascinating project. The CMOS oscillator and driver and the switch-mode final amplifier make this design cleaner and more efficient than earlier designs. With lower static and better propagation coming up in the winter months, communications enthusiasts should really enjoy working with it.

John H. Davis
Warm Springs, GA

Author Updates

• Those readers who would like to obtain a printed-circuit board with improved layout and ground plane for the "Frequency-to-Voltage Converter" featured in the November 1987 issue of *Modern*

(Continued on page 71)

FAX GOES PUBLIC. The use of facsimile machines to transmit and receive documents, which is expanding rapidly, will be getting an extra boost if US FAX Inc. has its way. The company announced plans to place more than 2,000 public fax machines in hotels, airports, quick-print shops and other retail locations in 1988. Its nationwide fax transmission system will be used, employing digital packet-switched communications technology that is said to make it cheaper to communicate via fax than over telephone lines. Subscribers to US FAXSYS ($10/month; $2/month charter subscribers) can transmit a three-page document from Boston to Los Angeles, for instance, at a reported cost of only 24 cents vs. 91 cents charge over voice phone lines that carry fax traffic today. Subscribers can, of course, receive and send messages to non-subscribers. Each subscriber is also assigned one or more electronic mailboxes that can be accessed from any fax machine in any location.

EEPROMS IN A FLASH. Commonplace ultraviolet-erased EEPROMs can be expecting a challenger soon in the form of the FLASH EEPROM. Through an agreement between SEEQ Technology and National Semiconductor Corp., a line of pin-compatible FLASH EEPROMs will be marketed, starting with SEEQ's 128-Kb NMOS device up to SEEQ's 1-Mb CMOS device. Each company will serve as a second source to the other. The FLASH devices can be electrically erased and reprogrammed in less than one minute compared to the 20 minutes required for a UV EPROM. Additionally, the erase/program process of the FLASH can be achieved in a single step using one piece of equipment, while the UV type requires a two-step cycle with several pieces of equipment.

ARTISTIC VCR'S. Sony Corp. introduced three SuperBetamax VCRs that incorporate digital video-processing circuits that can turn a user into a video artist. The digital machines can fill a TV screen with 9 or 16 separate images that can be updated in six discrete time periods. A zoom feature enlarges selected picture areas up to four times normal size. Special effects can be generated, too, such as solarizing a picture's color. Also, a picture within a picture can be inserted in a TV screen's corner.

COMPUTER AIDS. Learning Odyssey is shipping its first computer-aided instruction program for teaching computer-aided design (CAD), a booming computer application area. Called "Basic CAD Operations Course," it works together with the "Junior Drafter" PC CAD software, providing 60 hours of on-line instruction in CAD and mechanical drafting. It's the first of ten educational CAD programs being readied. (For more info, call 619-488-0533.)...Plies Development Corp.'s Quikinfo software ($49) for engineers, techs and scientists converts any number in the equivalent unit of another measurement system, such as horsepower to kilowatts. Containing hundreds of conversion equivalents, grouped by category, the memory-resident, low-cost pop-up software can be called from within any application program such as Lotus 1-2-3. It runs on IBM-compatible machines and occupies 80K of memory. (713-493-3679 for information.)

SW AID FOR AIDS. The BBC World Service had an AIDS disease phone-in over its shortwave transmissions that gave listeners a chance to question a leading medical expert on the health problem. Calls to a London phone number and Q & A's were broadcast worldwide. The one-hour phone-in was preceded by a 30-minute documentary on the disease.

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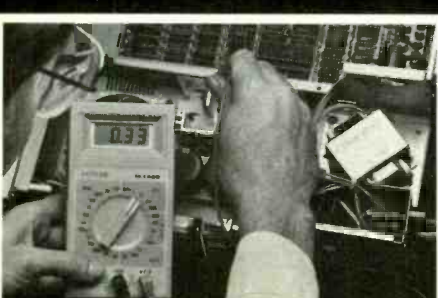
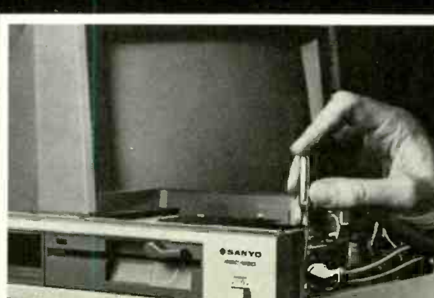


The power supply is assembled in the main unit of the computer. You check out keyboard connections and circuits with the digital multimeter included for training and field use.



Next, you install the disk drive. You learn disk drive operation and adjustment, make a copy of MS-DOS operating disk and begin your exploration of the 8088 CPU.

Using the monitor, you focus on machine language programming, an indispensable troubleshooting tool for the technician. You continue by learning BASIC language programming.

NEW PRODUCTS

For more information on products described, please circle the appropriate number on the Free Information Card bound into this issue or write to the manufacturer.

Beginner's Personal Computer

HeadStart from Vendex Pacific Inc. (Great Neck, NY) combines IBM PC- and XT-compatible hardware and a HeadStart operating environment designed for the novice user. The latter walks the user through the computer's operations and includes a most-used software package.

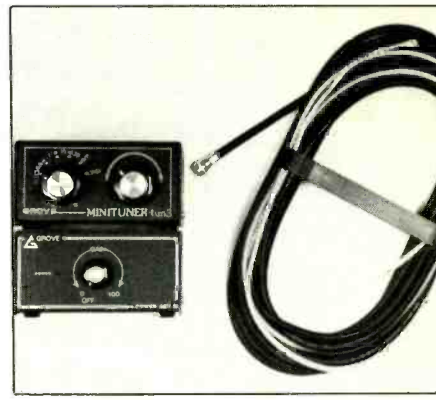
Turbo-888-XT is built around a 4.77/8-MHz 8088-2 microprocessor. It comes with 512K of RAM, battery-backed clock/calendar, two 360K 5.25-inch floppy-disk drives, seven IBM-compatible slots, one each serial, parallel and game ports, a floppy controller that handles up to four drives, high-resolution graphics card that is compatible with monochrome, Hercules and color graphics and a high-resolution TTL monochrome video monitor (color optional). The compact system unit can accommodate an optional hard-disk system and a 3.5-inch microfloppy-disk drive. Also included are MS-DOS and the HeadStart operating environment.

Software bundled with the system include: The Executive Writer and The Executive Filer from Paperback Software, MyCalc from Software Tool Works, the ATI Interactive Trainer and a custom version of HOT, a Desktop Manager from Executive Systems. $995.

CIRCLE 10 ON FREE INFORMATION CARD

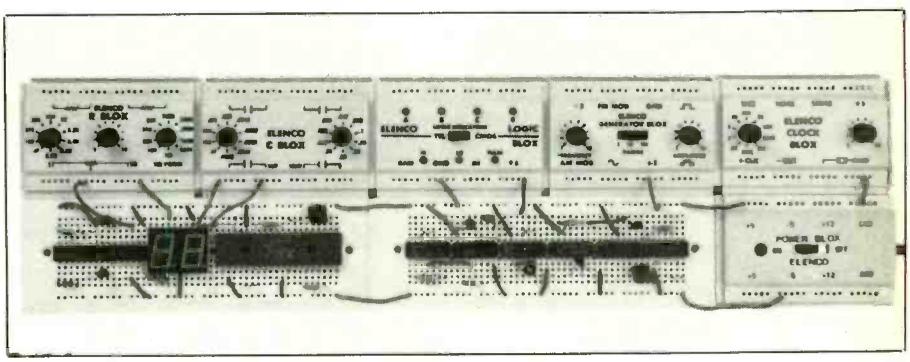
Hidden Antenna System

The "Hidden Antenna System" from Grove Enterprises (Brasstown, NC) combines a flexible antenna with a 30-dB-gain preamplifier for continuous 100-kHz to 1,000-MHz receiving applications, making it ideal for indoor shortwave, long-wave and vhf/uhf scanner listening, even TV and FM reception. Two output connectors permit simultaneous use of two receivers on the same



compact antenna system. A separate preselector is also available to eliminate shortwave intermodulation and image interference in particularly troublesome installations. $48 to $100, depending on options.

CIRCLE 11 ON FREE INFORMATION CARD



Breadboard Test Equipment

Everything needed to support breadboarding designs is one way to describe Elenco Electronics' (Wheeling, IL) Function Blox line of Breadboard Test Equipment. The Bloxs are designed to interlock with the original breadblox for a unique and inexpensive way of obtaining test equipment. Six different Function Bloxs are available: a dc regulated power supply, Function Generator, Logic Probe, Digital Clock, Resistor Decade box and Capacitor Decade box.

Outputs from the dc Power Supply Blox are +5 volts at 1 ampere, −5 volts at 0.4 ampere and +12 volts at 0.3 ampere. All supply lines are fully regulated and short-circuit protected. The Function Generator Blox provides sine, sawtooth and square waves from 0.1 Hz to 1 MHz, with amplitude or frequency modulation capability. The Logic Probe Blox has four logic level indicators and a standard logic probe. The Digital Clock Blox provides a square-wave frequency of 1 Hz to 50 MHz and includes crystal-locking capability. The Resistor Blox provides 20 different resistor values plus a 100,000-ohm potentiometer. The Capacitor Decade Blox provides 20 different capacitances from 47 picofarads to 10 microfarads.

All function Bloxs have eight solderless-connector slots that each consist of five contact points. Each accepts 20- to 26-gauge wires and component leads. $14.95 to $24.95.

CIRCLE 15 ON FREE INFORMATION CARD

Digital Storage Oscilloscope

Featuring a 60-MHz storage bandwidth, Tektronix's new Model 2221 digital storage oscilloscope adds measurement cursors and readout to a 4096-point record, averaging, and 100-ns peak-detect capabilities. This combination full-featured analog/digital-storage oscilloscope also offers accumulated peak-detect (enveloping).

Along with measurement cursors and more signal processing, the Model 2221's 4096-point record length features 100-ns peak detection. The 4096-point record equals four end-to-end scope displays, which quadruples time resolution over typical 1024-point DSOs and provides higher definition for biomedical, mechanical vibration and single-shot or low-duty-factor waveforms. Peak detection ensures at least one sample on noise or switching spikes as narrow as 100 ns for digital design and troubleshooting where narrow spikes or fault conditions are often missed with conventional scopes.

Waveform sampling is done as a 20-megasample/second rate. A separate reference memory can be used to store 4096-point single-channel captures or for dual-channel 2048-point records. Voltage and time cursors can be included on any stored waveform.

All waveform captures are supported by pre- and post-trigger capability. Other modes include signal averaging, accumulated peak detect (envelope mode), X-Y mode, and scan and roll modes on sweeps slower than 0.1 second/division.

For stored waveform output, the scope comes with X-Y plotter connections and pen-lift control. GPIB and RS-232C interfacing options are available for direct waveform output to a printer or plotter or for instrument control and waveform transfers to a computer. $3995.

CIRCLE 16 ON FREE INFORMATION CARD

Digital VHS VCR

Nine-picture channel search, picture-in-picture (P-I-P), freeze frame and digital strobe special effects highlight Sharp's new Model VC-D800U digital videocassette recorder. This VCR nine-channel picture search displays still pictures of programs on nine stations. P-I-P permits simultaneous viewing of a TV program and video tape by insetting either image in any corner of the TV screen so you can watch a prerecorded tape and still keep tabs on what is going on on a selected channel.

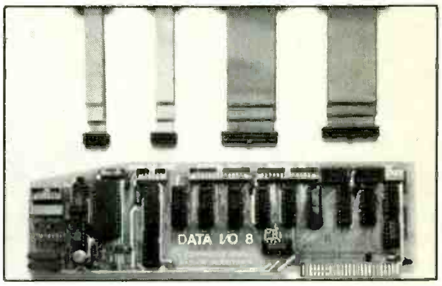
A simple record timer features a return function that enables you to simply set the VCR to record an ongoing program. When a recording is completed, the tape automatically rewinds to the beginning of the recorded segment for easy playback.

On-screen display simplifies programming by prompting you through the process of setting channel, week/day, start time and length, and recording mode for four programs. Other features include: a Blue Screen Noise Elimination system mutes the audio and turns the screen blue at the end of a tape; HQ and double comb filter for superior picture quality; 14-day, 4-event programmable timer with daily/weekly repeat; 35-function wireless remote controller; 110-channel PLL synthesized random-access tuner; and automatic power-on, rewind, play and repeat functions. $549.95.

CIRCLE 17 ON FREE INFORMATION CARD

Analog/Digital I/O Board for Apple Computers

Naylor Industries' (Indianapolis, IN) Data I/O 8 is an analog and digital interface card for Apple II, II+ and IIe computers. It provides eight channels of analog inputs (eight bits, 2.5-microseconds and 0 to +5.10 volts) and eight channels of analog outputs (eight bits and 0 to +5.10 volts) as well as 24 TTL-level digital input bits and 24 TTL-level latched digital output bits. The card allows the computer to make electrical measurements, send and receive control signals and generate waveforms for industrial, scientific and educational applications.



The Data I/O 8 is easily programmed in BASIC and, for maximum speed, assembly language. It comes with a 40-page manual that contains eight software examples of BASIC programs, 11 specification tables and a glossary. Also included are four cables that bring the signals from the card to the back of the comuter. The card is designed to be installed in any slot 1 through 7. $295.

CIRCLE 18 ON FREE INFORMATION CARD

Trigger-Grip Solvent Applicator

Micro Care Chemical Corp. (Farmington, CT) has announced the Trigger Grip Applicator, a reusable remote sprayer for spot defluxing of printed-circuit cards and cleaning electronic assemblies with the company's solvents. Made of aircraft-quality aluminum and rugged nylon, Trigger Grip is equipped with an Omniglass™ heat shield to protect the feeder tube from hot soldering iron tips. It attaches directly to the valve orifice of solvent aerosol cans. The grip is designed for operator comfort and to increase control while in use.

Fresh solvent constantly flows through a brush to eliminate contamination that occurs with traditional swab-dipping and brush procedures. Strong, dense white nylon or natural bristle Spray Thru brushes insert into the Trigger Grip assembly. The brushes are replaceable when worn out and can be trimmed for cleaning hard-to-reach places. An optional bench mounting kit that keeps the Micro Care Solvent System and Trigger Grip applicator off the workbench but close to the operator is also available.

CIRCLE 19 ON FREE INFORMATION CARD

Telephone Switcher

AutoSwitch TF 4 from Command Communications, Inc. (Denver, CO) is a telephone switcher that permits remote access to and control over three different telephone devices that are all connected to a single telephone line. Especially designed for facsimile machines, the TF 4 incorporates a special circuit that automatically recognizes an incoming FAX carrier signal and directs the call to the receiving FAX machine.

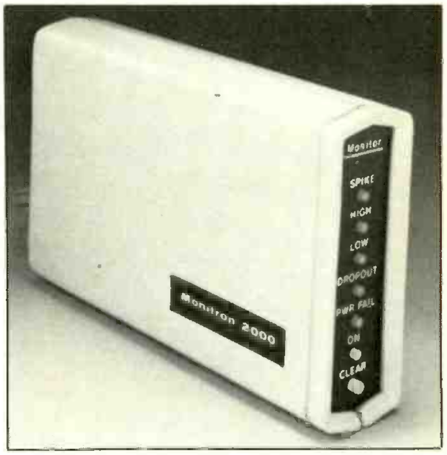
This patented branching device is claimed to eliminate the need for installing a dedicated telephone line

just for FAX or for other telephone-activated peripheral equipment. If a dedicated line is already in use, the TF 4 can further expand usage of the line by providing a private voice mailbox (answering machine), access to a FAX machine and one other additional telephone device. Equipment that can be used with the switcher include such items as a computer modem, order-taking system, information announcement system, and any other telephone-related device. The TF 4 offers many connection arrangements and provides greater usage of a standard telephone line, with or without a key system. It comes with modular connectors for easy installation.

CIRCLE 20 ON FREE INFORMATION CARD

Voltage Disturbance Early Warning Device

A low-cost power-line monitor that detects and classifies power-supply irregularities that can adversely affect computer software, hardware and data integrity has been announced by Mendon Electronics Corp. (Pittsford, NY). The Monitron 2000 features individual single-function LEDs that are clearly labeled for spike, high voltage, low voltage, dropout and power failure. A dual mode off/on LED indicates the unit's operational status: green for normal continuous operation or flashing red to indicate power resumption after a blackout. (All fault detection trigger points are factory set in accordance with ANSI standard C84.1.) A Clear button resets the unit and automatically provides full-function testing of all electrical circuits and LEDs.



Monitron 2000 responds to a voltage disturbance or power interruption in 0.5 microsecond, identifies the source and locks on the appropriate LED until the Clear button is pressed. It monitors all 117-volt ac power-supply lines at a range of frequencies in accordance with IEEE 587 Category A standards.

With its own desktop stand, Monitron 2000 can be placed anywhere within a work station where it provides continuous visual access for checking its functioning status and power supply condition. Velcro mounts can be used to secure it to a computer terminal, power filter or auxiliary power supply.

The product is mounted in an ABS plastic case that measures 5″D × 3″H × 1″W. $299.

CIRCLE 21 ON FREE INFORMATION CARD

Clock/Calendar Module

Integrity Technology's (Milpitas, CA) PC-Clock Calendar module is designed to be used in IBM PC, XT, Personal System/2 Model 25 and compatible computers without occupying an expansion slot. The mod-

(Continued on page 84)

A Delayed-Trigger Accessory for Oscilloscopes

A low-cost way of adding a laboratory-grade facility to inexpensive general-purpose oscilloscopes

By Jan Axelson & Jim Hughes

Laboratory-grade oscilloscopes often include a delayed triggering capability that allows you to "hold off" the sweep until a specified time (which you select) after a trigger signal occurs. With this feature, instead of being limited to the trigger points available in a circuit, you can trigger at any time you choose. If your oscilloscope doesn't have built-in delayed triggering, you can add to it the circuit to be described to upgrade it at very low cost.

To use our delayed-trigger accessory, you need an oscilloscope that has an external trigger input or two channels, a signal to examine, and a signal on which to trigger. Delayed triggering is generated by an ICM7250 programmable timer integrated circuit. Width of the timer's output pulses, and thus the delay time, is fully adjustable from 10 microseconds to 300 milliseconds.

The Programmable Timer

This project uses a 7250 programmable timer integrated circuit whose outputs are optimized for decimal counting. By wiring selected outputs in an AND configuration, you can choose any pulse width from 1 to 99 times the width of the main timebase oscillator pulses. Our delayed trigger accessory takes advantage of this feature to provide several user-selectable delay ranges.

Figure 1 illustrates how the delayed trigger accessory can be used to extend the capabilities of an oscilloscope. Figure 1(A) shows an oscilloscope display of a square-wave pulse followed by a decaying, oscillating waveform. The sweep is triggered near the top of the main pulse. But what if you want to examine the oscillations more closely? Trying to trigger at a lower voltage will cause multiple traces, as in Figure 1(B).

Figure 1(C) shows how, with delayed trigger, you can have the oscilloscope's sweep begin at any point you select. The trigger is delayed so that the oscilloscope sweep begins at the point of interest in the waveform. Then the timebase can be expanded, as in Fig. 1(D), for more detailed observation.

You can also use delayed triggering to focus on a particular pulse in a stream of data. In this case the delay would be timed from a trigger signal—perhaps a "write" pulse—that occurs at a specific time before the pulse stream.

About the circuit

Shown in Fig. 2 is the schematic diagram, minus power supply, of the delayed trigger circuit. The circuit consists of three basic parts: comparator *IC1*, which senses the trigger voltage; flip-flop *IC2*, which triggers a timer; and programmable timer *IC3*, which outputs the delay pulse.

Action begins when a signal is connected to one input of LM311 comparator *IC1*, whose trip level is set by potentiometer *R1*. This trip level is adjustable from −15 to +15 volts. When the input at pin 2 of *IC1* goes higher than the input at pin 3, the output at pin 7 goes high. Switch *S1* transposes the two comparator inputs, permitting triggering on either

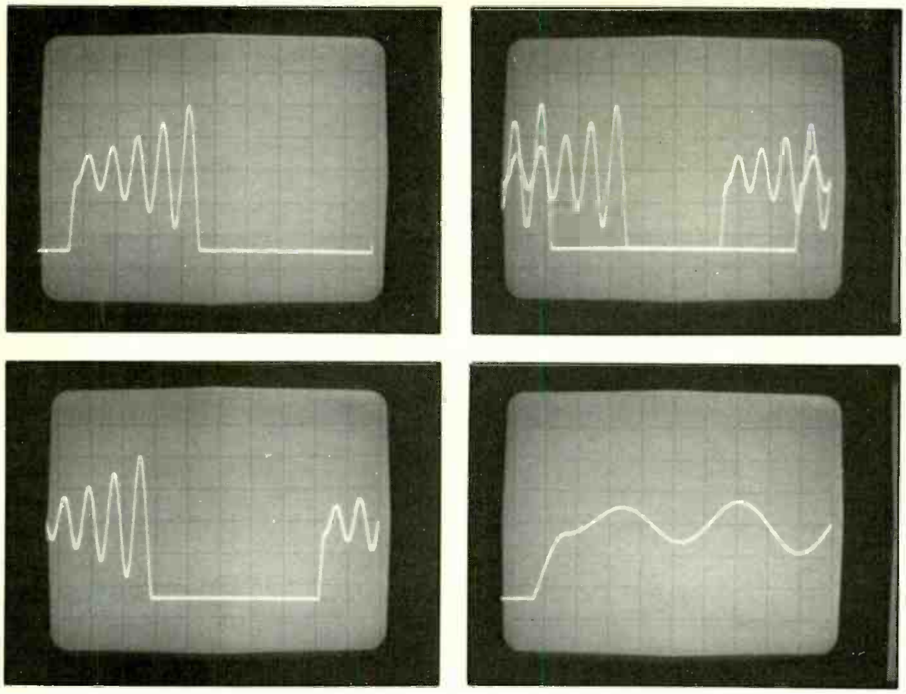


Fig. 1. Waveform (A) is triggered near the top of the main pulse. Lowering the trigger voltage results in the multiple traces shown in (B). Because the trigger signal is delayed in (C), the oscilloscope sweep begins at point of interest on waveform. For closer examination, timebase can now be expanded as shown in (D).

the rising or falling edge of the input signal.

Resistor *R4* provides hysteresis to give the comparator "snap-action" response, which is important for quick response to slowly varying inputs. Diodes *D1* and *D2* protect *IC1* against damage from inputs that are greater in magnitude than the supply voltages.

When pin 7 of *IC1* goes high, it clocks D-type flip-flop *IC2*, causing the Q output of *IC2* at pin 13 to go high. Capacitor *C3* then charges through resistor *R6*, resetting the flip-flop. The result is a 5-microsecond duration pulse that triggers *IC3* and prevents this timer from retriggering until the next time *IC2* is clocked. (Only half of *IC2* is used in this project. Inputs to the unused flip-flop on the chip are tied to ground to assure stable operation.)

Timer *IC3* is configured to operate in a monostable, or one-shot, mode. The pinout for the *IC3* 7250 programmable timer is shown in Figure 3. The IC's output, a single low-going pulse, connects to TRIGGER OUT.

TRIGGER OUT also connects to the trigger input (external or channel 2) on the oscilloscope with which this project is used. When TRIGGER OUT goes high, the oscilloscope sweep is triggered; so the width of the output pulse equals the delay time for the oscilloscope sweep. In addition, the timer resets and waits for another trigger pulse.

Width of the divide-by-1 output pulse at pin 1 of *IC3* equals the RC time constant of the components at pin 13. In this circuit, the RC timing components are *R7*, *R8* and *C4* or *C5*. When *IC3* is triggered with *C4* selected and potentiometer *R7* set for minimum resistance, the width of the pulse at pin 1 is 10 microseconds (10 microseconds is the product of *R8* times *C4*, which is 10,000 ohms times 0.001 microfarad.)

Four of the eight programmable outputs of *IC3* are used in this application. Each output divides the timebase-oscillator frequency by a specified amount, permitting programming of different pulse widths. Wiring together two or more outputs has the effect of ANDing the individual outputs so that an output goes high only when all connected outputs are high, and the output pulse width is the sum of all of the connected outputs.

Different pulse widths are selected by *S2*, *S3* and *R7*. The Table details the outputs that are available for each position setting for *S2*.

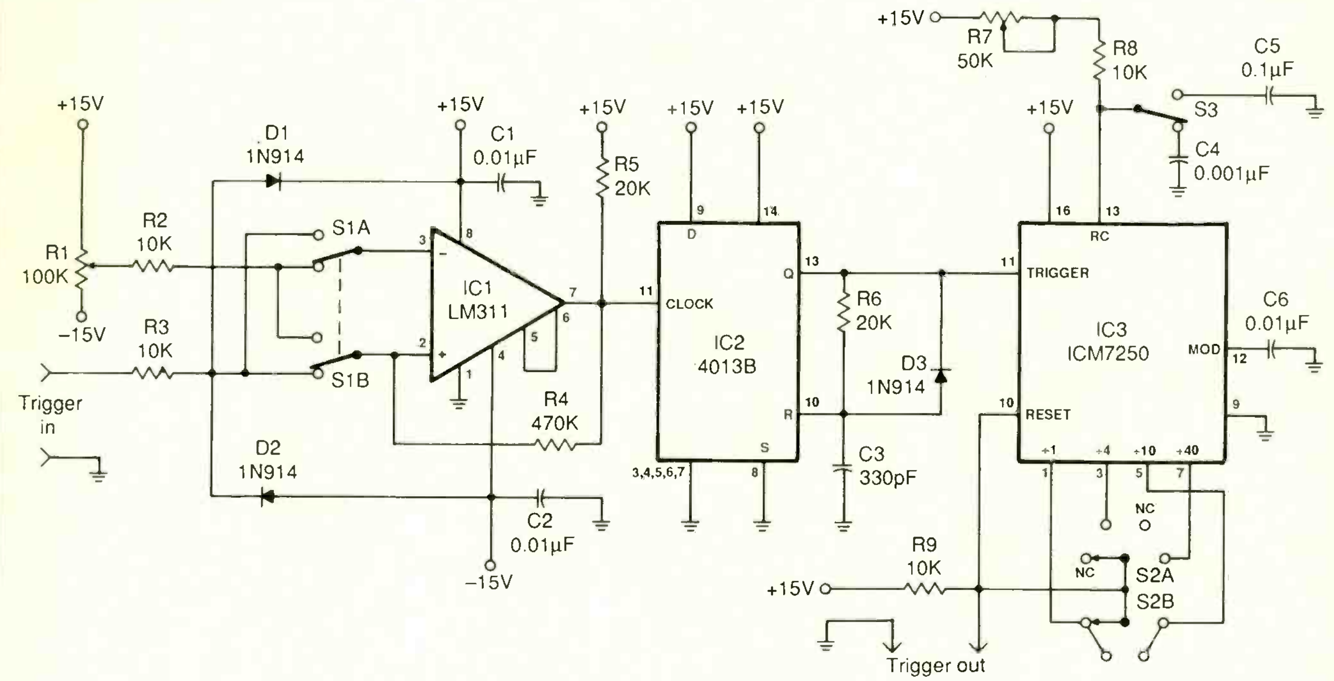
Switch *S2* is a double-pole six-position switch (only four positions are used) that is used to select different *IC3* outputs. With *S1* set to position 1, TRIGGER OUT connects to pin 1, the divide-by-1 output, and the output pulse goes low for 10 microseconds. In position 2 of *S2*, the divide-by-1 and divide-by-4 outputs are wired together to give a pulse width of 50 microseconds (10 plus 40 microseconds). Position 3 (divide-by-10) gives a pulse width of 100 microseconds, and position 4 gives 500 microseconds (divide-by 40 and divide-by-10).

By adjusting potentiometer *R7*, you can increase the width of the outputs by up to six times. The delay available at each position overlaps the range provided by the previous position, so any delay from 10 microseconds to 3 milliseconds is available.

For longer delays, *S3* is used to deselect *C4* and select *C5*. This causes the pulse width of the timebase oscillator, and thus the delay times, to increase by a factor of 100. The result is full pulse width, or delay time, adjustability from 10 microseconds to 300 milliseconds.

The bipolar power supply for the delayed-trigger accessory is shown schematically in Figure 5. This supply uses a 25-volt center-tapped transformer to generate the +15 volts and −15 volts required by the circuitry in the accessory.

Transformer *T1* steps down the 117-volt ac line potential to 25.2 volts and bridge rectifier *RECT1*



PARTS LIST

Semiconductors
D1,D2,D3—1N914 or similar silicon diode
IC1—LM311 comparator
IC2—4013B CMOS D-type flip-flop
IC3—ICM7250 programmable timer (ICM7240 can be substituted; see text)
IC4—78L15 +15-volt regulator
IC5—79L15 −15-volt regulator
RECT1—50-volt, 1-ampere bridge rectifier
Capacitors (25 WV minimum)
C1,C2,C6—0.01-µF ceramic
C3—330-pF ceramic
C4—0.001-µF timing
C5—0.1-µF timing
C7,C8—100-µF electrolytic
C9,C10,C11,C12—0.1-µF ceramic
C13,C14—10-µF electrolytic
Resistors (¼-watt, 10% tolerance)
R2,R3,R8,R9—10,000 ohms
R4—470,000 ohms
R5,R6—20,000 ohms
R1—100,000-ohm, linear-taper, panel-mount potentiometer
R7—50,000-ohm, linear-tape, panel-mount potentiometer
Miscellaneous
F1—0.5-ampere slow-blow fuse
S1—Dpdt toggle or slide switch
S2—2-pole, 6-position rotary switch
S3—Spdt toggle or slide switch
S4—Dpst toggle or slide switch
T1—25.2-volt, 450-mA center-tapped power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware; sockets for IC1, IC2 and IC3; suitable enclosure; pointer-type control knobs (3); fuse holder; ac line cord with plug; rubber grommet; labeling kit and clear acrylic spray (see text); ½-inch spacers; machine hardware; hookup wire; solder; etc.

Fig. 2. Complete basic schematic diagram of delayed-trigger accessory minus its +15- and −15-volt ac power supply.

changes the stepped-down ac voltage to pulsating dc. Because transformer ratings are given as rms voltage (0.7 × peak voltage), peak output from *T1* is actually about 36 volts, which is sufficient to enable using *T1* to generate potentials that can be converted to both +15 and −15 volts. Using *T1*'s center tap as a reference, *IC4* regulates the +15-volt, *IC5* the −15-volt supply rails.

Construction

Component values for this project are not critical. However, because the combination of *R7*, *R8* and *C4* or *C5* sets the delay time, components that are stable in value are recommended here. If available, use 1-percent precision resistors and temperature-stable capacitors, such as the Y5P series.

If you cannot obtain a 7250 programmable timer, you can substitute the ICM7240, which is nearly identical to the 7250 but has binary-coded outputs. For this project, the only difference between the two is in the delay ranges. With the 7250 the outputs selected at positions 3 and 4 of *S2* are divide-by-10 and divide-by-50. With the 7240 these will be divide-by-16 and divide-by-80. These

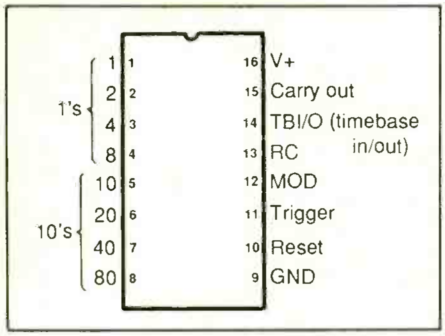


Fig. 3. Pinout for ICM7250 programmable timer integrated circuit.

will give slightly different, but still usable, delay ranges on the accessory.

You can fabricate a printed-circuit board on which to mount and wire the components, using the actual-size etching-and-drilling guide shown in Figure 6. Alternatively, if you prefer not to make a pc board, you can use perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware. Whichever method of wiring you choose, use sockets for the DIP integrated circuits.

Referring to Fig. 7, insert and solder the IC sockets—*not* the ICs themselves—into place. Set aside the ICs themselves for installation after initial checks have been made on the fully wired circuit. Follow up wiring the board with the capacitors, diodes and resistors, making sure to observe proper polarity for the electrolytic capacitors and the diodes. Then solder into place a bare wire at JUMPER, which can be either a cut-off resistor or capacitor lead or a length of stripped solid hookup wire. Install and solder into place regulators *IC5* and *IC6* in their respective locations, referring back to Fig. 4 for pinout details.

When you've finished wiring the circuit-board assembly, remove ¼ inch of insulation from 18 8-inch lengths of hookup wire. Plug one end of these wires into all unoccupied holes on the circuit-board assembly, except those labeled T1 and T1 C.T., and solder into place.

Next prepare the enclosure by drilling appropriate-size holes in the front panel to accommodate the four switches, two potentiometers and four jacks (see lead photo for details). Drill a hole through the enclosure's back panel to provide entry for the power cord and install the fuse block. Then drill the holes for mounting the circuit board and transformer in the case. Use a dry-transfer lettering kit or tape labeler to identify the front panel controls and jack. If you dry-transfer lettering to the panel spray on two or three *light* coats of clear acrylic to protect the lettering. Wait until each successive coat dries before spraying on the next.

When the acrylic spray has completely dried, mount the various controls and jacks on the front panel. Make sure the potentiometers and rotary switch are properly oriented so that their knob pointers are positioned properly for the panel markings.

Mount the fuse holder and power transformer in their respective locations inside the enclosure. Twist together the fine wires in both conductors at the end of the cord and sparingly tin with solder. Route the cord through the rubber grommet and into the enclosure and tie a knot in it inside the case about 4 inches from the end. The knot serves as a strain relief.

Solder one line cord conductor to one of the fuse holder lugs and the other to one toggle lug on *S4*. Then connect and solder a short wire between the free lug of the fuse holder and the other toggle lug of *S4*. Determine which of the power transformer's leads are to the primary (117-volt) winding and connect and solder these to the stationary-contact lugs of *S4A* and *S4B*.

Plug *T1*'s secondary and center-tap leads into the holes labeled T1

Delay Outputs Available

Switch S2 Position	IC3 Output(s) Selected	Delay (C4 Selected) in Microseconds (μs) Minimum	Maximum	Delay (C5 Selected) in Milliseconds (ms) Minimum	Maximum
1	1	10	60	1	6
2	1 and 3	50	300	5	30
3	5	100	600	10	60
4	5 and 7	500	3,000	50	300

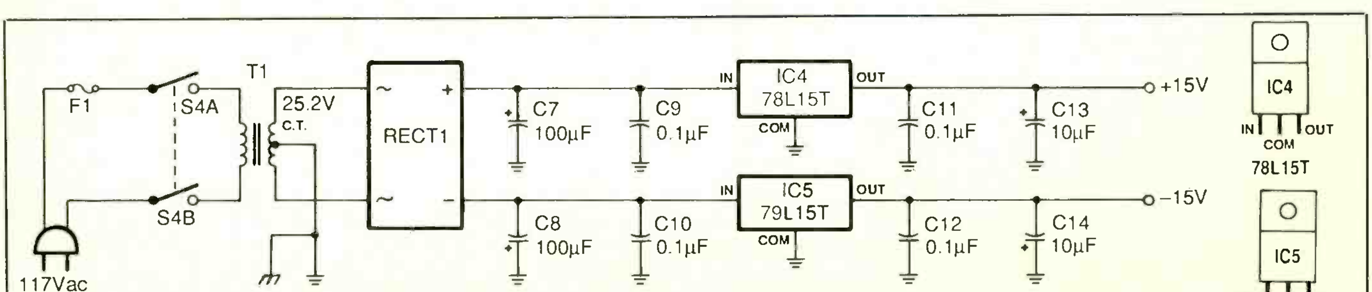


Fig. 4. Schematic diagram of delayed-trigger accessory's bipolar power supply.

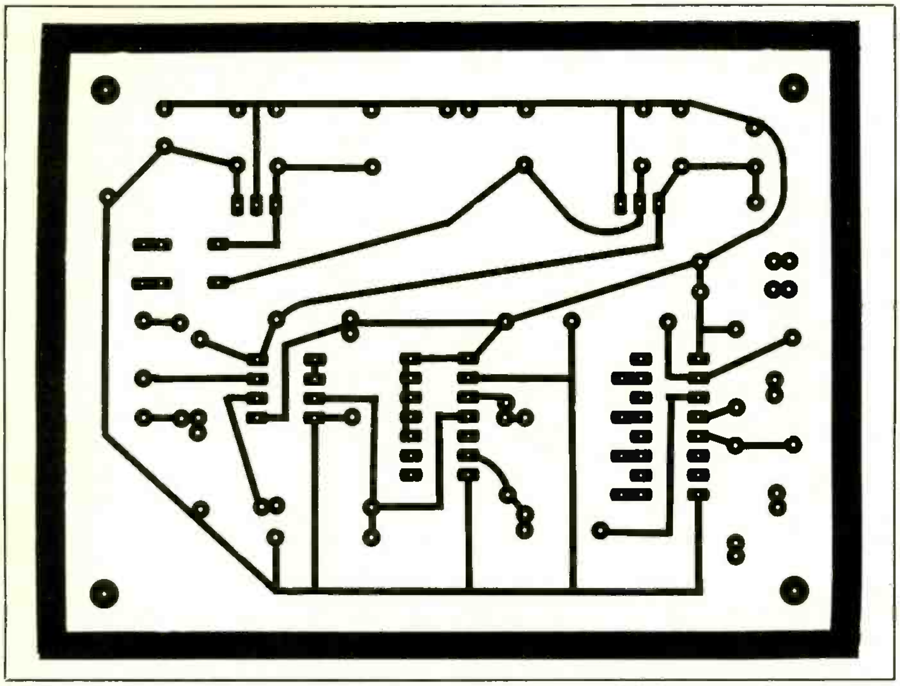


Fig. 5. Actual-size etching-and-drilling guide to use for fabricating printed-circuit board.

and T1 C.T. in Fig. 6 and solder into place. Then mount the circuit-board assembly inside the enclosure with ½-inch spacers and ¾-inch machine screws, lockwashers and nuts. Use electrical tape or heat-shrinkable tubing to cover all exposed 117-volt ac line-potential wiring on *S4* and the fuse holder.

Referring to Figs. 6 and 7, wire the free ends of the wires on the circuit-board assembly to the various controls, switches and input and output jacks into the circuit. Remove ¼ inch of insulation from both ends of an appropriate length of hookup wire and connect and solder this from the TRIGGER INPUT to the TRIGGER OUTPUT ground jacks.

Slide pointer-type control knobs onto the shafts of *R1*, *R7* and *S2*. Rotate the knobs and note the maximum counterclockwise and clockwise positions of the pointer on the potentiometer knobs. Rotate the knob on the rotary switch and note where the pointer rests for each position (remember that only four positions are of interest if you are using a six-position switch). If necessary, reorient the pot or switch to obtain perfect indexing with the panel markings.

Checkout & Use

Before plugging the ICs into their respective sockets, power up the circuit and use a voltmeter set to read at least 20 volts dc to check for proper power routing. Connect the meter's common lead to circuit ground (either ground jack on the front panel, for example). Then touch the "hot" meter lead to pin 18 of the *IC1* socket, pins 8 and 14 of the *IC2* socket and pin 16 of the *IC3* socket. In all four cases, you should obtain a reading of approximately +15 volts. Touching the hot lead to pin 4 of the *IC1* socket should yield a reading of −5 volts.

Once your readings are correct, power down the project and wait a couple of minutes for the charges to bleed off the electrolytic capacitors in the power supply. Then install the ICs in their respective sockets, taking care to properly orient each and making sure that no pins overhang the sockets or fold under between ICs and sockets as you push the ICs into place. Handle *IC2* and *IC3* as you would any other MOS device.

To check operation of the delayed-trigger accessory, you need a test os-

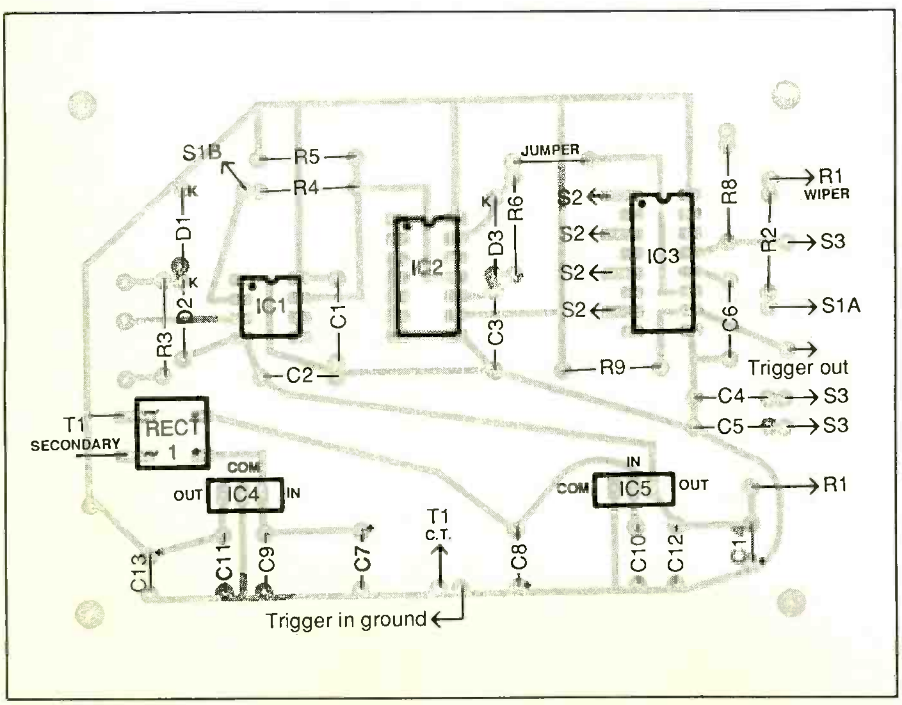


Fig. 6. Wiring guide for pc board. Use this as component-placement guide if you wire circuit on perforated board.

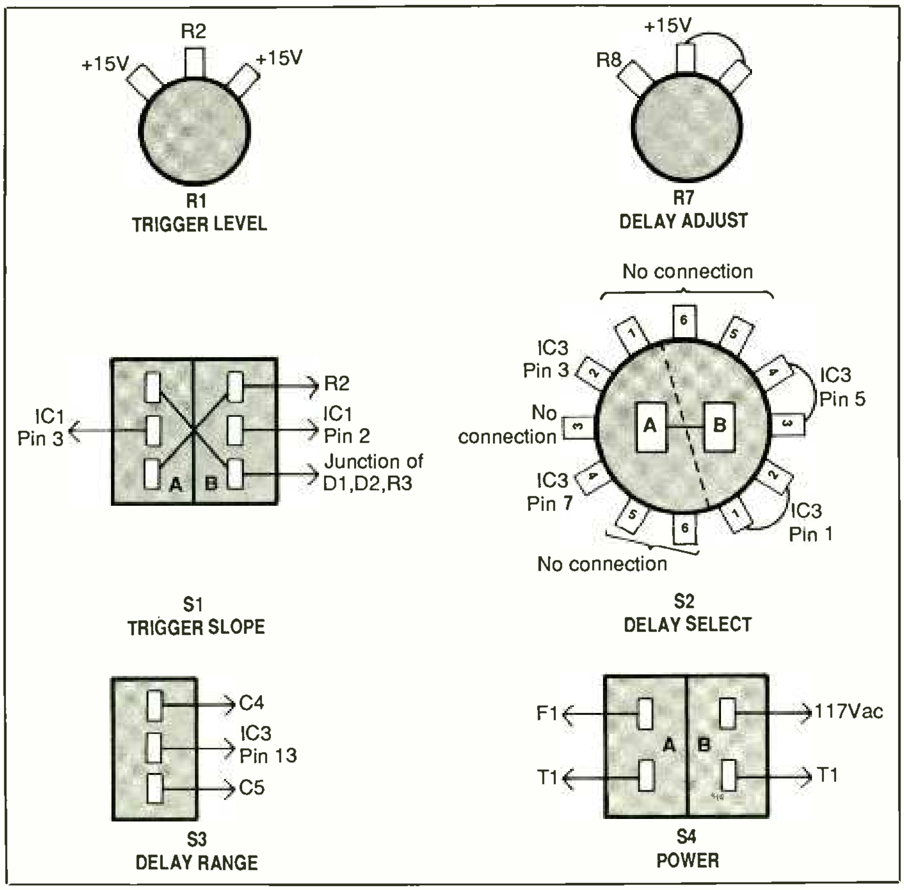
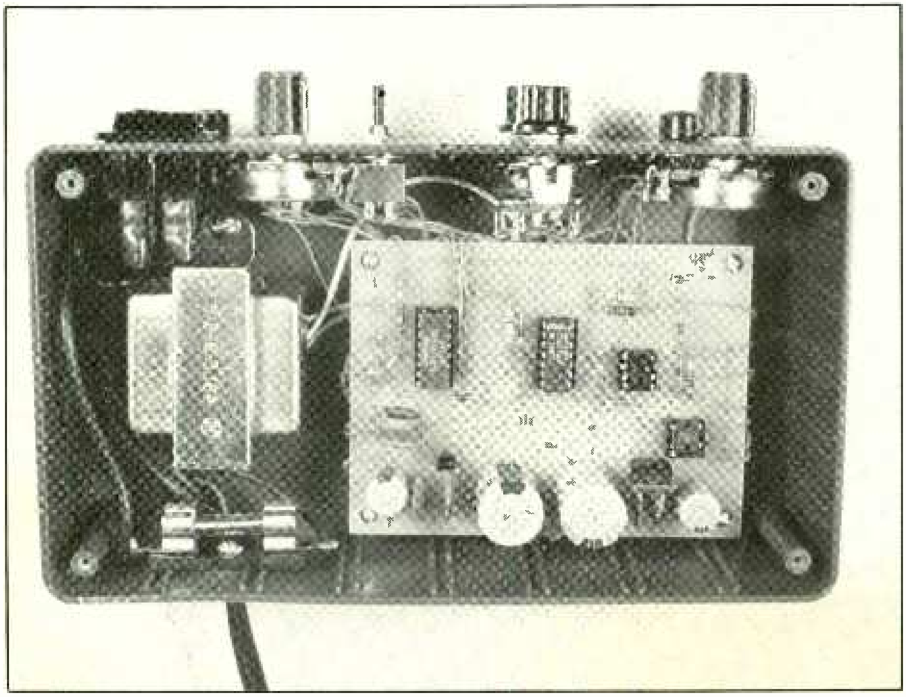


Fig. 7. Wiring guide for switches and potentiometers.



Circuit-board assembly and power transformer mount on floor of enclosure, switches, controls and jacks on front panel.

cillator. Circuit operation is easiest to observe when the period of the test signal is slightly longer than the delay time. Thus, it is best to have available signals of several frequencies; 10 kHz, 1 kHz, 100 Hz, 10 Hz, and 1 Hz are recommended. You can use a square wave output from a bench signal generator for these.

If a bench generator isn't available, you can use a spare 7250 IC to build the simple oscillator shown in Figure 8. By using two timing resistors and connecting a jumper wire to different outputs as shown, all the required frequencies can be obtained.

To begin checkout, set *S3* to "μs" (*C4* selected), set *S2* to position 1 (pin 1 of *IC3* selected), and set *R7* to minimum resistance. The position of *S1* isn't important at this point.

Power up the project, connect a 10-kHz signal and ground reference to the TRIGGER IN jacks, and monitor pin 7 of *IC1* with your oscilloscope. Adjust *R1* until a rectangular waveform appears at pin 7. Then check pin 13 of *IC2* for a 5-microsecond positive-going pulse occurring each time pin 7 of *IC1* goes high.

Next, connect your scope to TRIGGER OUT on the project and check for a 10-kHz rectangular wave. Varying the setting of *R7* will cause the "low" portions of the waveform to vary from 10 microseconds to 60 microseconds in width, though the total period of the waveform will remain constant. The length of time the waveform is low in each cycle is the delay time generated by the circuit.

To see the delay in action, set up your scope to display the 10-kHz output of the test oscillator on channel 1. Leave the oscillator also connected to TRIGGER IN on the project. Then set the scope to trigger on channel 2 or external trigger. Connect TRIGGER OUT of the delayed-trigger accessory to the trigger source you've chosen on the scope. Shown in Fig. 9 is a drawing of the test setup.

Adjust the trigger level on the scope for a stable display. The sweep

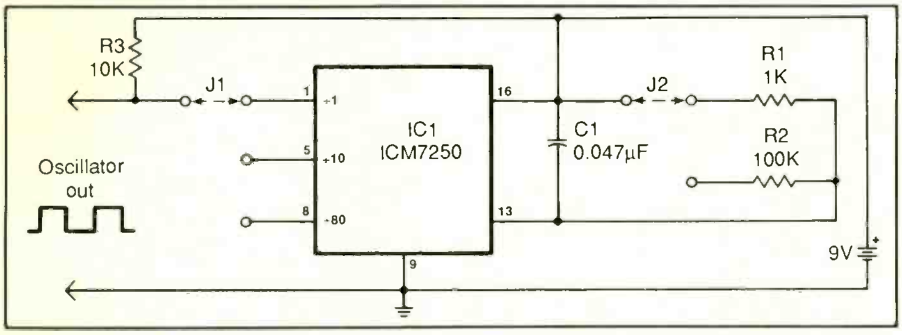


Fig. 8. A 7250 wired as shown here serves as a suitable test oscillator for checking out operation of project.

will begin 10 microseconds after the output of *IC1* goes high. Varying *R7* will increase the delay and cause the waveform to "shift left" on the display even farther. The trigger delay is easy to see when displaying a rectangular wave because the sweep can now be set to begin anywhere along the flat parts of the pulses, not just on their rising and falling edges.

Flipping switch *S1* to its alternate position will turn the display "upside-down" as you change the trigger slope from the rising to falling edge or vice versa.

When you set *S2* to position 2, the delay increases by a factor of 5; instead of 10 to 60 microseconds, the delay will vary from 50 to 300 microseconds. Change the input signal to 1 kHz and expand your timebase on the scope for better observation of this delay. Again, varying *R7* will cause the waveform to shift as the delay is increased and decreased.

Use this same 1-kHz input to check position 3 of *S2*. Then use a 100-Hz signal to observe position 4. Refer to the table for the delay times available at each position. Then change *S2* back to position 1, select *C5* with *S3*, and observe delays ranging from 1 to 6 milliseconds—100 times as long as the original 10-microsecond delay.

Input a 10-Hz signal and check the delays at positions 2 and 3 of *S2*. Finally, a 1-Hz signal will allow you to observe the longest delays, at position 4 of *S2*. The final delay should be adjustable to about 300 milliseconds.

To use the accessory, do the following:

(1.) Select a trigger signal of equal or lower frequency than that of the signal to be observed.

(2.) Connect the signal to be observed to channel 1 of the oscilloscope.

(3.) Set the oscilloscope's trigger slope to + and trigger source to external or channel 2.

(4.) Connect the trigger signal to TRIGGER IN on the delayed-trigger accessory.

(5.) Connect TRIGGER OUT on the accessory to the trigger source input (external or channel 2) selected on the scope.

(6.) Adjust trigger slope and level on the delayed-trigger accessory for a stable display on the oscilloscope screen.

(7.) Adjust the delay range and delay time on the accessory to "tune in" the desired portion of the waveform.

(8.) Expand the timebase on the scope if desired to examine the signal more closely.

As you use the delayed trigger accessory, you'll almost certainly come to rely on it as much as laboratory users do with their very expensive scopes. In fact, you may even decide that you don't have to trade your old scope in for a newer-technology model if you had that in mind. **ME**

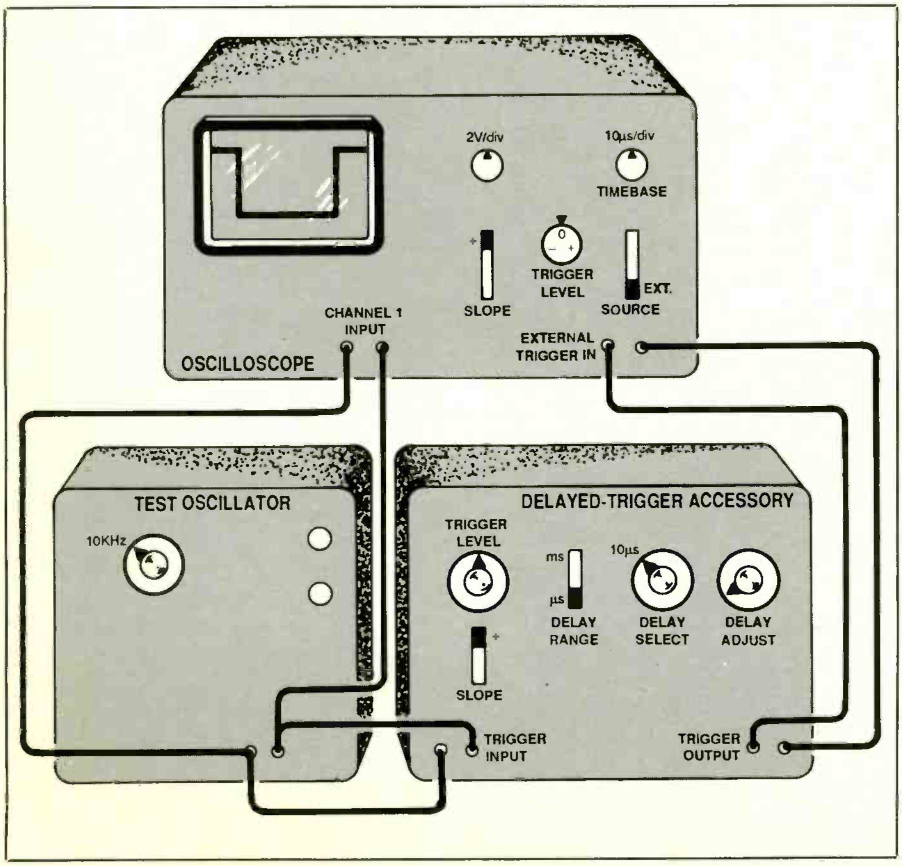


Fig. 9. Initial setup for testing delayed-trigger accessory.

An FM Wireless Microphone

A battery-powered microphone eliminates the trailing cable while it transmits on a frequency in the FM broadcast band

By Anthony J. Caristi

Microphones for recording and public-address applications are cumbersome to handle due to the long umbilical cord that connects them to an amplifier. Many professionals eliminate the cable problem by using miniature *wireless* microphones that have their own built-in amplifier/transmitter, doing away with cables. As a result, they have more freedom to move around without worrying about snarling cable and a trip hazard. The FM wireless microphone to be described here can give you the same advantages. It is low in cost, yet high in audio quality.

Our wireless microphone is designed to work with an FM receiver, tuner or radio. Since its r-f output is very low in power, and has a usable transmitting range of 50 feet or less, it should not interfere with your neighbors' FM reception. Its extremely high sensitivity allows it to pick up voices and sounds several feet away; so there is nothing critical about locating it in a pick-up area. If this inherent sensitivity is too "hot" for your application, such as in PA announcing where the user usually speaks directly into the microphone element, an option allows you to reduce the sensitivity so that background noises will be largely excluded.

Some of the applications for this project include using it as a miniature PA system or as an electronic babysitter while you monitor sounds from another room. You can even build two wireless microphones to use as a simple wireless system in your home. For the kids, this can be a fascinating toy that lets them sing and talk through an FM radio.

About the Circuit

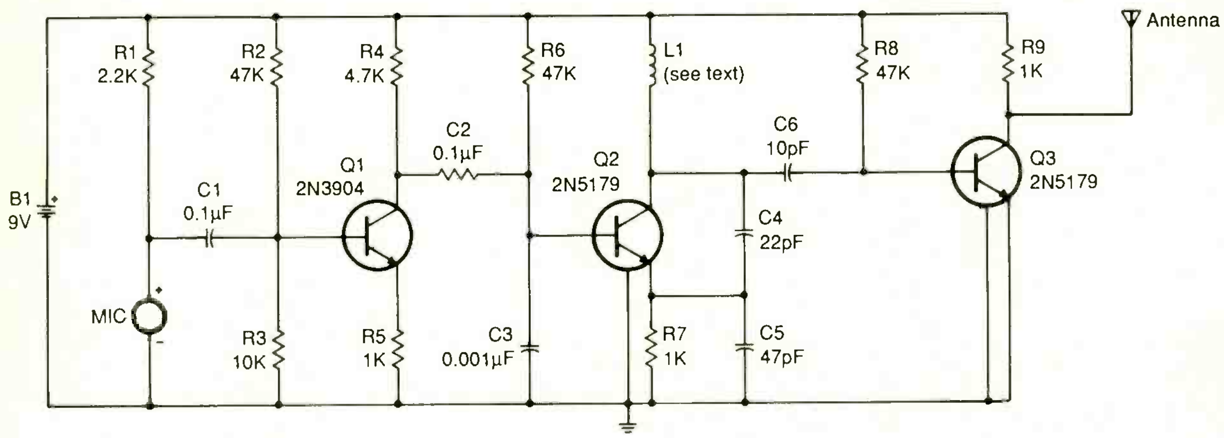
Shown in Fig. 1 is the complete schematic diagram of the FM wireless microphone. Microphone element *MIC* is an electret type that is powered from battery *B1* through resistor *R1*. When sound reaches the microphone element, the current through *R1* is varied in accordance with the intensity of the sound intercepted. This produces an ac voltage through *R1* that is coupled through *C1* into the base of audio amplifier stage *Q1* as a small ac voltage.

Gain of the *Q1* stage is held at about 4.7 by the ratio of the collector and emitter resistance values. The output of the audio amplifier stage, at the collector of *Q1*, is then coupled to the base of r-f oscillator *Q2*.

Transistor *Q2* and its components make up a classic Colpitts oscillator. To produce oscillation, the transistor's base and collector are connected to opposite ends of an LC "tank" circuit, with the emitter connected somewhere between these two points. When the gain of this arrangement exceeds unity (1), the circuit oscillates at a frequency determined by the parallel resonant frequency of the tank circuit.

In the oscillator stage, the LC tank is composed of coil *L1* and the series combination of *C4* and *C5*. The base of *Q2* is held at r-f ground potential by *C3*, and the "cold" side of *L1* is held at ground potential by *C7*. This effectively places the base of *Q2* at the same r-f point as the cold end of the tank circuit.

The voltage-divider action of *C4*



PARTS LIST

Semiconductors
Q1—2N3904 or similar silicon npn transistor
Q2,Q3—2N5179 or similar silicon r-f npn transistor
Capacitors (50 WV)
C1,C2,C7—0.01-µF ceramic
C3—0.001-µF ceramic
C4—22-pF ceramic (NPO temperature stable)
C5—47-pF ceramic (NPO temperature stable)
C6—10pF ceramic (NPO temperature stable)
Resistors (¼-watt, 10% tolerance)
R1—2,200 ohms
R2,R6,R8—47,000 ohms
R3—10,000 ohms
R4—4,700 ohms
R5,R7,R9—1,000 ohms
Miscellaneous
B1—9-volt transistor battery
L1—Inductor (see text)
MIC—Electret microphone (Radio Shack Cat. No. 270-090 or similar)
Printed-circuit board; shield (see text); snap connector for B1; wire for antenna; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Pc board, $5.00; 2N5179 transistor, $3.75 each; set of 22-, 47- and 10-pF NPO temperature-stable capacitors, $1.75. Ass $1.00 P&H. New Jersey residents, please add state sales tax.

Fig. 1. Complete schematic diagram of wireless FM microphone.

and *C5* provides a simple means of placing the emitter of *Q2* at the optimum r-f point. This is one-third (33 percent) above ground potential and ensures that the circuit oscillates.

Resistor *R6* forward biases *Q2* so that the transistor draws collector current and is forced into oscillation. Since the bias voltage at the base of *Q2* is modulated by the ac signal voltage variations from *Q1*, the frequency of oscillation in the *Q2* circuit varies in accordance with the frequency of the sound reaching the microphone element. Thus, the oscillating signal from *Q2* is frequency modulated to conform with the needs of the FM receiver, tuner or radio with which the project is used.

To enhance the frequency stability of the oscillator, an additional stage has been included in the circuit to buffer the oscillator from the antenna. With this stage, *Q3*, small changes in capacitance due to physical positioning of the antenna will have an attenuated effect on the oscillator circuit. The result is much less frequency drift.

Taken at its collector, the output of *Q2* is capacitively coupled into the base of r-f amplifier/buffer *Q3*. Resistor *R8* forward biases transistor *Q3*. The resulting current flow in this stage causes *Q3*'s collector to output an r-f signal composed of the frequency-modulated output from *Q2*. Resistor *R9* in *Q3*'s collector circuit limits current flow. The antenna for the microphone connects directly to the collector of *Q3*.

Construction

Due to the r-f nature of the wireless microphone's circuit, printed-circuit construction is mandatory. For this board, you need a pc blank that is clad on both sides with copper. One side will be etched in the usual manner to produce the wiring pattern to which component leads are soldered. The other side will serve as a ground plane to which only selected leads (those that are grounded, of course) are soldered as well. It serves a second function as a shield for the circuit. You can make your own pc board or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List.

You can home fabricate your own pc board with the aid of the actual-size etching-and-drilling guide shown in Fig. 2. Note in Fig. 2 that the ground-plane side of the board is not shown in the usual etch-and-drill format. Because this side of the board is not to be etched at all, only the hole-drilling/clearing information is graphically presented. In this illustration, all holes to be drilled are identified by either circles or solid black dots.

When fabricating the board, make sure to mask off the top side with etch resist to prevent the copper from being removed by the etchant. After the board has been etched, trim it to size. Then carefully drill all holes through the board as indicated, using the pattern of pads on the *wiring* side to accurately locate where each hole is to be drilled.

After using a No. 60 bit to drill the component lead holes, turn over the board and orient it as shown in the ground-plane illustration in Fig. 2. Carefully mark all holes indicated by open circles. Then *very* carefully isolate these holes from the copper-clad ground plane by drilling with a 3/16-inch diameter bit only enough to clear copper from around the holes. Do *not* drill all the way through the board! When you are finished, there should be eight holes from whose edges you have not removed the copper cladding, all indicated by the solid black dots in the illustration.

Now wire the board exactly as shown in Fig. 3. Start with the transistors, making sure that they are properly based as you plug their leads into the holes. Note that *Q2* and *Q3* have four leads, one each for the emitter, base and collector and a final one that is internally connected to the case. Make sure all leads are soldered to the pc board after installing each transistor. Solder the grounded leads of *Q2* (case only) and *Q3* (emitter and case) to the copper trace on the bottom *and* the ground plane on the top of the board. When the transistors are soldered into place, there should be no more than 1/4 inch of space between the bottoms of their cases and the board.

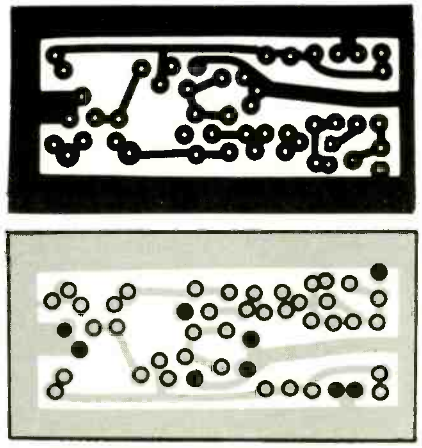


Fig. 2. Actual-size etching-and-drilling guide (upper) and drilling/hole-clearing details (lower) for double-sided printed-circuit board.

Use an ohmmeter to check that any lead that is not supposed to be grounded does not short to the copper cladding on the top of the board. Refer back to Fig. 1 to make sure. If you find any lead that does short to the ground plane but should not, gently bend it until it no longer does.

Once the transistors have been mounted, install and solder into place *C3*, *C5*, *R3*, *R5* and *R7*, all of which have one lead that goes to circuit ground. Solder this lead to the copper cladding on both sides of the board as you did for the transistors. When installing these components, leave about 1/16 inch of lead length on the top of the board to make it easy to solder the appropriate leads to the ground plane.

It is easiest to solder the connection first on the bottom of the board, clip off excess lead lengths and then solder the ground-plane side connection with only enough solder to make a secure electrical connection. Then use the ohmmeter to make sure that the other leads do not short against the ground plane. Install and solder into place the remaining capacitors and resistors.

At this point, you might wish to consider the circuit option that lets you reduce the sensitivity of the microphone pickup. If your wireless microphone is to be used to pick up sounds at some distance from the microphone element, you need do nothing. On the other hand, if you wish to use the project as a hand-held microphone for direct close-up pickup, this option should be incorporated to prevent overmodulating the r-f carrier and, thus, audio distortion.

For reduced microphone sensitivity, you can eliminate the *Q1* amplifier stage in its entirety. That is, omit *C2*, *Q1* and *R2* through *R5*. Then simply connect *C1* from the junction of the microphone's + terminal and *R1* to the *R6/C3/Q2* base junction.

No changes need be made to the pc board if you exercise this option. In fact, if you wish, you can build in a switching arrangement between the output side of *C1* and the base inputs of *Q1* and *Q2* in alternate positions of a miniature two-position slide switch. Doing this gives you a choice between full-sensitivity and reduced-sensitivity modes of operation.

You can mount the microphone element directly at the edge of the board, using short lengths of cut-off component lead between the element's terminals and the appropriate holes in the board. Be sure to properly polarize the microphone element. Solder the negative (−) lead of the microphone element to the copper cladding on both sides of the board.

Instead of mounting the microphone element directly on the board, you can locate it elsewhere and make interconnections with an appropriate length of shielded cable. Use the center conductor for the "hot" (+) and the shield for the ground (−) sides of the element.

Now hand-wind inductor *L1*, using either 20-gauge enameled copper wire (preferred) or 20-gauge bare solid hookup wire. First cut the wire to *exactly* 4½ inches long so that it "tunes" to the center of the FM broadcast band. Carefully scrape away ¼ inch of the enamel insulation.

Wrap this wire around an ordinary pencil, making 3½ turns and winding as tight as possible. Slide the coil off the pencil and note that it should have two equal-length "tail" ends that are parallel with each other. (They may not be exactly parallel with each other, due to the springiness of the wire, but will become so once the tails are plugged into the holes in the circuit board.)

Press the coil end-to-end between your thumb and forefinger until the spacing between the turns is about one wire diameter. This spacing is not critical, but if done correctly will make it easier to plug the tails into the holes in the circuit board.

If you used ordinary bare solid hookup wire to wind the coil, place a strip of electrical tape on the ground plane in the *L1* area to provide insulation in case the coil sags or is pushed against the copper cladding. Plug the coil into the holes in the board so that the tails protrude about 1/16 to ⅛ inch on the bottom of the board and there is air space between the bottom of the coil and the circuit board's ground plane. Solder into place.

Tightly twist together the fine wires in both battery snap connector leads and sparingly tin with solder. Place the circuit-board assembly solder side up and plug the red snap connector wire into the hole labeled B1+ and the black wire into the hole labeled B1− (see Fig. 3). Solder both connections to the pads on the bottom of the board. Flip over the board and clip the excess length of the red-insulated wire as close as possible to the board's surface. Then solder the black-insulated wire to the ground plane and clip off its excess lead length. Check with your ohmmeter to make sure that the red wire is not shorted to the ground plane.

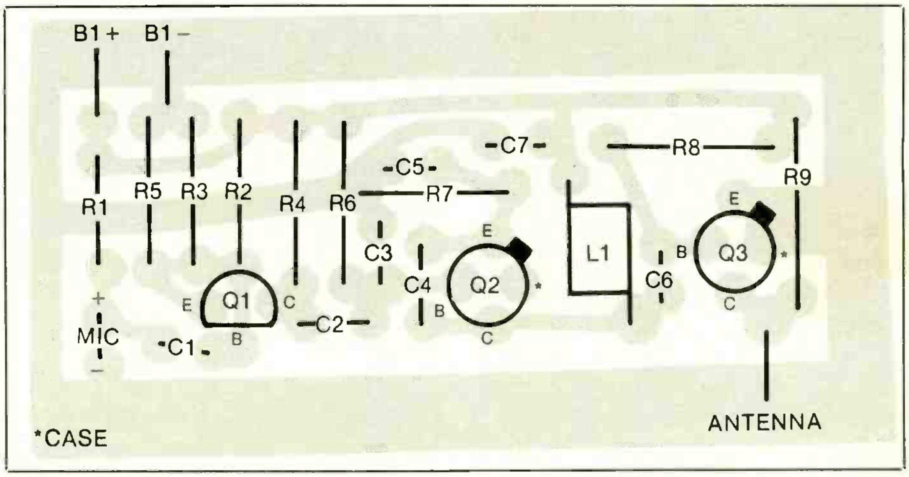


Fig. 3. wiring diagram for pc board.

The antenna for your wireless microphone should be as short as possible but not so short that it provides less than satisfactory operation. Start with a 6-inch length of insulated solid hookup wire. Strip ¼ inch of insulation from one end and plug this end into the hole labeled ANTENNA and solder into place.

With the circuit board fully wired, refer back to Fig. 1 and use your ohmmeter to make certain that no component leads not shown connected to circuit ground touch the ground plane on the top of the board. Readjust the position of any component that registers a short circuit to the ground plane to eliminate the short circuit.

To preserve the frequency stability of the circuit, you must place an r-f shield on the top of the board after the circuit has undergone preliminary check. Fabrication of the shield is very simple, as shown in Fig. 4.

You can use any thin solderable sheet metal, such as copper or brass. Copper flashing, available from lumberyards and roofing supply houses, works well, as does thin brass sheet obtainable from most hobby shops.

Trim the copper or brass sheet to 2 7/16 by 2 inches. Then use a soft lead pencil or a scribing tool to strike the fold lines and mark the center of the ¼-inch diameter hole to be drilled. Place the marked sheet metal in the jaws of a vise, lining up one of the fold lines with the vise's jaws and bend first the inner-channel edges and then the outer tab edges. You will not be able to make complete 90-degree bends using the vise. The idea is to get clean, sharp bend lines. You can square up the bends by hand with the aid of slip-joint pliers.

Once the U-channel shield has been bent to shape, punch the location of the ¼-inch hole to be drilled. Then drill the hole, backing up the metal with a scrap wood block to get as clean a hole as possible. Use a 3/16-inch bit to drill the hole. Then carefully enlarge the hole to its final ¼-inch diameter with a tapered reamer.

Checkout

Before plugging the battery into its snap connector, perform a visual check of the board to ascertain that there are no short circuits or cold-soldered joints on either side of the board. Reflow the solder on any joint that appears to be questionable. Double check all transistor basings. If you wish to be absolutely certain of your wiring, perform a final ohmmeter check, with the aid of Fig. 1, to ascertain that all component leads that are not supposed to be grounded are not shorted to the ground plane. When you are satisfied that all is well, plug a 9-volt battery into the project's battery snap connector.

Use an ordinary FM radio to check that the circuit is working. Start at the low end of the FM band and very slowly tune the radio upward in the band. At some point near the middle of the band, you should hear either silence as the radio responds to the microphone's r-f carrier or "howling" as acoustic feedback between the radio and microphone causes oscillations.

If you turn the volume control on the radio low enough, you will be able to eliminate the feedback so that when you talk into the microphone you hear your voice. Keep in mind that the sensitivity of the microphone is very high (unless you opted for reduced sensitivity); hence, you need only whisper into the microphone for this test.

After you have pinpointed the wireless microphone's signal on the FM dial, mark the frequency at which it appears. You will note that when the shield is mounted to the circuit-board assembly the received signal will be shifted some 3 MHz higher in frequency on the dial.

If you wish to tune your microphone for a specific approximate frequency on the FM dial, perhaps to avoid interfering with a station on a given frequency, you can increase the spacing between the turns of *L1* to raise its operating frequency or decrease the spacing to decrease the frequency. Be sure as you do this that the coil's leads do not short to the ground plane (and that no turns of the coil touch the ground plane if you used bare solid hookup wire to make the coil).

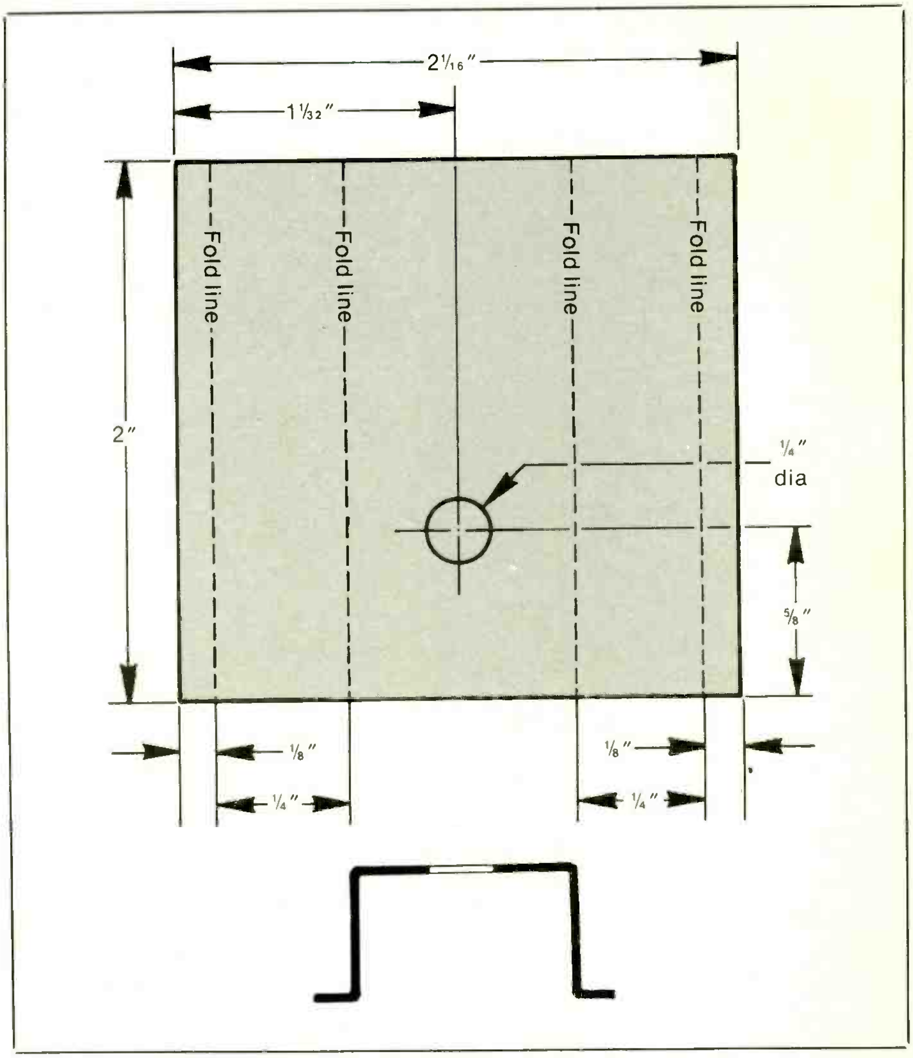


Fig. 4. Fabrication details for project's r-f shield.

When you are satisfied that your wireless microphone is operating as it should and is tuned to approximately where you want it to be on the FM dial, attach the shield by soldering it to the perimeter of the copper ground plane.

To simplify soldering, first flow a thin film of solder onto the ground plane at all four corners of the board and on the four corners of the underside of the shield's tabs. Make sure that no solder flows far enough to short a component lead that should not be connected to the ground plane. Place the shield over the circuit-board assembly with the ¼-inch hole centered over *L1* and use more solder at the four corners to make mechanically secure electrical and mechanical connections. You do not need continuous beads of solder; in fact, you do not want them should you ever have to service the circuit.

After the shield is in place, power up your microphone again and tune the FM radio to a dead spot on the dial, where no stations are broadcasting until you hear the micro-

(Continued on page 90)

The Photo(Tach)-Pulser

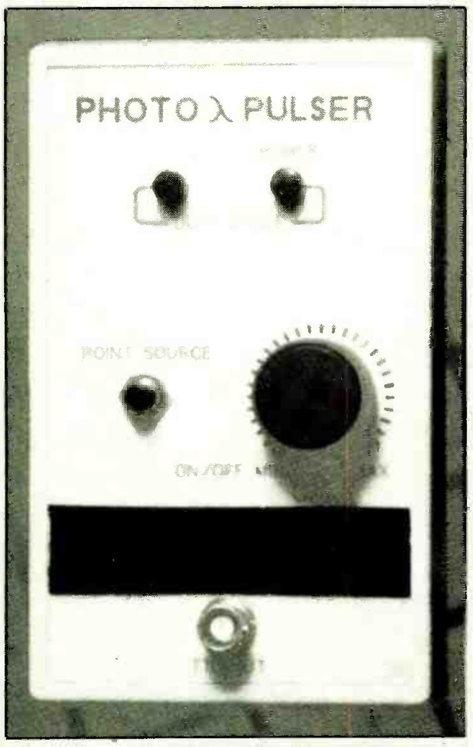
A phototachometer adapter for frequency counters

By Crady VonPawlak

When you need a phototachmometer to troubleshoot an infrared remote control transmitter for a TV receiver or VCR, to determine the rpm of a spinning shaft, etc., nothing else will do. Commercial phototachometers, of course, are expensive instruments. Fortunately, you can build the Photo-Pulser accessory described here at a cost that should not exceed about $30 for all new parts, including enclosure. Its low cost is made possible by connecting it to a frequency counter.

Our Photo-Pulser is a fairly simple accessory device to build and use. It is designed to serve as the "front end" for a frequency counter from whose display you can read revolutions per minute directly. Its TTL-level output will directly drive almost any digital frequency counter now in use, including the Frequency Counter Accessory for Digital Multimeters described in the November 1987 issue of *Modern Electronics*.

This accessory has only two controls: a combined power switch and rotary SENSITIVITY control and a pushbutton switch to turn on a built-in infrared-emitting energy source for those occasions when ambient or reflected light level is too low to provide a reliable reading.



About the Circuit

The complete schematic diagram of the Photo-Pulser is shown in Fig. 1. As light strikes the sensitive surface of phototransistor *Q1*, a proportional current is passed through the collector-emitter junction. This current is then converted to a voltage by potentiometer *R2*. The magnitude of the voltage developed is determined by the amount of light that strikes *Q1* and its proportional current and the resistance of *R2*. By varying *R2*'s resistance, the threshold or "sensitivity" of the circuit can be set to an incoming signal.

An LM324 quad operational amplifier is used in this circuit for *U1*. This particular chip was selected because it is conveniently designed specifically for use with a single supply voltage, eliminating the need for a more complex and costly split power supply normally required by many op amps. Consequently, the LM324 is an ideal choice for a battery-powered project, which this one is. The tradeoff, though, is the LM324's narrow bandwidth, which is unity gain at 1 MHz.

To prevent *U1* from reacting to small changes in ambient light, the chip's input is coupled to the emitter of *Q1* through capacitor *C1*. If the value of *C1* is small enough, simple changes in room or outdoor lighting will not be passed on and amplified. The penalty for this small value of capacitance is that it passes little current. To compensate for this, the value of *R4*, which provides the op amp's noninverting (+) input with a dc path to ground, must be fairly large to prevent attenuating the incoming signal. There is a penalty here, too. That is, if *R4*'s value is made too large, current through *C1* can cause the output of *U1* to latch. If *R2* is set to a high enough resistance, the amplifier can break into oscillation.

To obviate the possibility of oscillation and increase overall bandwidth of the circuit, the amplifier is made up of two op-amp stages as shown. The first stage, following *C1*, is a noninverting amplifier with a gain of 101. Here, gain is determined by the relationship of *R6* and *R5*, where $V_{out} = (R6/R5) \times V_{in} + 1$. The same is true for the second stage, which has a gain of 11. Therefore, overall gain with both op-amp stages in cascade is 101 × 11, or approximately 1,111.

If a gain on the order of 1,000 is selected, bandwidth is moved closer to 1 kHz. To achieve an overall gain of 1,000 and still retain reasonable bandwidth, the pin 7 output of the

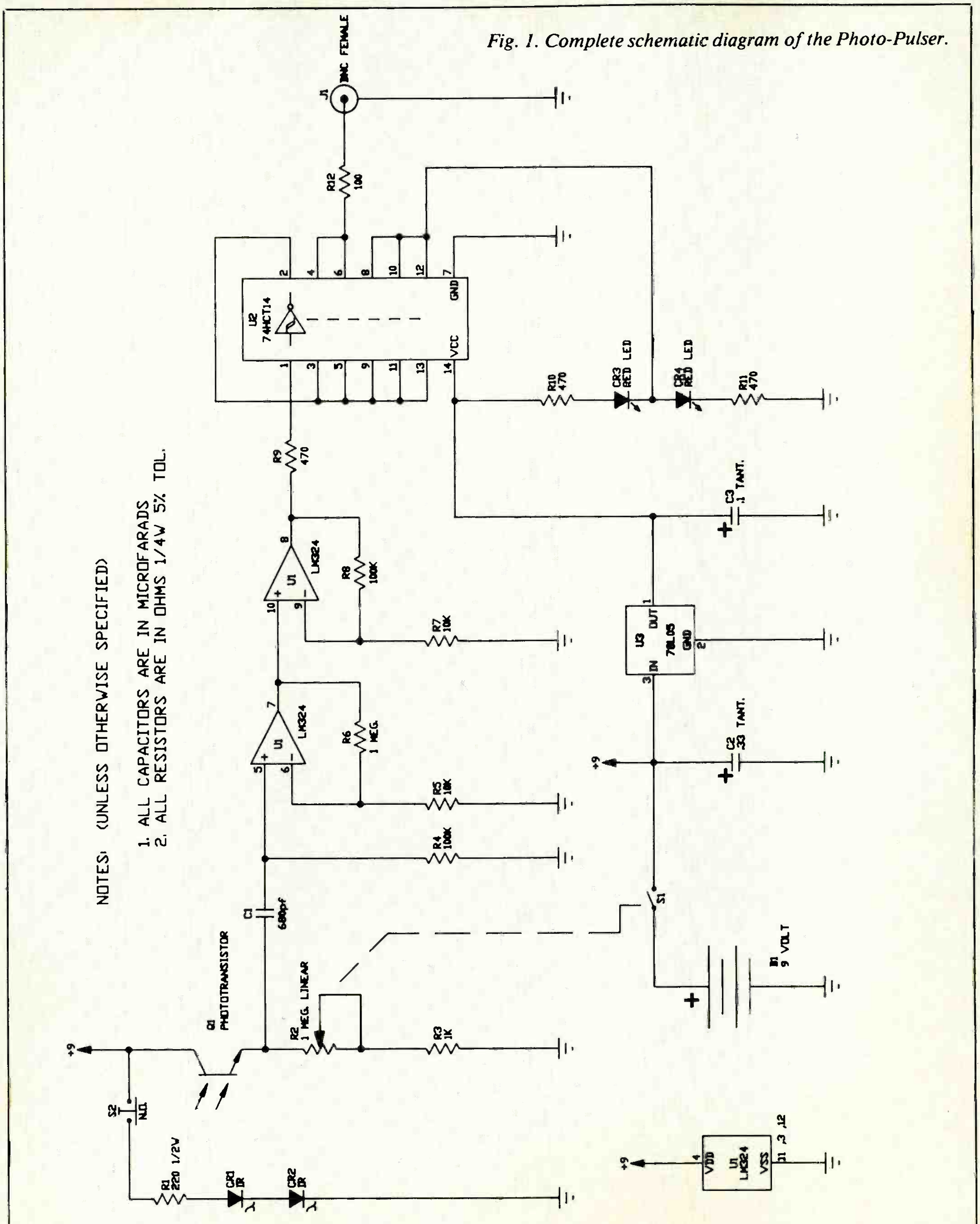


Fig. 1. Complete schematic diagram of the Photo-Pulser.

PARTS LIST

Semiconductors

CR1,CR2—High-output infrared light-emitting diode in T-1¾ package

CR2,CR3—Diffused-lens red light-emitting diode in T-1¾ case

Q1—Broadband phototransistor in T-1¾ case

U1—LM324 quad operational amplifier

U2—74HCT14 high-speed CMOS hex Schmitt trigger

U3—78L05 fixed +5-volt regulator in TO-92 package

Capacitors

C1—680 to 1,000 pF

C2—0.33-μF tantalum

C3—0.1-μF tantalum

Resistors (¼-watt, 5% tolerance)

R3—1,000 ohms

R4,R8—100,000 ohms

R5,R7—10,000 ohms

R6—1 megohm

R9,R10,R11—470 ohms

R12—100 ohms

R1—220 ohms, ½-watt

R2—1-megohm, linear-taper, panel-mount potentiometer

Miscellaneous

B1—9-volt battery

J1—Male BNC connector (see text)

S1—Spst normally-open, momentary-action pushbutton switch

S2—Spst switch (part of R2; see text)

Printed-circuit board; sockets of U1 and U2; suitable enclosure (Pac Tec No. HP-9VB or similar; see text); pointer-type control knob for R2; heat-shrinkable tubing; clear self-stick plastic sheet (see text); hookup wire; solder; etc.

first stage, which has a moderate gain of 100, is fed into the second stage—at the pin 10 noninverting (+) input—which has a lower gain of 10. With this type of arrangement, any noise produced by the first stage is amplified by the second stage, which makes this setup a poor choice where minimal distortion and low noise are key factors. However, in the case of the Photo-Pulser, the effects of this type of noise are insignificant.

Once the incoming signal has been amplified to a usable level, it is fed through dropping resistor *R9* to 74HCT13 high-speed CMOS hex Schmitt trigger *U2*, which has LS/TTL-compatible outputs. The output of *U3* is impedance and risetime matched with LS (low-power Schottky) devices. A 74HCT-14 was chosen for *U3* instead of a garden-variety 74LS14 for its low power consumption and increased fan-out characteristics.

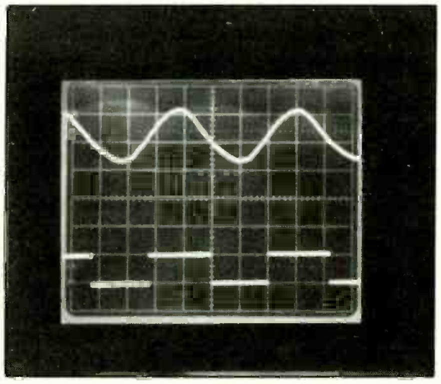


Fig. 2. Built-in hysteresis allows Schmitt trigger to operate on sine waves (upper trace) to produce square-wave output (lower trace).

A Schmitt trigger operates like a simple inverter, except that it has a small amount of hysteresis. For the output of the Schmitt trigger to change state from low to high or from high to low, the input waveform must pass through upper and lower thresholds. So long as this is true, the shape of the actual waveform is irrelevant. An example of this is illustrated in Fig. 2.

The upper trace in Fig. 2, taken at the emitter of *Q1*, shows a 120-Hz sine wave (generated by a fluorescent light 10 feet away) that has an amplitude of +200 millivolts. This sine wave is then amplified to meet the lower and upper threshold requirements of the Schmitt trigger. Hence, even though the signal at *Q1* is a sine wave, after amplification to at least VT+ (2.7 to 3.3 volts dc) and going below VT− (1.3 to 2.1 volts dc), it produces an output from the Photo-Pulser that is a clean 0-to-5-volt, TTL-level square wave whose frequency is the same as that of the input signal.

The square-wave output appears at two points: female BNC jack *J1* for connection to a frequency counter or oscilloscope, and at light-emitting diodes *CR3* and *CR4*. The LEDs serve two functions: When no signal is present, only *CR3* will be on and doubles as a power-on indicator; when a signal of proper amplitude appears at *U2*, *CR3* and *CR4* alternately flash at the rate of the input frequency.

In addition to simply indicating proper triggering, *CR3* and *CR4* will appear to glow (they are actually flashing) with equal intensity. On the other hand, if the signal is spiky, one LED will appear brighter than the other. This "spike" indication is important because even if the light source has a 50-percent duty cycle, as with a fluorescent light, the actual received signal may be greater or less than 50 percent due to reflections from nearby objects adding to (in-phase) or subtracting from (out-of-phase) the waveform. Careful aiming of *Q1* (moving the light source or the Photo-Pulser) will minimize the effects of reflections

Power for the project is supplied by a single 9-volt transistor battery (*B1*). This battery's output is regulated down to a stable 5 volts by positive low-power regulator *U3*. (Although the 78L05 operates identically to the 7805, its pinout is reversed. Input is at pin 3, output is at pin 1 and common or ground is at pin 2.) Tantalum bypass capacitors *C2* and *C3* stabilize the output and prevent *U3* from breaking into oscillation.

For *CR1* and *CR2*, infrared-emitting diodes were chosen for greater efficiency and an output wavelength that is closest to that of a given phototransistor's peak sensitivity. These IR-emitting diodes provide an on-demand reflected point-source of light via pushbutton switch *S2*. If you

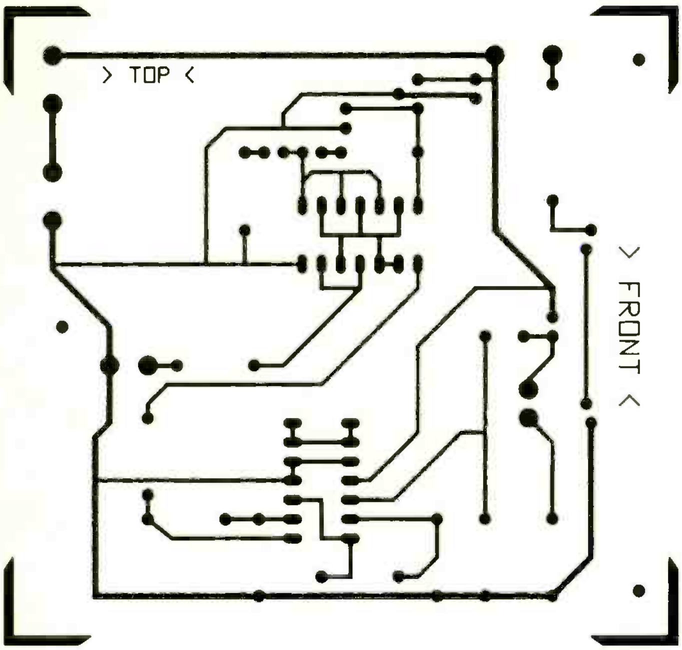


Fig. 3. Actual-size etching-and-drilling guide for fabricating printed-circuit board.

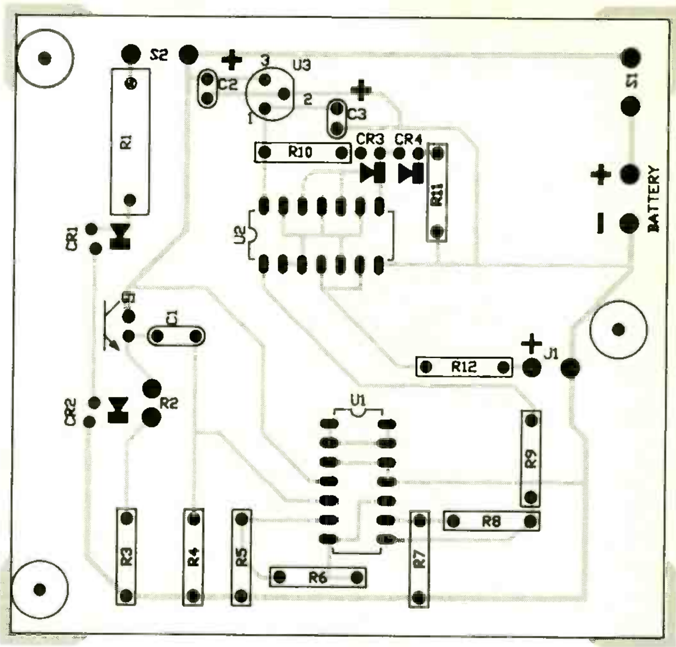


Fig. 4. Wiring guide for pc board.

were to measure the rpm of a spinning shaft that has alternating black and white surfaces in poor or indirect reflected light, for example, *CR1* and *CR2* would provide a light source for making measurements.

Before you select a phototransistor for *Q1*, make certain that it is sensitive to a broad spectrum of visible light. Motorola's MRD series is sensitive to light ranging from 450 to 1,000 nanometers (nm) in wavelength, with peak sensitivity in the 800-nm range. Using good judgment here will extend both the sensitivity and versatility of the Photo-Pulser.

If you want to learn more about pyroelectric devices, I highly recommend the *Optoelectronics Device Data Book* from Motorola. This book is chock full of circuit examples ranging from simple optical switches to ultra-high-speed fiber-optic data links. It also contains a detailed section on photo-semiconductor theory.

Construction

The small output at *Q1* and high gain of *U1* makes printed-circuit board construction of the Photo-Pulser almost mandatory to assure quiet operation. You can fabricate the single-sided pc board from the actual-size etching-and-drilling guide shown in Fig. 3. Wire the board exactly as shown in Fig. 4, using sockets for *U1* and *U2* (do *not* install the ICs in the sockets until after initial checks have been made). Make sure the LEDs, IR-emitting diodes and tantalum capacitors are properly polarized before soldering their leads to the copper pads on the bottom of the board. Also, make sure you properly base the transistor.

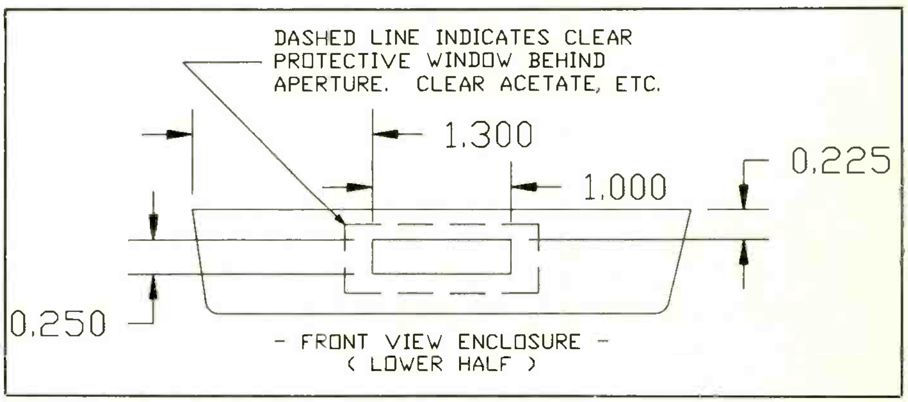


Fig. 5. Cutout details for machining end panel of enclosure lid to permit IR-emitting diodes and phototransistor to face outward.

A Pac-Tec No. HP-9VB enclosure is ideal for the project because it has a separate battery compartment with its own separate slide-off/on cover for convenient battery replacement. If you use this particular enclosure (or another with roughly the same dimensions), use Fig. 5 to guide you in cutting the slot through which *Q1*,

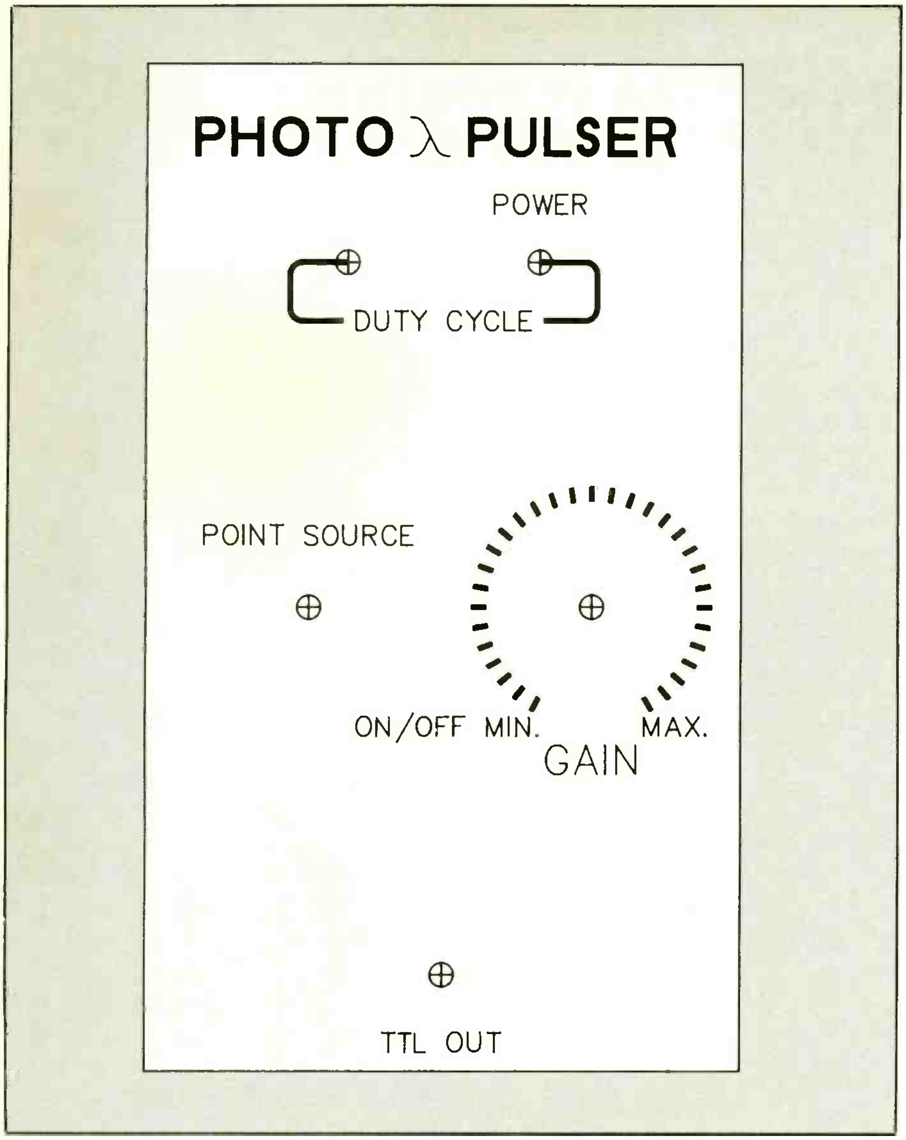


Fig. 6. Front-panel machining and legend details. Make photocopy of this artwork and use directly as panel label, as detailed in text.

CR1 and *CR2* point outward. Then use Fig. 6 to locate the holes for the LEDs, pushbutton switch, rotary control and BNC connector.

Make two same-size photocopies of Fig. 6. Trim one copy along the outside edge of the border line. Place this copy on the lid of the enclosure, carefully centering it all around, and mark the locations of the five holes on the box lid. Drill pilot holes with a $\frac{1}{16}$-inch bit and follow up with a $\frac{1}{2}$-inch bit. Then enlarge each hole as needed with a tapered reamer to just accommodate the LEDs, pushbutton switch, potentiometer and BNC connector.

Use the second photocopy of Fig. 6 as a panel label. Before trimming it to the outer border, carefully apply a sheet of clear self-stick "document protector" plastic to the artwork side. Work slowly and carefully. This self-stick plastic sheeting can be obtained from most stationery stores.

Once the plastic is down on the artwork, turn it over and apply enough wide double-sided permanent-type adhesive tape to cover the entire exposed area of the label. Do *not* remove the protective layer on the tape until you are ready to apply the label to the panel. Turn over the label and carefully trim it to the outside edge of the border.

Peel the protective layer from the tape and *carefully* apply the label to the panel, making sure the cross-points of the cutouts are centered in the holes in the panel. Burnish away any bubbles. Then use an X-acto knife fitted with a No. 11 blade to trim away the label material that covers the panel holes.

I used a potentiometer switch from Radio Shack for *S2*, attaching it to *R2*. To wire *R2* as a rheostat as shown in Fig. 1, first turn the shaft of the pot fully clockwise. Then use an ohmmeter to determine which of the pot's outer lugs register maximum resistance with respect to the center wiper lug. Solder 3-inch lengths of hookup wire to the wiper and maximum-resistance lugs of the pot. If you wish, you can solder a wire from the remaining lug to the center lug; otherwise, leave the minimum-resistance lug unconnected.

Mount the pot in its hole on the enclosure panel and rotate it's shaft fully counterclockwise. Place a pointer-type knob on the shaft, aligning the pointer on the knob with the MIN index on the panel. If necessary, remove the knob and reposition the pot to obtain perfect indexing.

Female BNC connector *J1* is too long to fit over the battery compartment. Therefore, modify it as follows: Use an X-acto or similar miniature saw to trim the connector's threaded length to about $\frac{5}{16}$ inch long. Then bend the center conductor at a 90-degree angle to the conductor's normal axis; make sure the center conductor does not short against the threaded portion of the connector.

Plug the BNC connector into the TTL OUT hole in the enclosure's panel. Solder a 3-inch length of hookup wire to the washer that came with the connector. Slide the washer onto the threaded end of the connector and follow with the supplied hex nut.

If you prefer not to modify the BNC connector as detailed above, you can use the *J1* hole as an exit for a 50-ohm coaxial cable (not longer than 1 meter) terminated in a male BNC connector at the outside end. The other end then directly connects to the appropriate points on the circuit-board assembly. Make sure to connect the cable's shield to circuit ground and the center conductor to the signal-output hole. Also, find a way to provide mechanical strain relief for the cable. A convenient means is to use a nylon cable tie that binds the cable to the circuit board via a small hole drilled in an unused area of the latter.

Note in Fig. 4 that even though *CR1* and *CR2* are positioned slightly forward of *Q1*, energy given off from the sides of the cases of these devices can strike and saturate the phototransistor. To prevent this from happening, slide a ¼-inch length of appropriate diameter heat-shrinkable tubing over *CR1* and *CR2* and shrink into place. Make sure that the forward-facing portions of the lenses on these IR emitters are not obstructed. Shrink the tubing until it just begins to conform to the shape of the diodes.

Wire visible LEDs *CR3* and *CR4*, BNC connector (or cable), switch/pot assembly and pushbutton switch to the circuit-board assembly as per Figs. 1 and 4. Tightly twist together the fine wires in each conductor of the battery snap connector and lightly tin with solder. Pass the free ends of these wires into the enclosure through the battery compartment and plug the red one into the + BATTERY and black one into the − BATTERY holes in the circuit board and solder into place.

Checkout & Use

With *U1* and *U2* still not installed, snap the battery into its connector. With power turned off, measure the voltage delivered to the circuit at the + BATTERY ("hot" meter lead) and − BATTERY points to confirm that the battery is delivering approximately +9 volts dc.

Turn on the power by rotating the control knob just until you hear and feel the click. Connect the meter's common lead to pin 11 and its hot lead to pin 4 of *U1*'s socket. The meter should indicate +9 volts. Next, connect the meter's common lead to pin 7 and its hot lead to pin 14 of *U2*'s socket. This time, your reading should be +5 volts.

Once you are satisfied that your wiring is okay, turn off power to the circuit and install *U1* and *U2* in their sockets. Make sure that each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets.

With power on once again and gain set to minimum (*R2* fully counterclockwise, just before the click of the switch), *CR3* should light. If not, check the wiring of *CR3* and *CR4* for proper polarity.

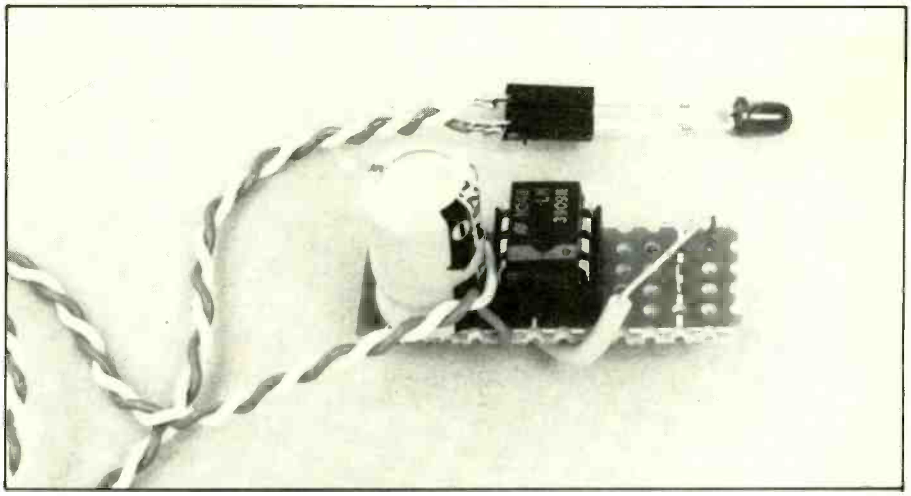
If everything looks good so far, aim the Photo-Pulser at a turned-on fluorescent light up to 15 feet away or a CRT screen between 1 and 2 feet away and adjust the gain until both LEDs light. To test the point-source LEDs, adjust *R2* for about mid-gain and wave your hand in front of the window at the end of the enclosure while pressing *S2*. Now *CR3* and *CR4* should flash as your hand or fingers pass by.

Once you know that your Photo-Pulser is working as it should, the project is ready to be put into service. To use it, simply connect its output to the input of a frequency counter via the TTL OUT connector or cable, turn on both instruments and select an appropriate range on the counter. Finally, adjust sensitivity as needed.

A Miniature LED Beacon

This easy-to-build project adds more realism to model airplanes, trains, etc., and can be used as an attention-getting device in jewelry and science-fair projects

By Dan Becker



If you operate model railroads, airplanes, etc., the battery-powered Miniature LED Beacon to be described can enhance their realism by providing a railroad warning light or an airplane or rocket strobe or landing light. Alternatively, the tiny circuit can be used to draw attention to signs or, with a wristwatch battery, to create electronic jewelry. The project is small and light enough in weight to fit inside or on any model. It uses only few low-cost components and can be assembled in an hour or less. In fact, if you are an experienced electronics experimenter or hobbyist, chances are good that you have all the components needed in your spare-parts box.

About the Circuit

The Miniature LED Beacon circuit is shown schematically in Fig. 1, which also illustrates the internal workings of the LM3909 integrated circuit that makes up the heart of the project. In this circuit, *IC1* performs as both a LED driver and an oscillator. The circuit is powered by a No. 357A 1.5-volt cell. Because circuit current drain is less than 1 milliampere, this cell will provide more than seven days of continuous operation.

Current flows from the positive (+) terminal of *B1* via pin 5 of *IC1* through internal resistors *RA* and *RB* and to the IC's pin 2 output. This current charges capacitor *C1* and flows through the *RC/RD* series resistor combination. Resistors *RA* through *RD* and capacitor *C1* make up an RC timing circuit whose time constant (charging time) is 2.16 seconds.

When the charge on *C1* reaches about 1.5 volts, the comparator inside *IC1* switches on. This, in turn, switches on transistor *Q1*.

Once *Q1* switches on, it provides a low-resistance current path in which the voltages across *B1*, *RE* and *Q1* are in series with each other. The advantage of this arrangement is that the 1.5 volts across *B1* and the nearly 1.5 volts of charge on *C1* add to put a 3-volt potential across *LED1*.

The discharge time constant is about 6 milliseconds. This yields a short, bright flash of light from *LED1*. When *LED1* flashes, it discharges *C1* so that the cycle can repeat. This charge/discharge cycle repeats once every couple of seconds.

Construction

The circuit can be assembled on a ½ × 1⅜-inch perforated board that has holes in 0.1-inch centers. For soldering convenience, each hole should be surrounded by a narrow circle of copper cladding on one side only.

Position the board as shown in Fig. 2, and install an 8-pin DIP IC socket ½ inch from the left end, with pin 1 positioned nearest the lower-right corner of the board. Solder the socket's pins to the copper circles on the board.

Plug electrolytic capacitor *C1* into the holes in the board, route its positive (+) lead to pin 2 of the socket and solder the connection. Clip off any excess capacitor lead length. Similarly, route the capacitor's negative (−) lead to pin 8 of the IC socket, solder the connection and clip off any excess lead length. Incidentally, to keep the circuit assembly as compact as possible, use a capacitor with a 6.3-volt rating. Of course, if you cannot find a 6.3-volt electrolytic,

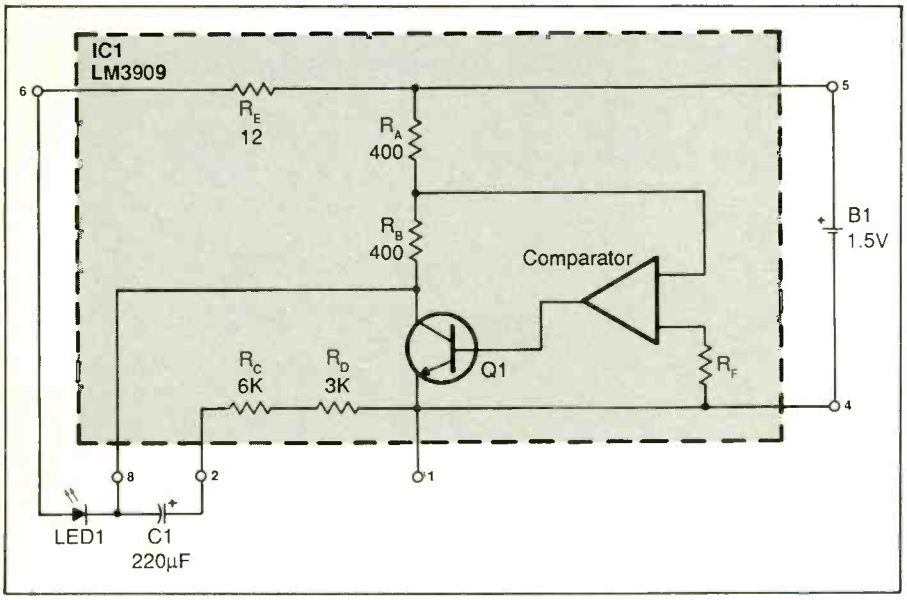


Fig. 1. Schematic diagram of Miniature LED Beacon.

PARTS LIST

B1—No. 357A battery (Radio Shack Cat. No. 23-115 or similar)—see text

C1—220-µF, 6.3- or 16-volt electrolytic capacitor with radial leads (see text)

IC1—LM3909 LED flasher/oscillator (Radio Shack Cat. No. 276-1705)

LED1—Any general-purpose red light-emitting diode.

Misc.—Perforated board with holes on 0.1-inch centers and thin solder rings around each hole (Radio Shack Cat. No. 276-185 or similar) 8-pin DIP socket for IC1; 2-conductor, light duty cable or individual 26-gauge stranded hookup wire (see text); 24-gauge solid hookup wire; insulating plastic tubing; solder; etc.

you can use one that has a 16-volt rating at the penalty of larger assembly size.

When you install *C1*, position it so that its negative lead is as close as possible to pin 8 of the socket. Before routing and connecting the positive lead to the socket, slip over this lead a ⅝-inch length of insulating plastic tubing and then route it to pin 2 of the socket.

A standard red light-emitting diode (*LED1*) connects to the circuit assembly via its cathode lead to pin 8 and anode lead to pin 6 of the IC socket via an appropriate length of two-conductor cable or two separate stranded hookup wires loosely twisted together.

To prepare the cable or wires, start by removing ⅛ inch of insulation from both conductors at both ends. Then tightly twist together the fine wires in each conductor and sparingly tin with solder.

Separate the conductors at one end of the cable about 1½ inches and then slip over each the 1-inch length of insulating plastic tubing. Clip the cathode lead of the LED to ½ inch and solder to it one of the cable conductors. Similarly, clip the LED's anode lead to ½ inch and solder to it the other conductor. Then slide the plastic tubing over the soldered connections until it contacts the bottom of the LED's case.

Connect and solder the other end of the cable to the appropriate pins of the IC socket. Make sure that the cathode conductor goes to pin 8 and the anode lead goes to pin 6.

To mount *B1* on the board, you need some sort of holder, which you can make from a ¾-inch length of 24-gauge solid tinned hookup wire from which all insulation has been removed. Bend the wire to form a "U" shape whose "legs" are parallel to each other and 0.1 inch apart. Plug the legs of the wire U into the holes at the center of the battery area in the perforated board.

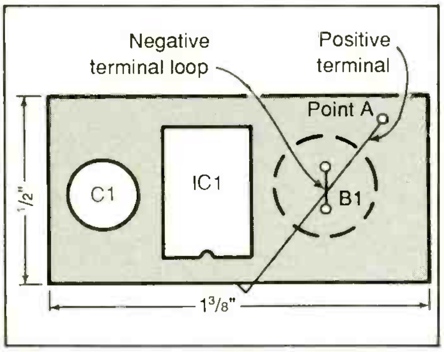


Fig. 2. Assembly details for project, which mounts on and is wired to a small perforated board.

Locate the center of the battery area as follows. First, set the No. 357A cell with its negative lead facing toward the board and immediately to the right of the socket. Then use a pencil to lightly trace the outline of the cell onto the board's surface. Remove and set aside the cell and count the number of holes across the outline to find the center. Plug the wire U into the holes that most approximate the center location. Bend one leg of the wire U flat against the board, route it to pin 4 of the IC socket and solder the connection. Bend the other leg flat against the board in the opposite direction and solder it to any convenient point on the board.

Press the part of the U that protrudes from the top of the board flat against the surface so that the cell sits as close as possible on the board.

(Continued on page 90)

A High-Performance Audible Continuity Tester

A stand-alone instrument that tests circuits and components for continuity down to 50 milliohms

By Adolph A. Mangieri

Most continuity testers have a relatively high resistance at which they trip, severely limiting their utility in many critical testing applications. With a trip threshold of 200 ohms, for example, *any* resistance less than this value will show up as a good indication, which would make just about any switch, relay or wire that is not an open circuit test good. So to be truly useful, a continuity tester should be able to tell you when a device or circuit has too much resistance, even if "too much" is less than 10 ohms, to adequately do its job. The continuity tester should have a trip point that can be adjusted to between, say, 50 milliohms and 10 ohms, as the high-performance continuity tester to be described does.

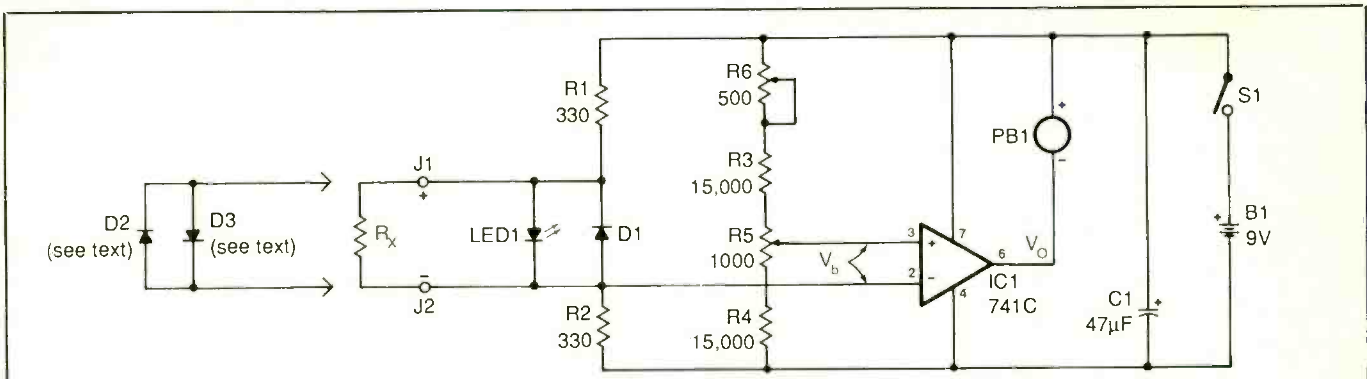
Our tester has a piezo-buzzer that sounds when continuity measures between 0 and 10 ohms. For general-purpose testing, a 10-ohm trip threshold would be selected. For more critical tests, the project would be preset against a 50- or 100-milliohm resistor to detect resistance differences of as little as 10 or 15 milliohms. A LED indicator is used when testing circuits whose resistance is greater than 10 ohms.

Only a 0.25-volt test potential is imposed on the circuit under test, making this continuity tester safe to use on digital circuits. For maximum versatility, the tester can be used as a low-range ohmmeter (you read resistance directly its dial) and as a good/bad indicator for a variety of solid-state devices.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the High-Performance Audible Continuity Tester. Resistors *R1* and *R2* make up two arms of a dc Wheatstone bridge, with resistor R_x in the *R1* arm representing the circuit or device under test. The other two arms of the bridge are made up of potentiometers *R5* and *R6* and resistors *R3* and *R4*. Potentiometer *R6* is used to set the threshold from 0 to 10 ohms on a calibrated dial, while potentiometer *R5* balances the bridge circuit.

Operational amplifier *IC1* senses the output voltage from the bridge circuit, V_b, via input pins 2 and 3. In this configuration, the *IC1* op amp is operated in the open-loop condition as a very-high-gain voltage comparator with a dc open-loop gain in excess



PARTS LIST

Semiconductors
D1—1N4001 rectifier diode
D2,D3—1-ampere Schottky barrier diode (Radio Shack Cat. No. 276-1165 or equivalent)
IC1—741C operational amplifier
LED1—Red T-1¾ light-emitting diode
Capacitors
C1—47-µF, 15-volt electrolytic
Resistors (½-watt, 1% tolerance)
R1,R2—220 ohms
R3,R4—15,000 ohms
R5—1,000-ohm trimmer potentiometer
R6—500-ohm, linear-taper panel-mount potentiometer
Miscellaneous
B1—9-volt transistor battery
J1,J2—5-way binding post (one red, one black)
PB1—Piezoelectric buzzer (Radio Shack Cat. No. 273-065 or similar)
S1—Spst toggle or slide switch
Suitable enclosure; printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware; DIP socket for IC1; snap-on connector and clip for B1; pointer-type control knob for R6; machine hardware; hookup wire; solder; etc.

Fig. 1. Complete schematic diagram of high-performance continuity tester.

of 100,000. Hence, a fraction of a 1-millivolt difference at pins 2 and 3 of *IC1* is sufficient to swing output voltage V_o at pin 6 from low to high or high to low, depending on the polarity of input V_b.

If R_x is an open circuit, pin 3 of *IC1* will be positive with respect to pin 2, causing Vo to go high and silence piezoelectric buzzer *PB1*. Conversely, if R_x is less than the value set by *R6*, input pin 3 goes negative with respect to pin 2, causing V_o to go low and sound *PB1*.

Light-emitting diode *LED1* serves as an on/off indicator, test-current indicator and visual continuity indicator. It also limits the open-circuit test potential to 2 volts.

When plugged into *J1* and *J2*, Schottky barrier diodes *D2* and *D3* further limit the open-circuit test potential to 0.25 volt. Rectifier diode *D1* provides circuit protection. The short-circuit test current passed through R_x is approximately 12 milliamperes.

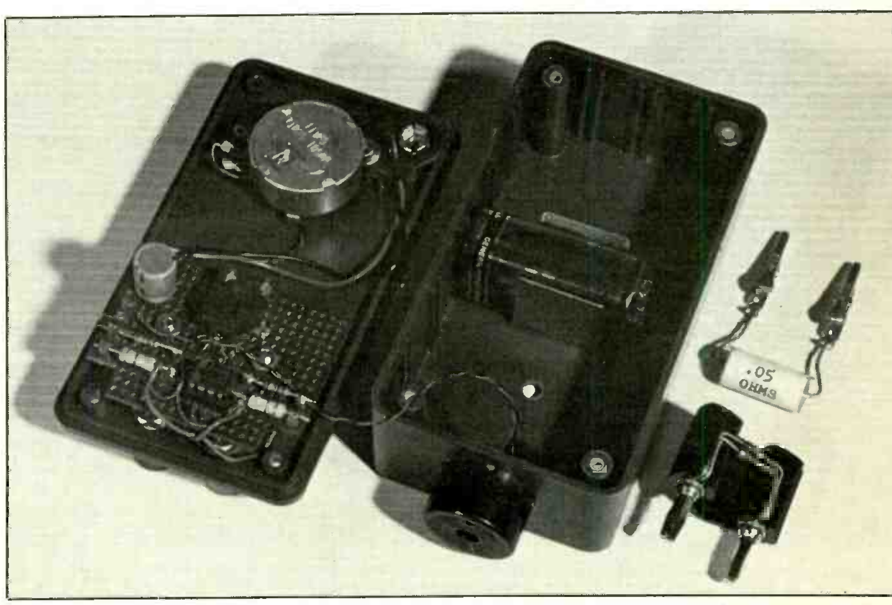


Fig. 2. All components can be mounted and wired on perforated board that then mounts on front panel of enclosure.

In designing the project, the range of R_x covered by *R6* was calculated using the formula $R_x = (R1 \times R6)/(R3 + 0.5R5)$. With the component values specified, R_x is 10.6 ohms. The range covered by *R6* would be doubled to nominally 20 ohms if this potentiometer's 1,000-ohm value or halved to 5 ohms if the potentiometer's value is 250 ohms.

Sensitivity of the bridge circuit to small differences in R_x is determined by the amount of current in arms *R1* and *R2*. The greater the current, the higher the sensitivity.

Values for *R1* and *R2* were chosen as a compromise between loading of battery *B1* and bridge sensitivity. Making *R1* and *R2* larger in value to reduce battery drain reduces sensitivity because *R1* becomes appreciably larger than R_x. Contrariwise, making *R1* and *R2* appreciably lower in value than 330 ohms increases bridge sensitivity but places a greater drain on *B1*. Keep this in mind if you decide to make circuit changes.

Construction

Figure 2 shows how the high-performance continuity tester can be assembled in a small plastic enclosure with all circuitry except the piezo buzzer and battery in its holder mounted on the lid. Component layout and wiring are not critical, permitting you to use any assembly technique that suits you. You can use perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware as shown or a printed-circuit board on which to mount the components, which is then mounted to the enclosure's lid.

Fabricate the pc board using the actual-size etching-and-drilling guide shown in Fig. 3. Then install the components on it exactly as shown in Fig. 4. Use a socket for *IC1* and make sure that *C1* and *D1* are properly polarized before soldering their leads to the copper pads. Do *not* install the IC in the socket until after initial checkout has been performed. You can use an ohmmeter to select matched pairs of 5-percent-tolerance resistors for *R1* through *R4*.

Next, trim ¼ inch of insulation from both ends of eight 5-inch hookup wires. Plug one end into the LED1, B1-, S1 and R6 holes and solder them into place.

When machining the enclosure's lid, drill two mounting holes for *J1* and *J2* exactly ¾ inch apart to accommodate a double banana-jack assembly. Then drill the holes in which to mount *LED1* in a panel clip and POWER switch *S1* and potentiometer *R6*. Mount the LED, switch and pot in their respective holes.

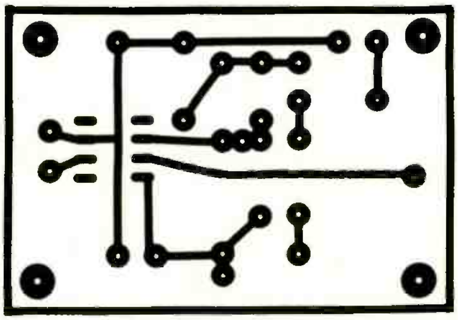


Fig. 3. Actual-size etching-and-drilling guide for making printed-circuit board that can be used instead of using perforated board.

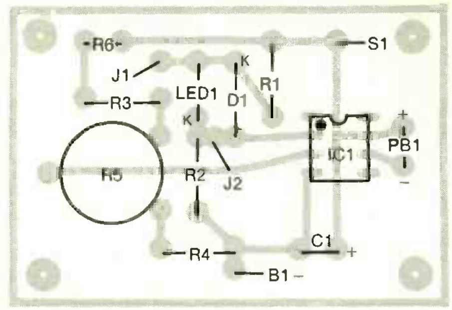


Fig. 4. Wiring guide for printed-circuit board. Be sure to use a DIP socket for IC1 and observe proper component orientations.

Wire potentiometer *R6* so that its resistance increases with clockwise rotation of the shaft. File a flat on the shaft of this pot so that its knob pointer falls at about the 7 o'clock position with the control shaft set fully counterclockwise. Set *R6* fully counterclockwise and place a small dot on the panel at the pointer location to serve as the minimum reference mark.

Install two 40-volt, 1-ampere Schottky rectifier diodes in parallel with each other and back-to-back on a double banana plug. This "accessory" can plug either way into the *J1/J2* assembly. It is used to limit the open-circuit test potential to 0.25 volt for digital circuit tests.

Carefully check the polarities of *C1*, *J1*, *J2* and *PB1* before applying power to the circuit. Connect a voltmeter, set to its lowest dc voltage range, from *J2* (common lead) to the wiper lug of *R5* or to pin 3 of the *IC1* socket. Set *R6* to its fully counterclockwise position. Set POWER switch *S1* to ON and verify that *LED1* lights. Connect a jumper wire across *J1* and *J2* and adjust *R5* over its entire range. The polarity of V_b should change from + to − and vice-versa.

If you used 1-percent resistors in the bridge circuit, potentiometer *R5* will be near its mid-point setting when the bridge is at null setting. If you cannot null the bridge circuit, check the resistors here for possible mismatch caused by soldering heat.

Power down the circuit and install *IC1* in its socket, taking care to properly orient it as shown. Make sure that no pins overhang the socket or fold under between IC and socket.

Use an ohmmeter to set *R6* to about 25 ohms and mark a temporary 0-ohm index on the project's panel. Connect a short, heavy U—shaped jumper wire across *J1* and *J2* and adjust the setting of bridge BALANCE control *R5* just to the point where the buzzer sounds.

Advance the setting of *R6* from its fully counterclockwise reference mark until the buzzer sounds and note whether this corresponds with the 0-ohm index. If not, trim the *R5* setting slightly and recheck.

Connect a 10-ohm resistance across *J1* and *J2* and advance *R6*'s setting until the buzzer sounds. If the value of *R6* is too low, maximum range may be 8 or 9 ohms.

To calibrate the BALANCE dial, you need six 1-ohm and two 5-ohm resistors to make up all the values between 0.5 and 10 ohms in 0.5-ohm increments. Two 1-ohm resistors in parallel make up a 0.5-ohm resistor.

With *J1* and *J2* shorted together, advance the setting of *R6* until the buzzer just sounds and mark and label this as the 0-ohm index. Connect resistors ranging from 1 to 10 ohms across *J1* and *J2* and mark off on the panel the 1-ohm intervals. Then, using the 0.5-ohm resistance you prepared in series with the 1-ohm resistors, label the 0.5-ohm intervals.

Remove the pointer knob from the potentiometer and label the control panel as shown in the lead photo. You can use a dry-transfer lettering kit for this. When the panel is ready, spray onto it two or three *light* coats of clear acrylic to protect the lettering. Wait until each coat completely dries before spraying on the next. Then replace the knob on the potentiometer's shaft and double check that the pointer index properly lines up with the counterclockwise reference mark.

The resistance per foot of solid copper wire is as follows:

Wire Gauge	Milliohms/foot
12	1.62
14	2.56
16	4.10
18	6.51
20	10.4
22	16.5
24	26.2
26	41.5
28	66.2
30	105
32	167

Armed with this information, fabricate a 50-milliohm and a 100-milliohm resistor, using suitable lengths of wire wound onto larger-value (100-ohm or greater) 1- or 2-watt carbon resistors. For example, a 6-inch length of 30-gauge wrap wire is 50 milliohms, which is close enough for our purposes.

Connect the 50-milliohm resistor across *J1* and *J2*. With the buzzer sounding, very slowly rotate the control knob on *R6* counterclockwise until the sound from the buzzer ceases. Replace the resistor with the heavy wire jumper. If you have not overshot the first setting, the buzzer should sound, indicating that the resolution of the tester is well under 50 milliohms.

If you cannot obtain the above result, try again using the 100-milliohm resistor instead of the 50-milliohm one. If even this fails to give you the proper response, the problem is low open-loop gain of the particular 741 op amp being used. You will then have to change chips until you have one with sufficient open-loop gain. When you replace an op amp, it may be necessary to touch up the setting of *R5* to reset the 0-ohm index.

Make a pair of test leads with phone tips at one end and collet-type test-probe handles at the other end. The collet accepts steel phono needles that easily bite into copper pads and terminals. Check your spare-parts box for old computer cable connectors that have machined female pins. You may be able to chuck the pin in the probe collet and use the probe to make contact with the top ends of Wire Wrap posts.

Make another pair of test leads, this time terminating one end in heavy-bite alligator clips and the other end with phone tips. Jumper-wire the two jaws of the alligator clips with copper braid to assure low-resistance connections.

Using the Tester

For general-purpose tests, merely set the dial to a resistance threshold of your choice, from 0.25 ohm to 10 ohms, and proceed with your tests. The buzzer will sound when the resistance of the circuit or component under test is equal to or less than the value set on the dial. If the buzzer does not sound and *LED1* is off, indicating test current flow, you can adjust the setting of *R6* until the buzzer does sound and read off the indicated resistance from the tester's BALANCE dial.

Switch and relay contacts usually have contact resistances of 2 to 10 milliohms or so when new. The small reed relay may have up to 100 or even 200 milliohms of contact resistance. Used toggle, slide and microswitches often exhibit much higher contact resistance, the result of contact wear and oxidation.

To test switches, flip their toggles or sliders back and forth a number of times to burnish their contacts, removing oxidation. Then set the tester's dial well up-scale, say, to 5 ohms. Make connections to the switch and rotate the control knob on *R6* counterclockwise until the buzzer stops sounding. If the dial is at or very near the 0 index, the switch is in good condition. Many of the used switches I have tested gave resistance readings of as much as 0.5 ohm (500 milliohms), 3 ohms and even 5 ohms. Slide switches can often be restored with a shot of lubricating cleaner spray.

When the resistance of a circuit is expected to be extremely low, do the following. Give the project a 30-second warm-up to stabilize the very small drift of *IC1*. Short together the test leads and adjust the dial setting counterclockwise to the point where the buzzer just sounds. Proceed with your test. In this case, you will be working at considerably lower than 100-milliohm thresholds, possibly as low as 50 milliohms or less.

If the above procedure cuts things just a bit too close, use the following procedure. Short the test leads through the nominally 50- or 100-milliohm resistor you made earlier. Adjust the tester's dial just the the point where the buzzer sounds. The actual resistance threshold is equal to the value of the calibrating resistor plus just a bit more. This gives you more leeway than does the preceding mode of operation.

You can also do the above the other way around. With the calibrating resistor connected to the test leads, adjust the project's dial to the point where the buzzer just stops sounding. Then remove the calibrating resistor and short together the tester's leads and verify that the buzzer sounds to be sure you have not overshot the adjustment. This sets the threshold to a point somewhat less than the value of the calibrating resistor.

Multiple-conductor ribbon cables, DIP jumpers and similar devices are tested by comparing the lines while looking for differences in resistance. You decide how close you want to cut this test.

For an example of how to use the tester, assume you are testing a 36-inch IDC ribbon cable made up of 28-gauge conductors. Armed with conductor length and gauge and the information given above, you know that the conductors should have a resistance that is close to 200 milliohms. The two IDC contact pins at the ends of the conductor may add 40 milliohms of resistance at worst.

Make connections to the IDC socket pins of any line selected as a standard for comparison. Use two wrap-post pins, preferably gold plated, to make connections. Adjust the setting of *R6* clockwise until the buzzer sounds. Check two additional lines. If the buzzer sounds, the three lines are typical; so you can proceed with testing. If the buzzer does not sound, the first selected line may be defective. Select another line as the standard for comparison and proceed in a similar manner.

A cable that passes this test is in excellent condition. If you want more leeway, nudge *R6* a bit more upscale, or calibrate the first line with your 100-milliohm test resistor temporarily inserted in series with it. Checking an IDC cable suspected of causing computer crashes, I found that the resistance of one line was 0.5 ohm greater than the others. This difference would be of little concern with a low-current signal line. However, as luck would have it, the defective conductor run was the 5-volt power-supply line. When you find a suspicious line, test it several times and flex the cable at each connector to identify which connector is causing the problem.

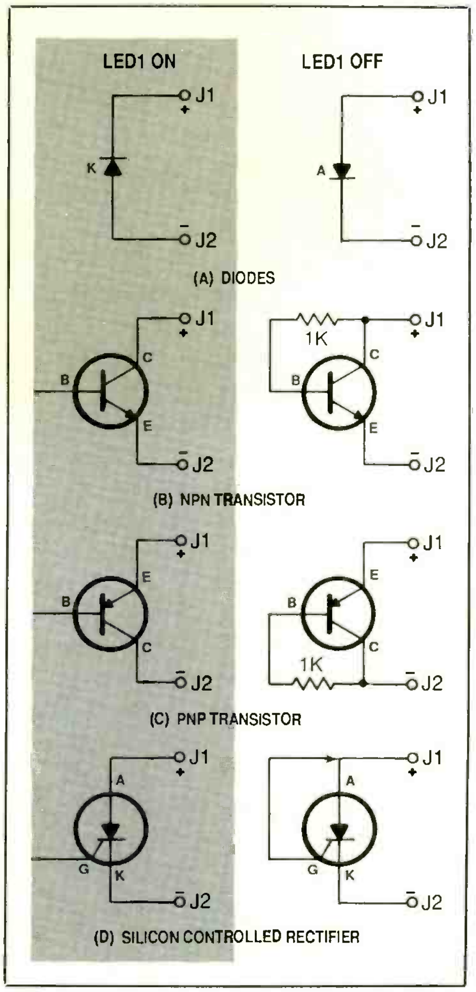


Fig. 5 Connection arrangements to use when testing various types of semiconductor devices.

To assist in cable testing, dedicate a male or female socket with all pins connected together at one end and probe each line at the other end. Ribbon cables and DIP jumper cables have the same wire gauge on all lines, but some bundled cables may have several wire gauges and several socket pin sizes that you must take into account when making tests on them.

When you test populated circuit-board assemblies, insert the *D2/D3* Schottky diode voltage limiter into *J1* and *J2*. For good indications, *LED1* should remain off when the tester is used in this manner. Perform your tests with no power applied to the circuit-board assembly. The low 0.25-volt test potential and 12-milliampere test current should not damage any ICs in the circuit, regardless of test lead polarity. Integrated circuits can typically withstand up to 0.6 volt of reverse bias current. If there is any doubt about this, check the device's specifications.

You can also use this continuity tester to measure resistances of up to 10 ohms. When it is used in this manner, adjust *R6* to the threshold point and read the value indicated on the control's dial. Another way you can use the tester is as a visual continuity tester in which *LED1* is off when the resistance between *J1* and *J2* is less than about 100 ohms or so. Use this mode to check continuity of audio transformers and the like.

Using the connection arrangements shown in Fig. 5, the continuity tester handily performs basic good/bad tests on a wide variety of semiconductor devices. If the device being checked fails the test, it has little or no chance of meeting its published specifications. If it passes the test, the device has a very good chance of meeting its specifications.

To check diodes and rectifiers, bridge the device across *J1* and *J2* in both directions, as shown in Fig. 5(A). With cathode K connected to *J1* (+) and anode A connected to *J2* (−), *LED1* should be on to indicate that the diode is blocking the flow of current. Reversing the device's connections to the jack, the LED should be off, indicating that the diode is conducting.

If *LED1* is on when the diode is connected across the jacks in both directions, the diode is either open or consists of multiple diodes in series with each other. If the LED remains off when the diode is connected across the jacks in both directions, it is shorted.

When checking a light-emitting diode, the LED should emit some light (though it may be faint and difficult to see) with its anode connected to *J1* and its cathode connected to *J2*.

Figures 5(B) and 5(C) show connections for checking small- and medium-power npn and pnp bipolar transistors. When using the tester to check bipolar transistors, check first with base lead B floating or disconnected. If the transistor is good, the LED should light, indicating that the transistor is off and is not shorted. Connecting a 1,000-ohm resistor from base B to collector C should cause *LED1* to turn off, indicating that the transistor has switched on and is amplifying.

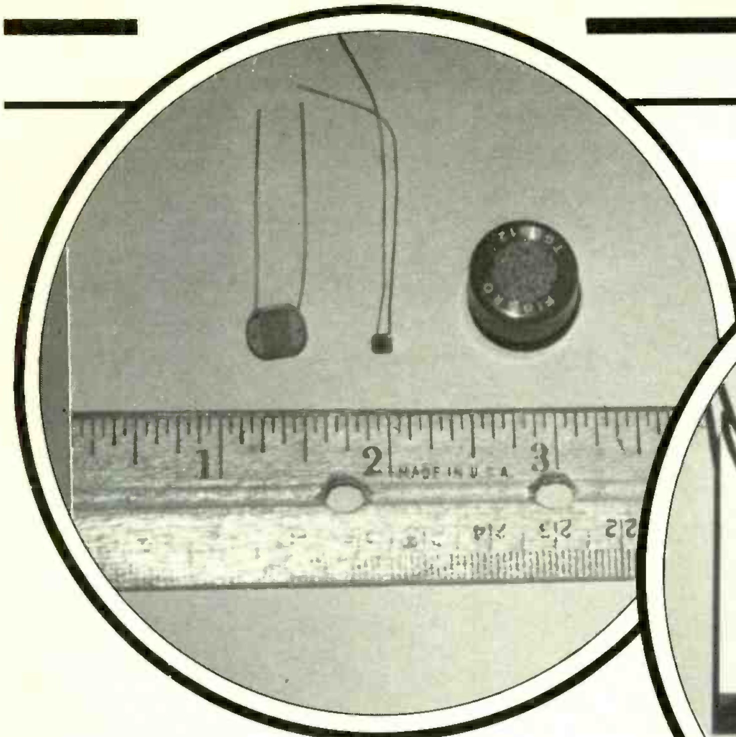
Check photodiodes and transistors as you would any ordinary diode and transistor. The only exception is that you should use a flashlight to switch on the device under test.

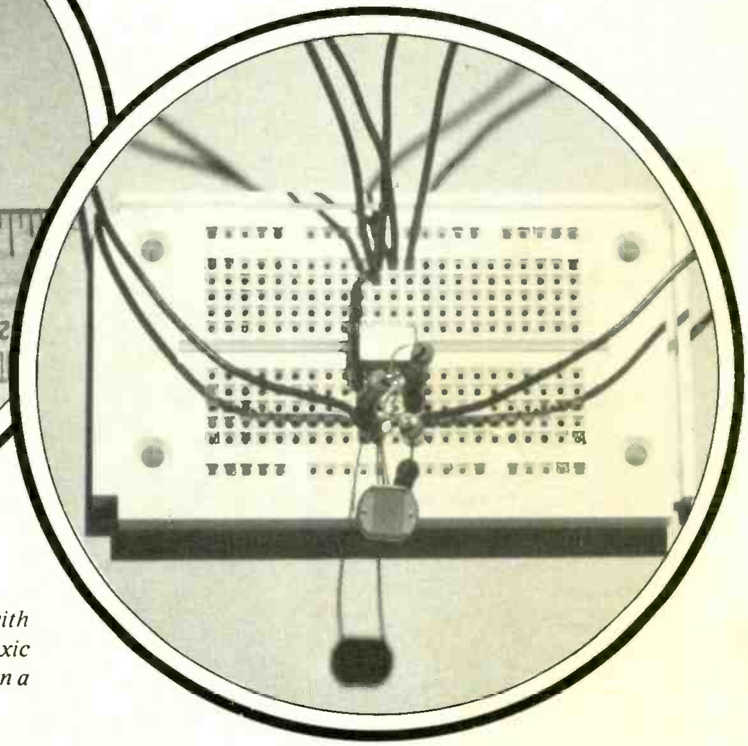
Figure 5(D) shows how to check low- and medium-current silicon controlled rectifiers (SCRs). With gate lead G not connected to anode A, *LED1* should be on to indicate that the SCR is blocking the flow of current. If the LED is off, try opening and closing *S1* on the continuity tester. With the SCR in the blocking mode, momentarily touch gate lead G to anode lead A; the LED should switch off, indicating that the SCR has switched on and is conducting current as it should.

With high-current SCRs, the device may not switch off when the gate lead is removed from the anode lead. This is because the test current is less than the SCR's holding current. With very-low-current SCRs, the device may switch on just by touching its gate lead. A high-current SCR that needs more than about 12 milliamperes of gate turn-on current will not switch on and, thus, cannot be properly tested with this tester.

The tester should rarely require any servicing, apart from occasionally replacing the battery when its output voltage under load drops to about 6 volts. Occasionally check the 0-ohm index with *J1* and *J2* shorted together, and adjust *R5* as needed.

ME





Typical sensors (above, left to right) that can be interfaced with computer: photocell for light, thermistor for temperature, toxic gas sensor. Circuits (like light detector at right) can be wired on a solderless breadboard.

Interfacing Commodore's User Port

Using a low-cost serial A/D converter chip and some simple software, you can use your C-128, C-64 or VIC-20 to monitor real-world analog events

By John Iovine

Commodore's series of personal computers—the C-128, C-64 and VIC-20—can be used to sense and monitor the "real-world" environment. To be able to use these computers in real-world applications, however, you must know a bit about interfacing to be able to translate real-world analog events into the two-state binary "language" that can be understood by a digital computer.

In this article, we will be examining serial interfacing and the 60-Hz interrupt routine used in Commodore computers, using a low-cost off-the-shelf analog-to-digital (A/D) converter. Knowing what your computer wants and needs and equipped with the hardware required to convert real-world analog events to a binary code that the computer can use directly will open up a whole new world of applications for your computer.

Our focus here will be on *sensing* the real-world analog environment, with the computer serving as a data "receiver." To illustrate the power of the computer when interfaced with the real-world environment, we will be discussing such useful applications as biofeedback monitoring, monitoring light and heat with transducers and detecting toxic gases. By providing these applications and dis-

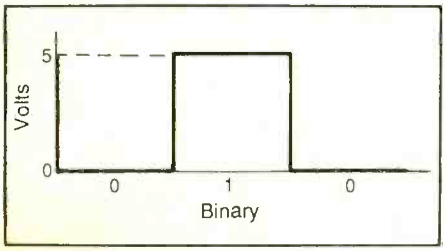


Fig. 1. Binary 1 and 0 are equal to +5 volts and 0 volt, respectively.

cussing them in enough depth to illustrate the principles of interfacing, you should be able to devise your own schemes to detect and monitor other physical phenomena, such as pressure, voltage, current, etc., among others.

A Brief Refresher

Before you can consider interfacing procedures for a computer, you must be thoroughly familiar with binary numbers as they relate to interfacing voltages. In the Commodore series of computers (indeed, *any* personal digital computer currently in use), a binary 1 is equal to 5 volts, while a binary 0 is equal to 0 volt, as illustrated in Fig. 1. In practice, though, there is a bit of "play" in each case. That is, the 5- and 0-volt figures are only approximate; the actual voltages required to initiate either binary level need approach only a volt or so of the +5- and 0-volt levels.

The type of interfacing used is important, too. There are basically two interfacing schemes commonly used in personal computers today: serial and parallel. To be able to successfully interface your computer with the real-world environment, therefore, you must understand the difference between serial and parallel interfacing.

In a parallel interface, eight data bits are transmitted or received simultaneously on eight parallel lines called a data bus. The details of the typical parallel interface used in personal computers like those from Commodore are given in Fig. 2, which also shows the eight PB lines of the Commodore User Port.

To read the binary number on the port, you add the decimal values represented by the 1s under Binary Values, reading from bottom to top, assigning a 1 for all PB lines that are at 5 volts and a 0 for all PB lines that are at 0 volt. Hence, the binary number in this example is 10011010. Translating this binary number, you would obtain a decimal value of 89 (1 + 0 + 0 + 8 + 16 + 0 + 64 + 0).

As its name implies, in a serial interface, the same information can be transmitted and received over a line consisting of only two conductors, one bit at a time. Figure 3 illustrates how this is accomplished. The first bit transmitted or received is bit 7. The clocking line correlates the precise moment to receive or transmit data on the line.

Commodore computers have a built-in serial register and clocking line that can receive or transmit data in such a serial fashion. This greatly simplifies your programming task.

You might be wondering just what an analog event is. This should be an easy question to answer, since we deal with analog such events as temperature, speed, etc., every day of our lives. Therefore, an analog event is one in which the reading or measurement is infinitely variable between two points. The possible voltage events between 1 and 2 volts, for example, can be virtually any value between these two levels, such as 1.1 volts, 1.00009 volts and any number up to and including 2 volts, with any number of decimal places. As you can readily see, the voltages can vary by infinitesimal amounts, making the possible number of readings infinite.

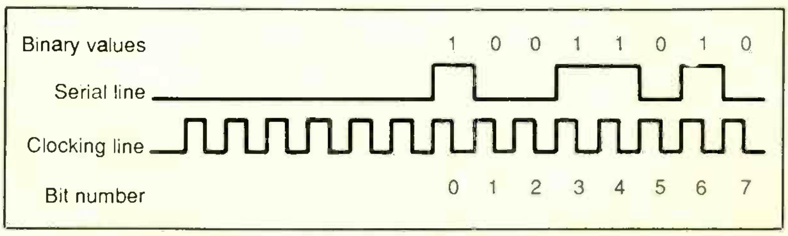
In contrast, a digital event occurs in a discrete, predefined step. A simple example of this is an electrical light switch that can be either on or off, with no positions in between. A rising voltage that is digitally plotted against time would not trace a smooth, continuous line, as in the case of plotted analog events, but would jump in increments that resemble a staircase. The illustration shown in Fig. 4 shows how analog

DECIMAL EQUIVALENT	DATA BUS LINES	SIGNAL VOLTAGES	BINARY VALUES
128	PB7		0
64	PB6		1
32	PB5		0
16	PB4		1
8	PB3		1
4	PB2		0
2	PB1		0
1	PB0		1

10011010 (Binary) = 89 (Decimal)

Fig. 2. On a parallel I/O bus, eight data bits are transmitted or received simultaneously.

Fig. 3. On a serial I/O arrangement, one bit is transmitted or received at a time.



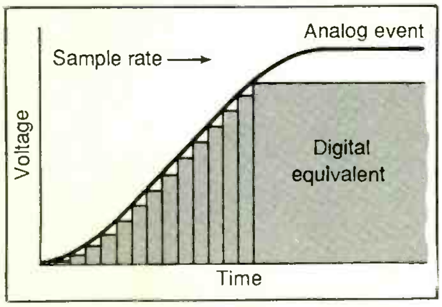


Fig. 4. A smooth analog line is represented digitally by a staircase-like waveform.

and digitally plotted data compare to each other.

Serial A/D Converter Chip

An analog-to-digital converter does just as its name implies. It "reads" an analog voltage and then converts it to a specific digital (binary) value that the computer can use. This digital value is then fed into the computer.

A TLC548 serial A/D converter integrated circuit useful for our applications is readily available at any Radio Shack store (Cat. No. 276-1796) for just $6.95. This 8-pin DIP chip, whose package configuration and pinout details are given in Fig. 5, is extremely easy to interface to the Commodore User Port. It can handle 40,000 samples per second and has an internal clock and an 8-bit conversion resolution.

To use this chip, you need four lines on your experimenter card that has connector fingers that match up with your computer's User Port contacts, as illustrated in Fig. 6. Two of these are the serial and clocking lines for the serial register. Figure 6(A) shows the arrangement to use for C-128 and C-64 computers. The serial and clocking lines for these two computers are at CNT2 and SP-2, respectively, on the User Ports. The arrangement to use for the VIC-20 computer is shown in Fig. 6(B), which picks up the serial line at CB2 and clocking line at CB1 on the User Port. The other two lines that provide the clocking signal and chip-enable function come from the computer's parallel port.

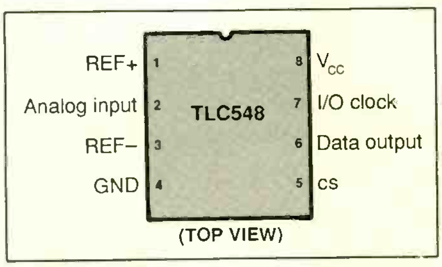


Fig. 5. Case configuration and pinout details for TLC548 serial A/D converter chip.

When building the appropriate Fig. 6 circuit for your particular computer, be sure to use a socket for the serial A/D chip. The outer lugs of the 10,000-ohm potentiometer shown in both circuits must be connected between +5 volts and ground at pins 1 and 4 of the A/D chip. The potentiometer's wiper then wires directly to the chip's analog input at pin 2. This control is used here for testing purposes.

Once you have breadboarded the appropriate circuit for your specific model Commodore computer, plug the circuit assembly into the computer's User Port. (Note: Make sure to turn off the computer *before* you attempt to plug the card into or remove it from the computer's User Port. If you plug or unplug the card while the computer is running, you can irreparably damage the A/D circuit, the computer or both!)

With the A/D card plugged into the computer, turn on the power and type in and run the BASIC Loader Program for your specific computer (Program Listing 1 for C-128 and C-64 models or Program Listing 2 for the VIC-20). Slowly vary the setting of the potentiometer and note the results on the computer's video monitor screen. The numbers displayed on the screen represent the digital equivalent of the voltage present on pin 2 of the A/D converter. If you have a voltmeter handy, you can connect it between the pot's wiper lug and circuit ground to compare the computer's displayed voltage values against those displayed on the voltmeter.

The serial register in Commodore computers and the A/D chip is one byte (eight bits) long. The largest value one byte can contain is 11111111, which is decimal 255. With this 8-bit A/D chip, therefore, you have 255 possible increments between the minimum and maximum voltages being measured.

The relationship between the maximum 255 count of the A/D converter and V_{ref} tells you what each increment represents with respect to the voltage being measured. If the range is from 0 to +5 volts, each increment is 5 volts/255 = 0.01960788431 volt per step. Each time the voltage varies by this amount, the reading of the serial point will vary one point. If the computer is reading 100, the voltage at pin 2 of the A/D converter chip is 100 × 0.01960788431 = 1.960788431 volts, or approximately 2 volts. By substituting different transducers for the potentiometer shown in the Fig. 6 circuit, you can have your computer measure levels of light, heat, toxic gas and galvanic skin resistance.

The BASIC programs used to demonstrate operation of the interface is slow and cumbersome. Therefore, later on, we will use a machine-language program that works with the 60-Hz interrupt to speed things up. In the C-128/C-64 and VIC-20 BASIC programs (Listings 1 and 2), two additional registers are being used aside from the parallel port (56579) that is commonly used in interfacing projects with Commodore computers. They are the 56588 Serial Register and the 56589 Interrupt Control Register. In the former, you PEEK the register to see what number the A/D converter transmitted, while in the later, you mask all interrupts.

The CRA Control Register, located at 56590, controls whether the

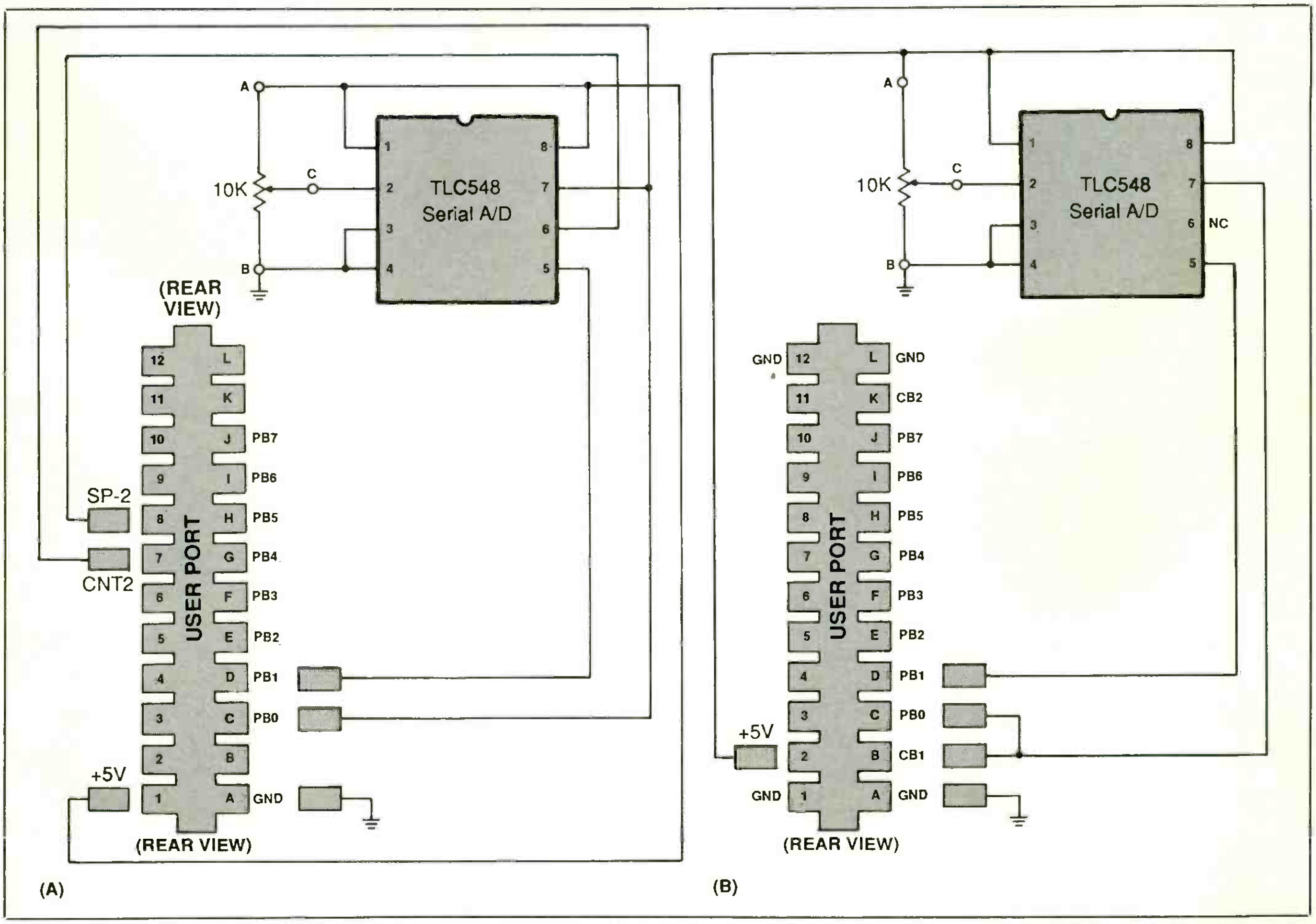


Fig. 6. How a TLC548 serial A/D converter chip is used to interface the C-128 and C-64 (A) and the VIC-20 (B) to the real-world environment.

serial line will be an input or an output. This register has the proper configuration needed on power-up; so it is not necessary to change it. You use the PB0 line to provide the clocking pulse to both the CNT line and the A/D converter chip. PB1 provides the high-to-low pulse needed every eight clock cycles to start the chip transmitting its latest conversion.

The program for the VIC-20 operates in a similar manner. Detailed information is provided in the Programmer's Reference Guide that came with your computer to help you to understand the serial register, interrupt register and CRA.

Listing 1: BASIC Loader for C-128 & C-64

```
2 REM  ** SERIAL ANALOG TO DIGITAL CONVERSION **
3 REM  ** FOR    COM-128    AND    COM-64      **
4 REM  ** JOHN IOVINE                  1987    **
5 POKE56579,255
7 POKE56577,0
10 POKE56589,127
12 FORX=0TO7
14 POKE56577,0:POKE56577,1
15 NEXTX
20 IF(PEEK(56589)AND8)=0THEN20
30 X=PEEK(56588)
40 PRINTX;
45 POKE56577,2
50 GOTO12
```

Transducers

The first of the transducer types with which we will work are in the variable-resistance category. That is, as the sensor (transducer) detects a physical analog event, its resistance will change. The change in resistance will cause a change in the voltage dropped across the transducer that is sensed as a varying voltage at the analog input at pin 2 of the A/D converter chip. The voltage on pin 2 will

Listing 2: BASIC Loader for VIC-20

```
10 REM VIC SER IRQ.BAS
15 REM J IOVINE
20 FORJ=7430TO7510:READX:POKEJ,X:NEXT
30 SYS7463:NEW
40 DATA160,8,169,0,141,16,145,169,1,141,16,145
50 DATA136,192,0,208,241,173,29,145,173,26,145
60 DATA133,255,169,2,141,16,145,108,84,29,173,20,3
70 DATA141,84,29,173,21,3,141,85,29,120,169,6,141
80 DATA20,3,169,29,141,21,3,169,255,141,18,145,169
90 DATA0,141,16,145,169,127,141,30,145,165,12,141
100 DATA27,145,88,96,234,234,234
```

be displayed as before, with changes in the transducer's resistance tracking in much the same manner as occurred before with the test potentiometer.

● *Light*. A cadmium-sulfide (CdS) cell like the Radio Shack Cat. No. 276-1657 changes its resistance in accordance with the intensity of the light that strikes it. Resistance is greatest in complete darkness and decreases in proportion to the intensity of the light it detects. Figure 7 shows the simplest method of connecting a CdS cell to the A/D converter.

There is a disadvantage in this particular arrangement in that only half of the converter's possible 255 count range (128 to 255) is being used. This is easily corrected with the circuit in which two 1,000-ohm resistors in series make up a voltage-divider network that changes $-V_{ref}$ from 0 volt to 2.5 volts. The voltage-per-step figure also changes to 2.5 volts/255 = 0.00980392157 volt per step. Thus, simply by adding the voltage divider to the basic circuit, potentials between 2.5 volts ($-V_{ref}$) and 5 volts ($+V_{ref}$) can be read, providing a full-scale reading with a simple CdS photocell.

Using the Fig. 7 arrangement, a photographer could use his computer as an exposure meter for his enlarger. In the laboratory, this arrangement could be used as a spectrophotometer to perform spectrographic analyses to determine what elements are in an unknown compound or even to determine the composition of our Sun or other star.

● *Temperature*. To measure temperature, you simply substitute a thermistor for the CdS photocell in the previous example, as shown in Fig. 8. The thermistor must have a negative-temperature coefficient (NTC) whose resistance decreases as temperature increases, as shown in the resistance plot in Fig. 8. Using a Digi-Key Cat. No. KC006N-ND thermistor, whose resistance at 25 degrees C (77 degrees F) is 10,000 ohms and maximum operating temperature is 150 degrees C (302 degrees F).

Resistor *R1* in Fig. 8, in series with the thermistor, is used to "scale" the reading range of the system. With the 47,000-ohm value shown, the circuit will respond to a 0-to-120-degree F range of temperatures. To change the response range, you must change the values of the voltage-divider resistors. If you do this, make sure you remain within the range detailed in the A/D chip's specifications sheet.

Calibration of the temperature-sensing setup is needed before using the sensor for any critical measuring applications. One way to do this is to immerse the thermistor "probe" in first ice water and then in boiling water and make a note of each reading obtained. The first number recorded is equivalent to 32 degrees F (0 degree C), the second to 212 degrees F (100 degrees C).

● *Toxic Gas*. A toxic-gas sensor responds to a wide variety of air-borne toxic and not-so-toxic compounds, including natural and butane gases, kerosene and gasoline, and even perfumes and colognes. It operates in a manner similar to that of of the thermistor in that as it detects a "toxic" compound its resistance decreases.

Figure 9 illustrates how a Figaro TGS812 toxic-gas sensor ($12 from

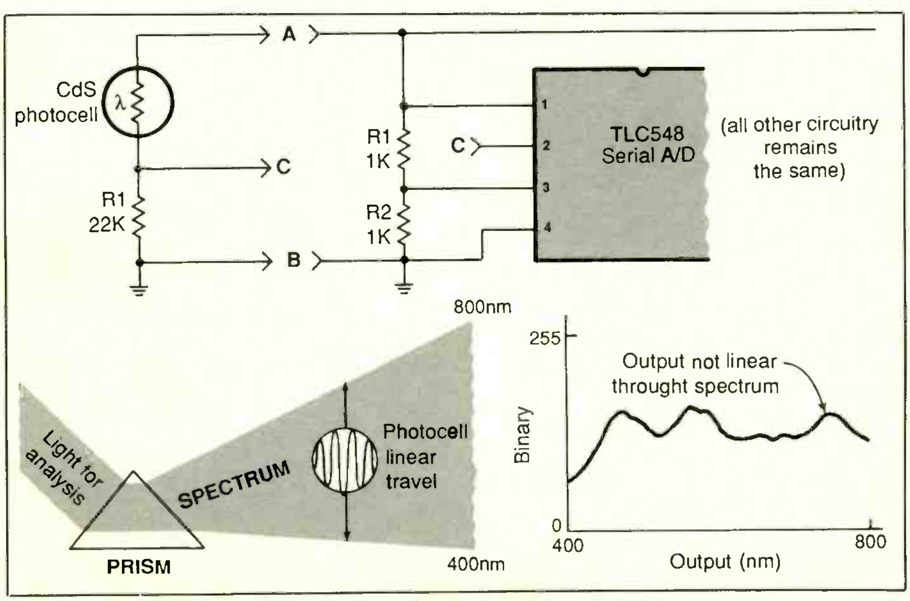


Fig. 7. Interfacing a photocell to the computer to measure intensities of light.

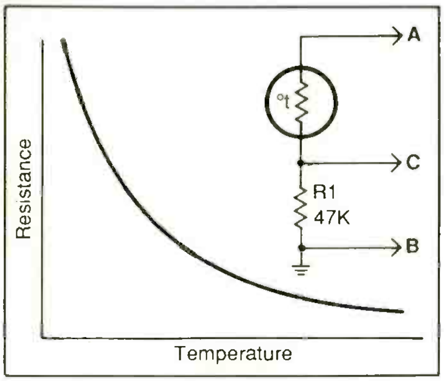


Fig. 8. Interfacing an NTC thermistor to the computer to measure temperatures.

Figaro Engineering, Inc., P.O. Box 357, 322 Wilshire Dr. East, Wilmette, IL 60091; tel. 312-256-3546) connects to the A/D converter chip. The heater coil between pins 2 and 5 of the sensor requires 5 volts dc at approximately 115 milliamperes for the sensor to operate. Because this current is somewhat beyond what Commodore computers can provide at their User Ports, a separate dc supply must be used. Shown is a 9-volt battery that feeds a 7805 fixed +5-volt regulator to provide the required 5 volts dc. If you expect heavy usage of this sensor, you might consider using a commonly available plug-in power supply that has an output of at least 7.5 volts dc at 250 milliamperes or more to avoid having to frequently replace spent batteries.

The Figaro TGS812 toxic-gas sensor specified contains two sensing elements. When connecting this device into the circuit, use pins 1 and 4 or 3 and 6. Pins 1 and 3 are connected to each other internally, as are pins 4 and 6. Polarity is not important for either the heater coil or the sensor elements.

When you fire up the toxic-gas sensor for the first time, you may notice that it becomes fairly warm to the touch. This is the normal operating condition. In fact, when you fire it up for the very first time, you might have to give the sensor a 2-minute or so warm-up period before it will respond as it should. The warm-up time required thereafter should decrease with successive uses, until it settles down to a fairly brief interval whenever you fire up the sensor.

After the warm-up period has elapsed, you can test the sensor around your home, workshop and garage. For example, you can release the gas form a butane lighter (make sure there is no flame!) into the sensor and note the reading. As I was performing this test, I noted that the reading immediately jumped from a base line of 0 to a full 255. Breathing on the sensor will register the level of carbon dioxide of an exhalation. You can also make tests with various cleaning fluids and solvents and the exhaust from your car.

● *Biofeedback*. The biofeedback arrangement shown in Fig. 10 has two obvious uses: lie detection and stress measurement. It is designed to detect changes in galvanic skin resistance.

A person's galvanic skin resistance at any particular moment is an indicator of his current state of stress/tension. This base-line conductance will vary as you use the

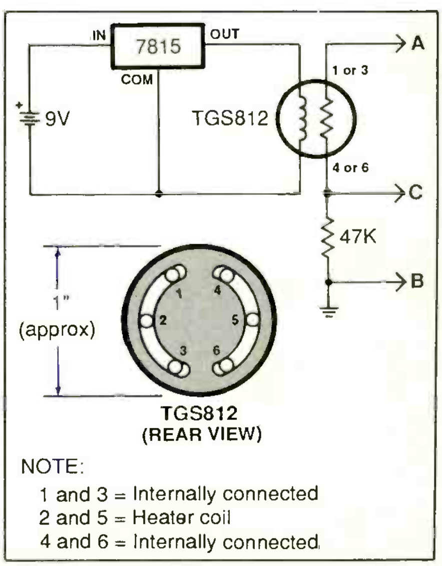


Fig. 9. Interfacing a Figaro TGS812 toxic-gas sensor to the computer.

biofeedback device, which makes it necessary to make occasional adjustments to the circuit.

Because the circuit must have a very high sensitivity to produce measurable voltages, a 741 operational amplifier is used in conjunction with a bridge circuit to drive the serial A/D converter chip. Bipolar power (V+ and V− with respect to circuit ground) required by the op-amp portion of the circuit is provided by a pair of 9-volt transistor batteries, while power for the A/D converter chip is obtained from the computer's User Port, as was the case in previous circuits.

Use a pair of dimes as the electrodes. Solder the dimes to the wires at one end of a short (24-inch or so) length of two-conductor cable. Connect the other end of the cable into the circuit at ground and the negative (−) side of the battery in the bridge circuit, as shown. Then wire the rest of the circuit exactly as detailed. You can use either 1N914 or 1N4148 silicon diodes for *D1*, *D2* and *D3*.

To use the biofeedback monitor, place a fairly wide (¼ inch or wider) rubber band around the wrist of the subject to be monitored and slip the dimes between the rubber band and wrist skin about 2 inches apart, unsoldered side toward skin. The rubber band should make a snug fit but should not be tight enough to cut off blood circulation.

Set both potentiometers to about the center of rotation and turn on the system. Depending on whether you are using the biofeedback monitor as a lie detector or stress-level monitor, adjust *R1* until you reach a point where a small amount of rotation produces a reading that jumps up or down a significant amount; this is the trigger point. How you are using the monitor determines where to set *R1*.

Potentiometer *R5* is used to adjust the gain of the op-amp stage. Normally, you will not have to adjust the setting of this control.

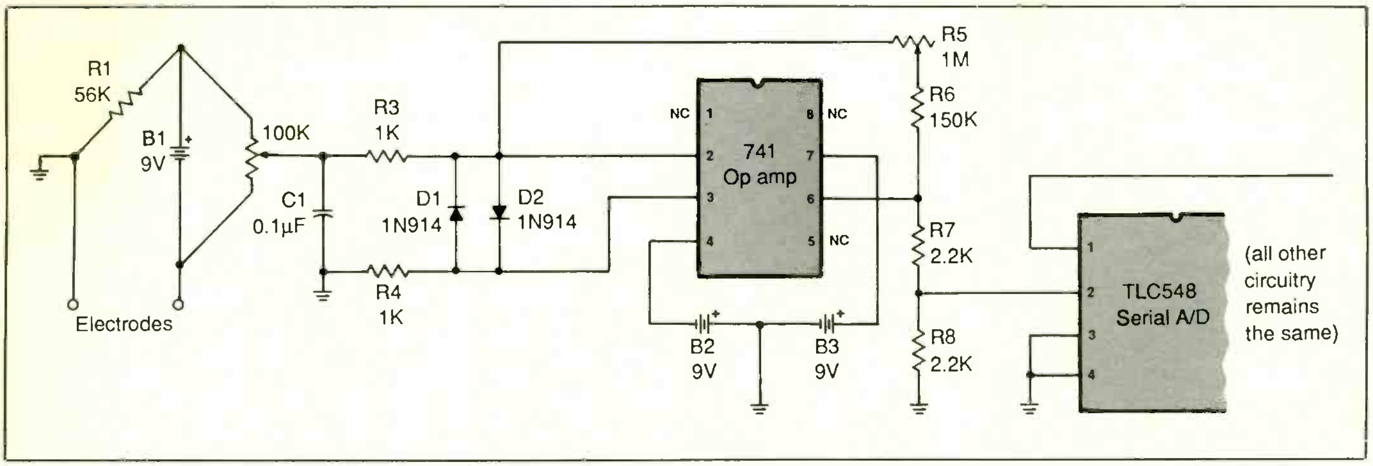


Fig. 10. A biofeedback arrangement for using the computer as a lie detector/stress-measuring device.

To use the monitor as a lie detector, adjust the setting of *R1* until you obtain a reading that is just a bit above 0. Pressing the electrodes firmly against the skin of the subject being monitored should cause the reading to jump to 255. Releasing the pressure should cause the reading to settle back to about the point from which it started. (Remember to attach the electrodes to the subject *before* adjusting *R1*.)

When you ask a question that evokes an emotional response, the displayed readings will increase. Anything that evokes a strong emotional response can be detected by this device. Be aware, though, that the nature of a question, regardless of the response given, can cause a "lie" response. Hence, even if an answer is truthful, you can get a lie indication if the subject is highly charged emotionally. Keep this in mind when you use the monitor.

To use the biofeedback monitor to reduce stress, place the electrodes on your wrist and adjust *R1* until the displayed reading is almost 255. Then sit back and relax by imagining yourself to be in any place or situation you find soothing. As your body responds (relaxes) more and more, the displayed readings will begin to fall toward 0.

It is interesting to note that your mind can be in a state of high-level awareness, even though your body might be relaxed. With practice, your ability to quickly reach a state of relaxation will become second-nature even without the biofeedback monitor to keep tabs on your progress.

You can also reset the project to give a reading of almost 255 after you have zeroed it out so that you can try again to lower the readings to achieve an even greater state of relaxation.

The reason you do not set the biofeedback monitor to 0 or 255 when adjusting *R1* is that you can overcompensate. This could make reading the changes occur below or above 255. Until you become fully familiar with operating the biofeedback monitor, it can be frustrating to set the potentiometers for a good reading. The solution, of course, is to give

Listing 3: Machine-Language Program for C-128

```
100 REM JOHN IOVINE
120 FORJ=4864TO4937:READX:POKEJ,X:NEXT
130 SYS4897:NEW
150 DATA160,8,169,0,141,1,221,169,1,141,1,221,136
160 DATA192,0,208,241,173,13,221,173,12,221,133,255
170 DATA169,2,141,1,221,108,160,19,173,20,3,141,160
180 DATA19,173,21,3,141,161,19,120,169,0,141,20,3
190 DATA169,19,141,21,3,169,255,141,3,221,169,0,141
200 DATA1,221,169,127,141,13,221,88,96,0
```

Listing 4: Machine-Language Program for C-64

```
10 REM JOHN IOVINE
20 FORJ=40710TO40785:READX:POKEJ,X:NEXT
30 SYS40743:POKE56,PEEK(56)+1:NEW
40 DATA160,8,169,0,141,1,221,169,1,141,1,221,136
50 DATA192,0,208,241,173,13,221,173,12,221,133,255
60 DATA169,2,141,1,221,108,79,159,173,20,3,141,79
70 DATA159,173,21,3,141,80,159,120,169,6,141,20,3
80 DATA169,159,141,21,3,169,255,141,3,221,169,0
90 DATA141,1,221,169,127,141,12,221,88,96,0,255,74
```

Listing 5: Machine-Language Program for VIC-20

```
2 REM  ** VIC 20 SERIAL A/D BASIC **
4 REM  ** JOHN IOVINE        1987 **
10 POKE37138,255
20 POKE37150,127:REM INTERUPT FLAG ENABL
30 POKE37147,12:REM AUXILIARY CONTROL REG
35 POKE37136,2
40 FORX=0TO7
50 POKE37136,1:POKE37136,0
60 NEXT
70 X=(PEEK(37149)AND4):REM SERIAL FG
80 X=PEEK(37146)
90 PRINT X;
95 POKE37136,2
100 GOTO40
```

yourself time to learn the apparatus, its capabilities and limitations.

A/D Interrupt

The A/D interrupt programs read the A/D chip 60 times each second and place the information read into memory at location 255. All you need to do is PEEK the location for the current value. BASIC Listings 1 and 2 are not needed when using the machine-language programs given in Listings 3, 4 and 5 for the C-128, C-64 and VIC-20, respectively.

After typing in and SAVEing the specific version of machine-language Listing for your particular computer, RUN it. Then type in the following line:

```
10 X = PEEK(255):Print X:GOTO 10
```

This one-line modification will print serial A/D conversions. The program is not affected by the RUN/STOP key, but a RUN/STOP and RESTORE will reset the vector. To reinitiate the program, SYS the number in the program.

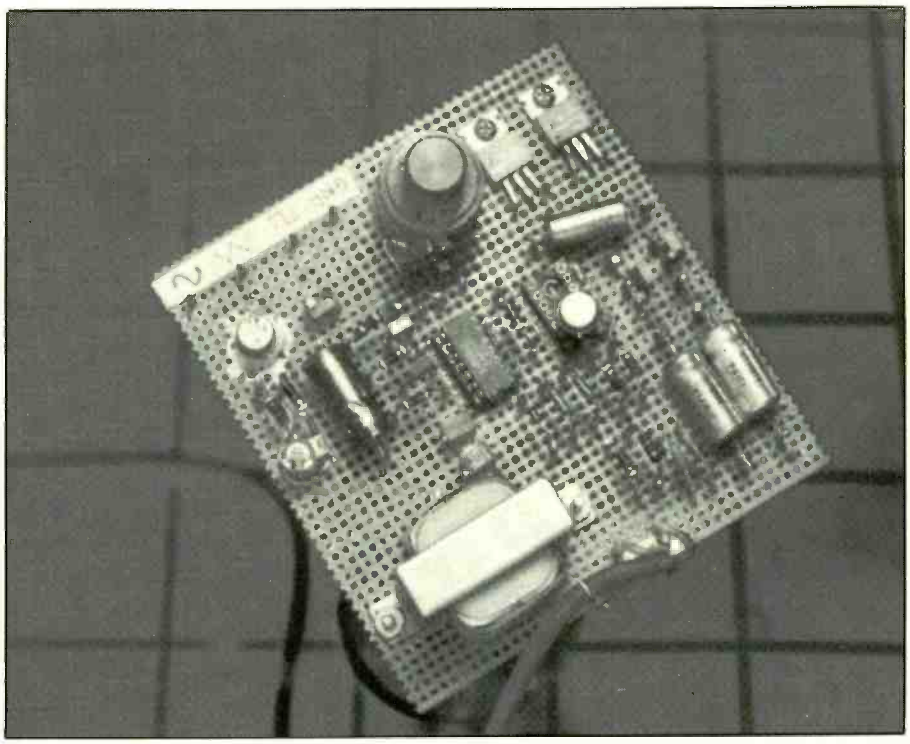
Be sure to SAVE the program before you RUN it because it automatically erases itself from memory!

Interfacing your computer to the real-world environment opens up an exciting new area for experimenting and practical applications. The few applications presented here should get you started on devising others of your own. ME

A Low-Cost Function Generator

This project delivers individually adjustable sine, triangle and square waves simultaneously over a frequency range of less than 1 Hz to almost 300 kHz into almost any load impedance

By Anthony J. Caristi



A commercial multipurpose signal source that can deliver a wide range of signal waveforms and frequencies into almost any load impedance usually costs $200 or more. With modern integrated-circuit technology, however, high cost need not be the case. The sine/triangle/square-wave function generator to be described is such an example. Built around a relatively inexpensive precision waveform generator chip from Intersil, the entire project costs less than $50 to build, including enclosure.

Depending on choice of options, the function generator can be made to cover a frequency range of less than 1 Hz to almost 300 kHz. The square-wave output has a respectable risetime that is close to 0.1 microsecond, and sine-wave distortion is typically less than 2 percent. Output impedance, at less than 1 ohm, makes the generator suitable for driving almost any load to be encountered in modern electronic circuits. Hence, except for extremely critical applications, this generator is suitable for use on both a hobbyist's and a professional's testbench.

About the Circuit

As shown schematically in Fig. 1, the function generator is designed around a low-cost integrated circuit (*IC3*) that has been designed by Intersil to serve as a precision waveform generator/voltage-controlled oscillator with only a minimum of external components. Operating frequency is selected externally by means of a given value of capacitance connected between pin 10 of the chip and the negative (−15-volt) supply rail and the voltage applied to pin 8 by means of potentiometer *R2*. Possible range from this IC is 0.001 Hz to almost 300 kHz. With the values specified for *C6*, *C7* and *C8*, three overlapping frequency ranges covering 15 Hz to 100 kHz can be selected with RANGE switch *S2*.

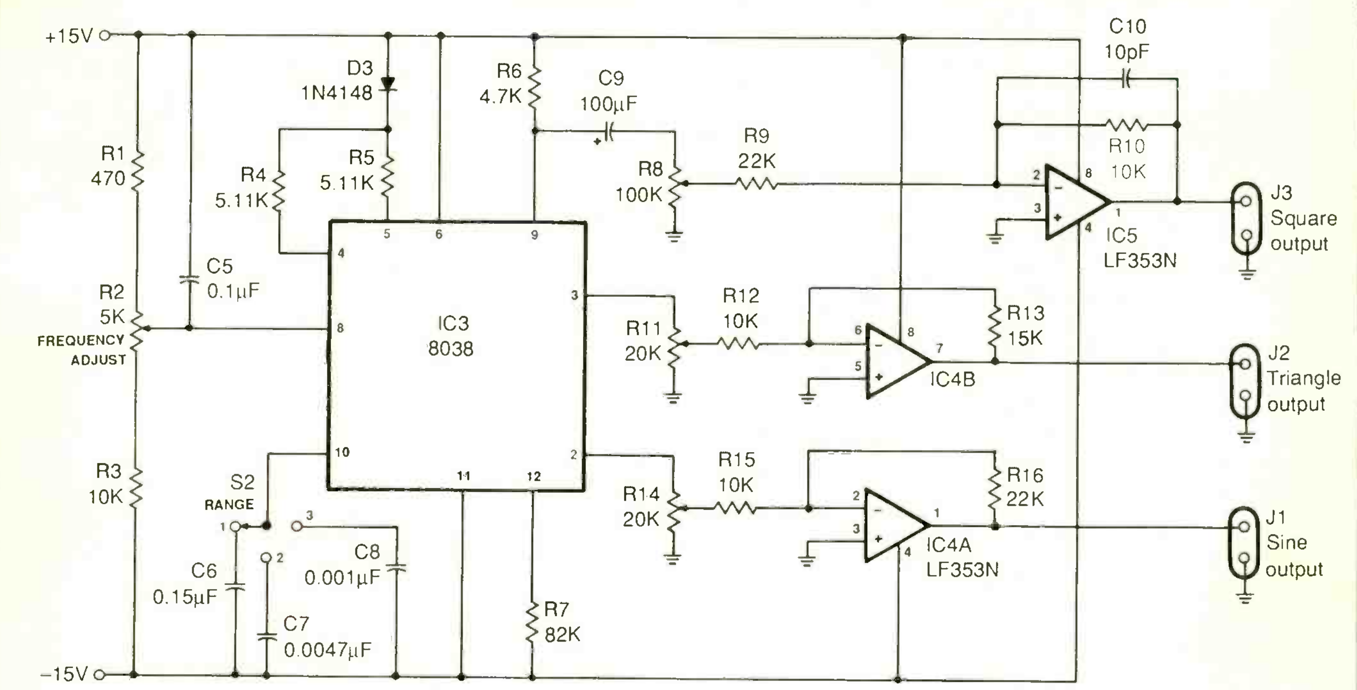
Since the chip's operating frequency is inversely proportional to the value of capacitance used, the choice of values can be changed to suit individual requirements. Also, if you want a greater range or operating frequencies, you can add bands simply by using a rotary switch with a greater number of positions to accommodate more capacitors.

For any given value of capacitance

inserted between pin 10 of *IC3* and the −15-volt rail, the frequency adjustment range provided by *R2* is about 40:1. For the values shown for *C6*, *C7* and *C8*, the frequency bands are 15 Hz to 600 Hz, 500 Hz to 20 kHz and 2.5 kHz to 100 kHz.

Simultaneous sine, triangle and square waveforms appear at pins 2, 3 and 9 of *IC3*. Amplitudes of the sine and triangular waveforms are about 6 and 9 volts peak-to-peak, respectively. The square-wave output is about 25 volts peak-to-peak.

Note that the circuit contains three amplitude adjustment controls (*R8*, *R11* and *R14*) and three output buffer amplifiers (*IC5*, *IC4B* and *IC4A*, respectively) so that each of the waveforms can be independently adjusted over a range of at least 12 volts peak-to-peak. With an amplitude of 12 volts peak-to-peak, the sine wave is equal to 4.2 volts rms.



PARTS LIST

Semiconductors

D1,D2—1N4001 rectifier diode
D3—1N4148 diode
IC1—LM7815CT +15-volt regulator
IC2—LM7915CT −15-volt regulator
IC3—ICL8038 precision waveform generator (Intersil)
IC4,IC5—LF353N high-slew-rate op amp

Capacitors (25 WV or more)

C1,C2—220-μF electrolytic
C3,C4,C5—0.1-μF ceramic disc
C6—0.15-μF ceramic disc or paper
C7—0.0047-μF ceramic disc or paper
C8—0.001-μF ceramic disc or paper
C9—100-μF, 35-volt electrolytic
C10—10-pF ceramic disc
C11—22-μF, 35-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1—470 ohms
R3,R10,R12,R15—10,000 ohms
R6—4,700 ohms
R7—82,000 ohms (see text)
R9,R16—22,000 ohms
R13—15,000 ohms
R4,R5—5,110-ohm, 1% tolerance metal-film
R2—5,000-ohm linear-taper panel-mount potentiometer
R8—100,000-ohm linear-taper panel-mount potentiometer
R11,R14—20,000-ohm linear-taper panel-mount potentiometer

Miscellaneous

F1—1-ampere slow-blow fuse
I1—Panel-mount neon-lamp assembly with current-limiting resistor
J1,J2,J3—Phono jack, binding post or other suitable output connector
S1—Dpdt toggle switch
S2—Single-pole, three-position, non-shorting rotary switch (see text)
T1—12.6-volt power transformer (Radio Shack Cat. No. 273-1385A or equivalent)

Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware; suitable enclosure (see text); ac line cord with plug; pointer-type control knobs (5); two 8-pin and one 14-pin DIP IC sockets; dry-transfer lettering kit and clear acrylic spray or tape labeler (see text); ½-inch spacers; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire pc board, $8.95; 7815 and 7915 regulators, $2.95 each; ICL8038 precision waveform generator, $9.95; LF353N high-slew-rate op amp, $3.50 each; two 5,110-ohm, 1-percent tolerance resistors, $1.25. Add $1 P&H. New Jersey residents, please add state sales tax.

Fig. 1. Basic schematic diagram of the sine/triangle/square-wave function generator.

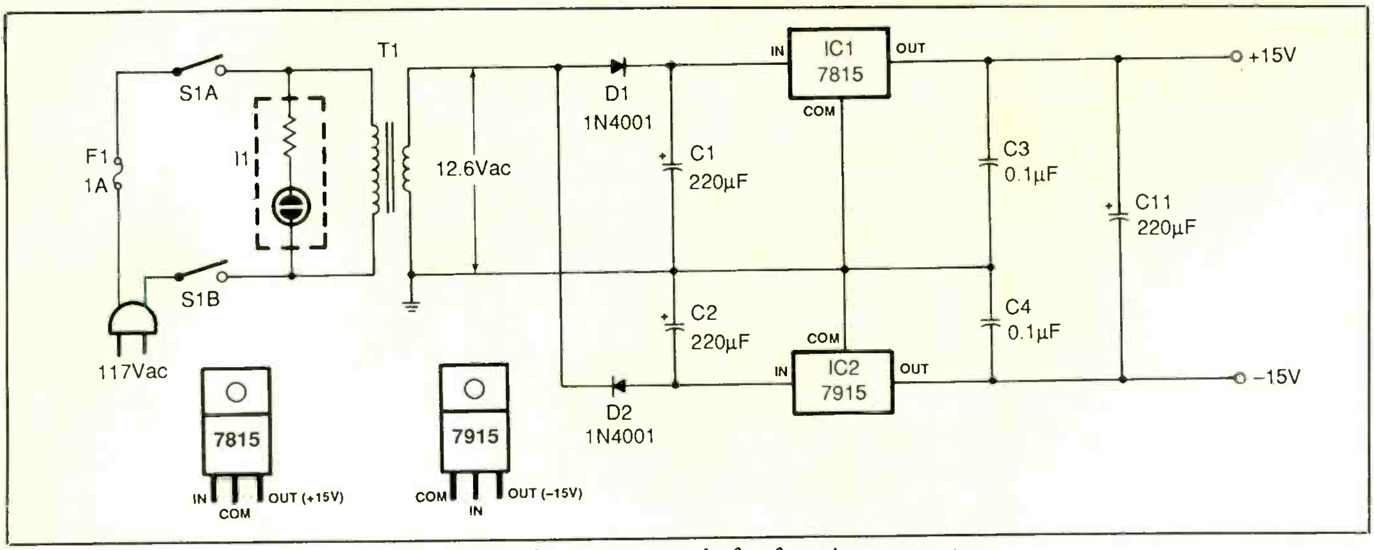


Fig. 2. Bipolar power supply for function generator.

Output impedance of the function generator is less than 1 ohm, as provided by operational amplifiers *IC4* and *IC5*. To preserve the fast risetime of the square-wave output at *J3*, a high-slew-rate LF353N op amp was chosen. Because ordinary op amps will not produce fast risetimes, they should not be used in this circuit.

The low output impedance of this generator can source a reasonable amount of current into virtually any load impedance. The outputs of the circuit are direct-coupled to preserve low-frequency response and should not be connected to any circuit that has a dc component unless a blocking capacitor is used.

Since the oscillator chip's output waveforms are sensitive to power-supply ripple voltages, it is necessary to use stable and pure dc voltages for the + 15-volt and − 15-volt supplies. As shown in Fig. 2, this is accomplished with fixed + 15-volt *IC1* and fixed − 15-volt *IC2* regulators.

To assure ripple-free outputs, the unregulated voltages fed into the inputs of the regulators should be at not less than 18 volts. The transformer used to power this project should deliver at least 14.5 volts rms at the lowest ac line voltage that will be encountered. Under the light load conditions of this project, the power transformer specified in the Parts List for *T1* will provide sufficient output voltage at a 117-volt ac line potential.

Power transformer *T1* drives a bipolar voltage doubler to provide the necessary positive and negative voltages to the regulators. Ripple voltage fed to the inputs of *IC1* and *IC2* is kept sufficiently low by filter capacitors *C1* and *C2*. Though larger values of filter capacitance can be used, avoid using values that are too small or power supply ripple will appear at the outputs of the regulators and, ultimately, in the output waveforms at *J1*, *J2* and *J3*.

Construction

This circuit is simple enough to be hard wired on ordinary perforated board with holes on 0.1-inch centers and using suitable solder or Wire Wrap hardware. Alternatively, you can use a printed-circuit board fabricated yourself using the actual-size etching-and-drilling guide shown in Fig. 3 or a ready-to-wire board from the source given in the Note at the end of the Parts List. Whichever way you choose to go, use sockets for *IC3*, *IC4* and *IC5*.

Regulators *IC1* and *IC2* install directly on the board without the use of sockets. Since very little power is drawn by the circuit, you do not need heat sinks on the regulators.

Figure 3 shows the component locations and orientations for populating the printed-circuit board. Use this illustration as a guide to laying out the components on perforated board as well.

Wire the board exactly as shown, installing first the IC sockets in the appropriate locations and then proceed to the resistors. Next, install the electrolytic capacitors and diodes, taking care to properly orient them before soldering their leads to the pads on the bottom of the board. When installing regulators *IC1* and *IC2*, make certain each goes in its respective location and is properly based. Referring back to Fig. 1, note the differences in pin identification for the + 15-volt 7815 and − 15-volt 7915 regulators.

RANGE switch *S2*, the output amplitude controls, and the SINE, TRIANGLE and SQUARE OUTPUT jacks all mount off the board, on the front panel of the selected enclosure. When wiring potentiometers *R2*, *R8*, *R11* and *R14* into the circuit, all adjustments should go in the clockwise direction to increase frequency and amplitude. If you have any doubts as to what potentiometer lugs wire to which holes, you can use an ohmmeter to make the final determinations.

Other components that mount off the board include pilot-lamp assembly *I1* (which consists of a neon lamp and current-limiting resistor in a panel-mount housing), POWER switch *S1* and fuse *F1*. These also mount on the project's front panel, except *F1*, which mounts near the entry hole for the ac line cord.

Select an enclosure that is large enough to accommodate the circuit-board assembly, controls, jacks, POWER indicator and fuse holder without crowding. You can use a plastic enclosure with a metal front panel or an all-metal enclosure. Machine the front panel so that the the mounting holes for *R14*, *R11* and *R8* form a line across the front of the panel along its center axis. Strike a line 1½ inch below the control hole line and parallel to it and drill the holes for the jacks or binding posts. Then the same distance above the control holes and centered between the first and second and the second and third drill the holes for mounting the rotary switch and remaining control. The POWER switch and lamp assembly mount in two other holes drilled in out-of-the-way locations.

When you are finished machining the front panel, drill the entry hole for the ac line cord through the enclosure's rear panel. For the fuse holder, you can use either a clip type that mounts via a single machine screw or a more convenient (and expensive) panel-mount bayonet type. The size of the mounting hole needed will depend on the type of holder used. Only two more holes remain to be drilled—for mounting the circuit-board assembly on the floor of the enclosure, via the same holes that mount *T1* to the circuit board. Deburr all holes.

Temporarily mount the controls, switches and jacks in their respective locations in the proper orientations.

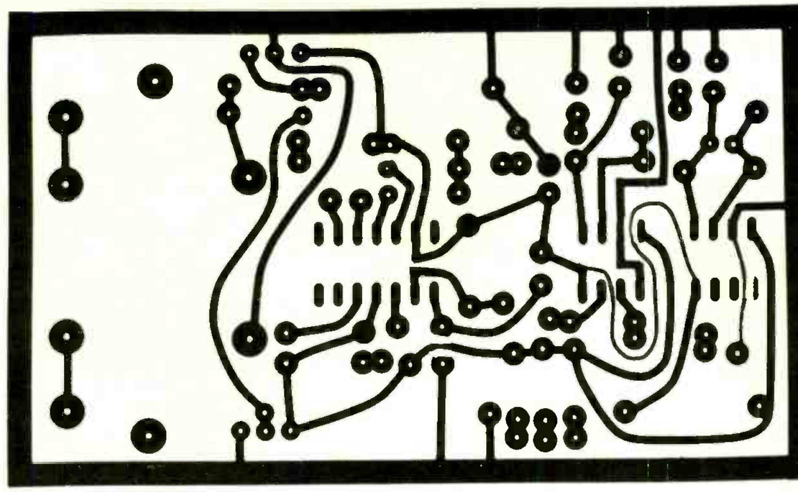


Fig. 3. Actual-size etching-and-drilling guide of function generator's printed-circuit board.

Place on the shafts of the rotary RANGE switch and all potentiometer controls a control knob. Note distances away from the holes the panel markings are to go. Then remove all components from the panel and set them aside.

Using a dry-transfer lettering kit or a tape labeler, label the panel with appropriate legends. If you use a dry-transfer lettering kit, follow up with two or three *light* coats of clear acrylic spray to protect the legends.

When the panel is ready, mount the components permanently. Tightly twist together the fine wires in each conductor of the line cord and sparingly tin with solder. Pass the prepared end of the line cord through its hole (line the hole with a small rubber grommet if you are using a metal enclosure) and tie a knot in it about 6 inches from the end inside the enclosure to serve as a strain relief. Then mount the fuse holder.

Wire the neon-lamp assembly across the POWER switch's open—*not* toggle—contacts but do not sol-

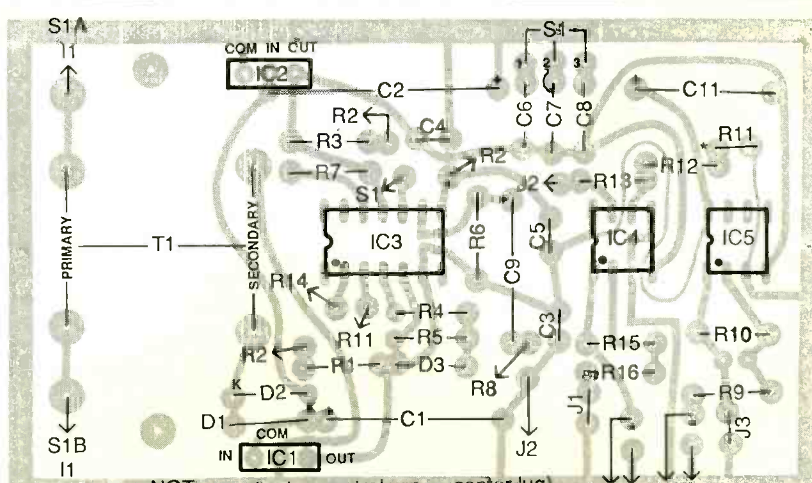


Fig. 4. Wiring diagram for pc board and layout for perforated- board.

der. Remove ¼ inch of insulation from both ends of 22 5-inch lengths of hookup wire. Plug one end of these wires into the signal and ground holes for *J1*, *J2* and *J3* (six wires); the holes for *S2* (four wires); and the holes for *R2*, *R8*, *R11* and *R14* (12 wires). Mount the circuit-board assembly using ½-inch spacers and machine hardware.

Connect and solder the free ends of the two wires for *T1*'s primary to the same lugs of the toggle switch to which *I1* is connected. Wire one side of the fuse holder to one toggle lug of the toggle switch and the line cord to the other toggle lug and the remaining fuse-holder lug.

Referring to Fig. 4, connect and solder the free ends of wires on the circuit-board assembly to the appropriate lugs of the panel-mounted potentiometers. Remember that you want the controls to be wired so that clockwise rotation increases frequency in the case of *R2* and increases amplitude of the output signals for the other potentiometers. Finally, connect and solder the last of the wires to the OUTPUT connectors.

Checkout and Use

Before you attempt to apply power to the generator, check the circuit-board assembly for poor soldered connections and possible short circuits between the closely spaced conductors and especially between the IC socket pads. Reflow the solder on any questionable connections.

With *IC3*, *IC4* and *IC5* still not installed, check the power supply section for proper operation. Plug the project's line cord into an ac outlet and set the POWER switch to ON. (Be very careful to avoid touching any part of the circuit between the ac line cord and *T1*'s primary as you perform your tests. Potentially lethal 117-volt ac line potential appears in this section of the circuit.) The neon lamp should now be on (it should be off when the POWER switch is set to OFF if it is properly wired into the circuit), indicating that ac line power is being delivered to the circuit.

Now use a dc voltmeter set to measure at least 25 volts to check the outputs of the voltage doubler. Connect the meter's common lead to circuit ground at the negative side of *C1* and touch the "hot" meter lead to first the positive (+) side of *C1* and then the negative (−) side of *C2*, which should yield readings of about +19.5 and −19.5 volts, respectively. Without removing the common meter lead from where you connected it, touch the meter's hot lead to first the positive and then the negative leads of *C11*, which should give readings of between +14.5 and +15.5 volts and between −14.5 and −15.5 volts, respectively.

If you do not obtain the proper voltage readings, check for proper orientation of *D1*, *D2*, *C1*, *C2* and *C11*. Also, check with Fig. 4 to ascertain that *IC1* and *IC2* are each in their respective locations and are properly wired into the circuit. Check the ac potential at the secondary of *T1*, which should measure at least 14.5 volts rms ac. With the line cord unplugged, check to see if the +15-volt and −15-volt supply rails are shorted to each other. Do not proceed until you have cleared up the problem.

Plug the project's line cord into an ac receptacle and turn on the power. Set your meter to measure at least 20 volts dc. Connect its common lead to the negative lead of *C1* and touch the hot meter lead to pin 6 of the *IC3* socket and pin 8 of the *IC4* and *IC5* sockets. You should obtain a reading of +15 volts in all three cases. Similarly, you should obtain a −15-volt reading when you touch the meter's hot lead to pin 11 of the *IC3* socket and pin 4 of the *IC4* and *IC5* sockets.

When you are satisfied that the power supply is working properly and that the power rails are correctly wired to the IC sockets, unplug the line cord and give *C11* time to discharge. Then carefully plug *IC3*, *IC4* and *IC5* into their respective sockets. Make sure that each is installed in the proper orientation and that no pins overhang the sockets or fold under between ICs and sockets.

Use an oscilloscope to check the outputs of the function generator. Set the generator's amplitude controls to maximum clockwise rotation to obtain maximum output amplitude and turn on the project. Examine the waveforms at *J1*, *J2* and *J3*, where you should observe sine, triangular and square waveforms, respectively, of about 12 volts peak-to-peak. If you note that any one or all of the waveforms are displayed at minimum amplitude, the potentiometer for that output amplifier is wired backward and must be rewired for proper operation.

Rotating the FREQUENCY ADJUST control over its entire range should cause the frequency to vary over a 40:1 range, with the frequency increasing as the control is rotated in the clockwise direction. Check each output individually. If you note a decrease in frequency as this control is rotated in the clockwise direction, the potentiometer is wired backwards and must be rewired for proper operation. If the extreme clockwise or counterclockwise settings of this control result in a distorted waveform or no waveform at all at the outputs, you can tailor the limit of the adjustment range by increasing the value of *R1* or *R3* as needed.

This generator is capable of producing a sine-wave output with a distortion figure of less than 2 percent. If you see some distortion, you can increase or decrease the value of *R7* to obtain the purest possible waveform. A variation of 20,000 ohms in either direction should be more than enough to produce an optimum distortion level.

If you do not obtain output waveforms at all, check pins 2, 3 and 9 of *IC3* to make sure the chip is oscillating and generating the three waveforms. If the waveforms are present at these pins, the trouble is in output buffer amplifiers *IC4* and/or *IC5*.

If *IC3* is oscillating, check the wiring associated with the FREQUENCY ADJUST potentiometer and BAND switch. Also make sure that *D3* is properly connected into the circuit.

To demonstrate the low-impedance characteristics of the function generator, set the project for a relatively low frequency (say, 1 kHz) that can be easily "read" on an ac voltmeter. Set the amplitude of the sine-wave output at *J1* to 1 volt rms on the voltmeter. Connect a 100-ohm, ¼- or ½-watt resistor across *J1* and note that the resulting voltage drop is very low, perhaps on the order of a few millivolts. This indicates that the output impedance of the generator is very much less than 100 ohms. A mathematical calculation of the output impedance using the voltage-drop method would yield an impedance of less than 1 ohm.

Of course, the generator cannot drive its full output of 4 volts rms into a very-low impedance like 100 ohms. However, you will find that it will be able to drive about 0.5 volt rms into 50 ohms, which is respectable at that impedance.

The procedure for using the function generator is very simple. First you select the output waveform(s) you want to use. Then you select the band of frequencies needed and adjust the amplitude control(s) for a usable signal level at the output(s). If you are interested in a specific frequency, you adjust the setting of the FREQUENCY ADJUST control until you obtain that frequency. That is all there is to it.

With this function generator on your testbench, you will find that whenever you need a variable signal source to check amplifiers and speakers and for general troubleshooting, it is always ready. Best of all, you can build it for only a fraction of what it would cost you to purchase a commercial instrument. **ME**

Touch Tone Remote Control

By Forrest M. Mims III

Though the Bell system developed the Touch Tone system specifically for telecommunications applications, it is also well suited for use in remote control. Touch Tone signals can be easily transmitted by means of wire, radio and light. They can also be transmitted directly through the air as sound waves.

The Touch Tone system provides up to 16 audio-frequency signals that can be used individually or, as when making telephone calls, in sequentially transmitted combinations. Several integrated circuits designed specifically for generating Touch Tone signals are readily available. These chips are designed to be used in conjunction with a crystal that provides a highly stable timebase.

Most tone-based remote-control systems use a single frequency for each signal. While these systems are easy to design and build, they are very susceptible to false triggering. For example, several years ago, I developed a remotely controlled camera system for taking photographs from kites and helium-filled balloons. The camera was triggered by transmitting an audio tone from a hand-held transmitter. The signal was detected by a small radio receiver with an integral tone decoder. When the tone decoder detected the transmitted tone, it actuated an optoisolator that tripped the camera's shutter and advanced the film to the next frame.

Though I obtained hundreds of aerial photos with this system, sometimes the camera was tripped when no signal was transmitted. The likely cause of this false triggering was other radio signals that just happened to be modulated at the same frequency, if only for a fraction of a second, as the tone from the system's transmitter.

The Touch Tone system was designed to be largely immune to such interference. Instead of a single tone, each signal in the Touch Tone system is a pair of superimposed tones. While this arrangement does not provide 100 percent noise immunity, it does substantially reduce the possibility of inadvertent false triggering by interfering tones.

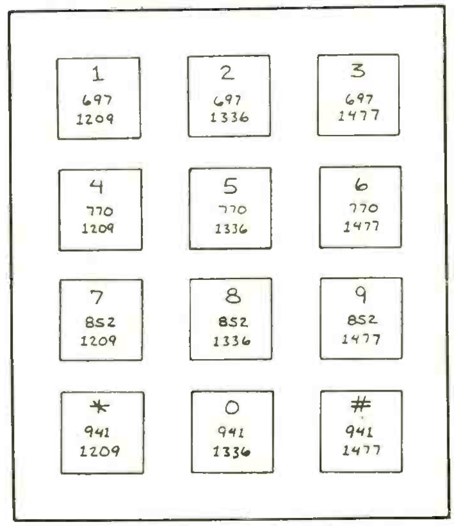


Fig. 1. Simultaneous tone frequencies for a Touch Tone keypad.

In the telecommunications industry, the Touch Tone system is often referred to to as the Dual Tone Multi-Frequency (DTMF) system. Figure 1 is a diagram of a pushbutton telephone keypad labeled with the frequency pair represented by each key position.

Though not present on standard telephone keypads, four additional frequency pairs are available. The frequencies are divided into a low group (679 to 941 Hz) and a high group (1,209 to 1,633 Hz). The 1,633-Hz frequency is omitted from standard telephone keypads.

When a telephone key is pressed, one frequency from both the low and high groups are selected, and the two tones are superimposed on each other. Since speech, transmission noise and DTMF tones can be simultaneously present on a telephone line, the Bell system carefully designed the DTMF system to avoid interference from non-DTMF signals. The Bell standard for DTMF signals allows a maximum frequency deviation of ±(1.5 percent + 2 Hz). The minimum time required for a tone pair to be recognized is 40 milliseconds, and the required pause between tones must be at least 40 milliseconds.

Here is a complete listing of available DTMF frequency pairs in Hertz:

Signal	Low Tone	High Tone
1	697	1,209
2	697	1,336
3	697	1,477
4	770	1,209
5	770	1,336
6	770	1,477
7	852	1,209
8	852	1,336
9	852	1,477
0	941	1,209
*	941	1,336
#	941	1,477
A	697	1,633
B	770	1,633
C	852	1,633
D	941	1,633

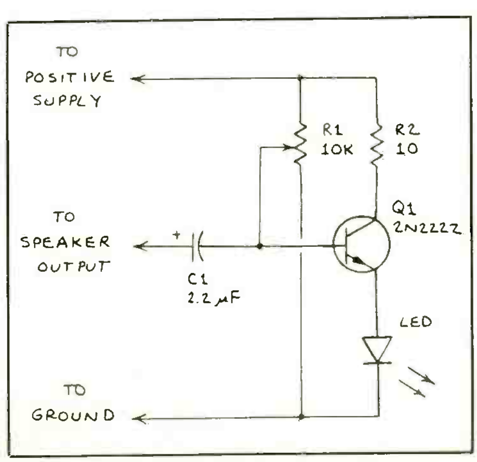


Fig. 2. A LED modulator for a pocket Touch Tone dialer.

Touch Tone Generators

A Touch Tone remote-control system requires a DTMF tone generator. DTMF tones can be generated by a pair of transistor or integrated-circuit oscillators that have switchable precision resistor networks for generating each of the required tones. A much more reliable and simpler approach is to use a crystal-controlled DTMF IC. Several such chips are available from major electronics parts distributors.

Fig. 3. *Two Radio Shack pocket-size Touch Tone (DTMF) dialers.*

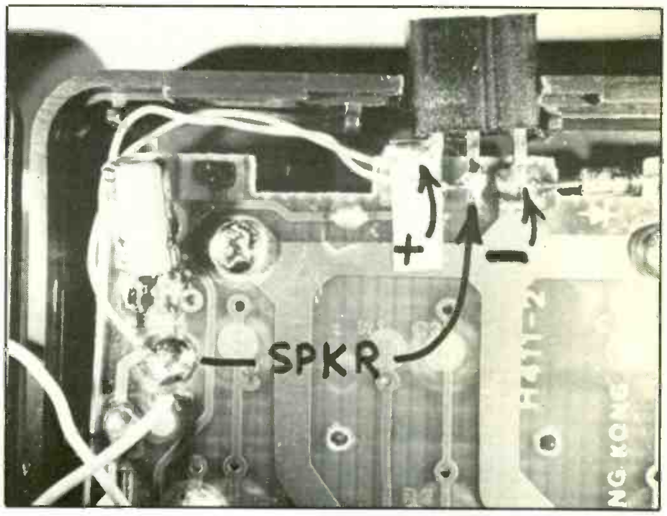


Fig. 4. *Internal view of a Touch Tone dialer showing the addition of an interface socket.*

Another solution is to salvage the DTMF tone encoder from a discarded telephone. Besides a working DTMF circuit, the telephone will be equipped with a keypad.

Still another approach is to use a pocket-size Touch Tone dialer. These devices are designed to permit a rotary telephone to access Touch Tone services. Some Touch Tone dialers are equipped with a readout and enough memory to store up to 60 or more telephone numbers. Memory-equipped dialers can be used for sophisticated remote-control applications.

An Infrared Touch Tone Transmitter

Touch Tone circuits can be easily adapted to drive an infrared or high-brightness red light-emitting diode. Figure 2 is the schematic for a simple intensity-modulated LED driver that is suitable for use with Touch Tone generators.

In operation, the driver biases the LED with a continuous flow of current. DTMF signals arriving at the base of *Q1* modulate the current through the LED, changing the intensity of the light the LED emits. Potentiometer *R1* controls the bias level of *Q1* and is used to allow the circuit to be tweaked for optimum operation. When adjusting *R1*, be sure to avoid turning its rotor to either extreme. If this should present a problem, add a 1,000-ohm fixed resistor in series with each leg of *R1*.

I have used the Fig. 2 circuit with two different Touch Tone dialers purchased from Radio Shack, both of which are shown in Fig. 3. The unit on the left has a liquid-crystal display and includes a memory that can store 60 numbers that have up to 16 digits in each. It can also store pauses, and it has an automatic shut-off feature.

Referring back to Fig. 3, note that a small rectangular object protrudes from the top of both dialers. These are sockets that are connected to the dialer's electronics. I installed these sockets to permit various LED transmitters to be conveniently connected and removed.

It's relatively easy to add an interface socket to a commercial Touch Tone dialer like the ones shown in Fig. 3. In doing so, it is important to observe CMOS handling precautions to avoid permanent and disabling damage to the dialer's internal circuitry. Incidentally, you should be aware that, in most cases, modifying a commercial device voids its warranty.

Since the free space inside a dialer is limited, it is necessary to use a very small connector. I have used Dean's three-terminal connector available from Ace R/C, a major supplier of radio-control equipment. These connectors are supplied in matched plug/socket pairs. The socket is required for the modified dialer and the plug for the transmitter circuit.

Before adding a socket to a tone dialer, plan ahead. Make sure there is ample room for the socket, and be sure the tone dialer is compatible with the LED driver. If you are uncertain about compatibility, temporarily connect mini-clips or solder short lengths of hookup wire to the appropriate terminals inside the dialer. You can then connect these wires to the LED driver and determine whether or not the combination works.

The Fig. 2 driver circuit works well with both of the Touch Tone dialers shown in Fig. 3. The circuits used in these products, however, are subject to change. Nevertheless, should this happen, it is unlikely that the Fig. 2 driver circuit will require modification.

Figure 4 shows a close-up of how a Dean's three-terminal socket can be installed inside the basic Fig. 3 tone dialer (Radio Shack Cat. No. 43-139). Adding the socket shown in Fig. 4 requires only about 15 minutes of your time. First, it's necessary to cut a slot for the socket in the dialer's plastic housing. Open the unit by inserting a thin tool in one of the thin slots below the battery compartment

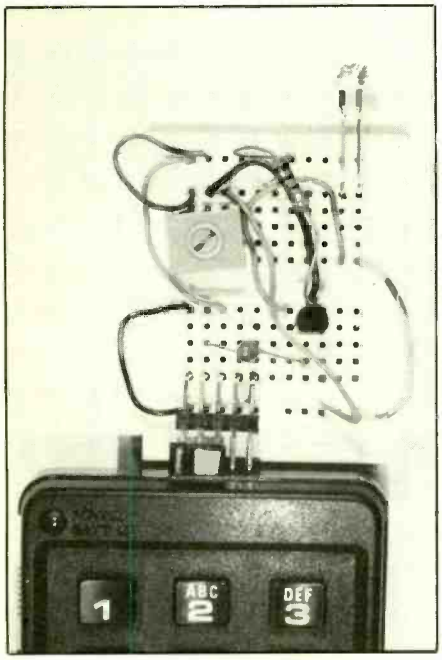


Fig. 5. Breadboarded infrared LED driver connected to a modified DTMF dialer.

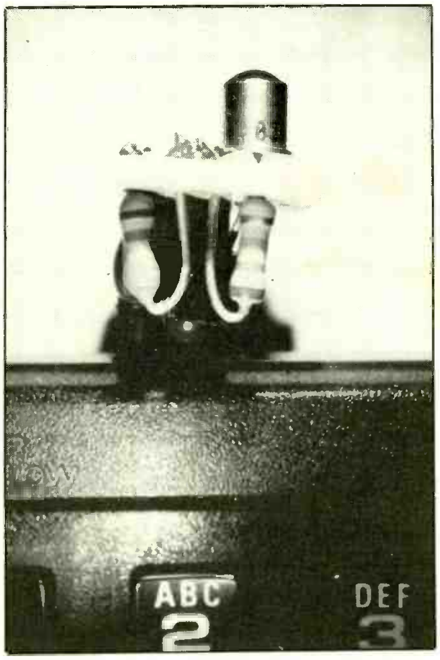


Fig. 6. A miniaturized infrared LED driver plugged into a modified DTMF dialer.

and carefully pry upward. Repeat with the other slot.

Before cutting the slot for the socket, be sure it will fit. Ideally, the socket should be positioned so that one of its terminals can be soldered directly to a power-carrying land or terminal on the circuit board. This is possible with both dialers pictured in Fig. 3. As can be seen in Fig. 4, it's possible to solder one of the socket terminals directly to a circuit-board terminal connected to the negative side of this dialer's three-cell battery power supply.

It is important to make sure that none of the socket's terminals touch the wrong conductors on the circuit board. Referring back to Fig. 3, note that a small rectangle of tape has been placed below the socket's left terminal to isolate it from the adjacent copper land.

After the right terminal of the socket is soldered to the negative supply land on the circuit board, the center terminal of the socket connects to the positive speaker terminal (indicated by a red dot) with a short length of wrapping wire. A second piece of wrapping wire is used to connect the left socket terminal to the positive power-supply terminal near the lower-left portion of the circuit board. (*Important:* Observe CMOS handling precautions when making these connections!)

A breadboarded version of the Fig. 2 LED driver connected to the socket of the modified Touch Tone dialer is shown in Fig. 5. Connection to the socket is made by means of a right-angle Molex™ connector. Using the Touch Tone dialer with a breadboarded version of the LED driver permits the driver to be tested before a permanent version of the circuit is assembled.

The breadboarded version of the transmitter pictured in Fig. 5 can be installed on a tiny perforated board that measures only 0.5 by 0.75 inch. Figure 6 shows a miniaturized version of the circuit plugged into the socket of the modified Tone Dialer shown in Fig. 4. With exception of the LED, all components and a three-terminal Dean's plug are installed on one side of the board. The two resistors shown in the photo replace *R1* in Fig. 2. Their values were selected after *R1* was adjusted for optimum results when the LED driver was used with the receivers to be described.

Touch Tone Receivers

Touch Tone receiver/decoder integrated circuits are made by several manufacturers. Precision switched capacitor filters played a key role in the development of such chips.

Silicon Systems Inc. and Teltone Corp. both manufacture single-chip DTMF receivers. I have experimented with receiver chips made by both companies, both of which require only a 3.58-MHz crystal and a single resistor. Both chips have a single signal input pin and four three-state binary-encoded output pins. Let's look at how a receiver made by each company can be used with a simple infrared detector/receiver to receive and decode DTMF signals transmitted by the Fig. 2 circuit.

- *Teltone M-957 DTMF Receiver.* This 22-pin DIP chip requires a positive supply of from 5 to 16 volts. Incoming signals can be directly or capacitively coupled to pin 12.

Several control and output pins add to the M-957's versatility. A complete description of this chip is given in its specifications sheet. Here are some of its key features:

The A and B inputs at pins 8 and 9, respectively, can be used to adjust the receiver's sensitivity to incoming signals that have an amplitude of as little as 31 dBm. Output Enable (OE) at pin 3 controls whether the output pins are active or placed in a high-impedance state. The hex input at pin 2 determines whether the four output pins provide a standard 4-bit binary hexadecimal output or a 2-of-8 binary code.

The Strobe output at pin 18 indicates when a valid frequency pair is present at the input. This output can be used to provide a shift-left pulse for a digital readout controlled by shift registers. Normally, pin 18 is at logic 0. When a valid DTMF signal appears at the input and is verified (decoded), pin 18 goes to logic 1.

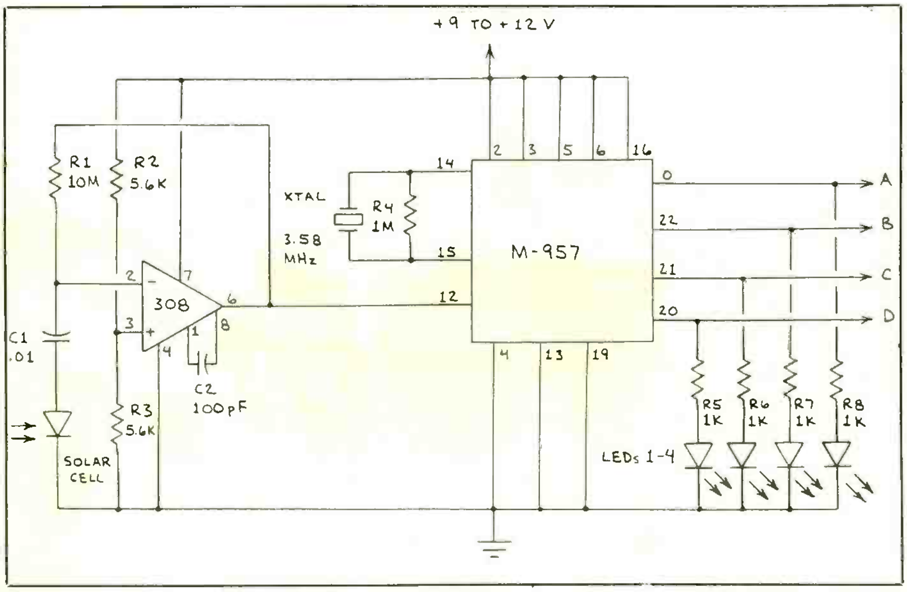


Fig. 7. A Touch Tone remote-control infrared receiver built around the Teltone chip.

Finally, output BD at pin 7 provides an early indication of the presence of a possibly valid DTMF signal. Normally, BD is at logic 0. Within 18 milliseconds of receiving a possibly valid DTMF signal, BD goes to logic 1. The Strobe output requires more than twice this time (40 milliseconds).

A kit consisting of the M-957 receiver, 3.58-MHz crystal, 10-megohm resistor and data sheet can be ordered from High Technology Semiconductors, 2512 Chambers Rd., Suite 204, Tustin, CA 92680 (714-259-7733). Cost is $14.95 plus $2.30 for UPS shipping in the continental U.S. California residents must add state sales tax. The company accepts telephone credit-card orders.

Shown in Fig. 7 is a straightforward DTMF infrared receiver designed around Teltone's M-957 chip. The circuit's detector is a standard silicon solar cell. It is coupled through *C1* to the input of an LM308 operational amplifier, which is operated with a 10-megohm feedback resistor to provide very high gain. The LM308's output is directly coupled to the M-957's signal input. Each of the four outputs of the M-957 directly drives an LED through a 1,000-ohm series resistor.

How the 4-bit output from the M-957 can be decoded to provide 16 individual outputs, one for each DTMF tone, is illustrated in Fig. 8. The outputs from the decoder can directly drive low-current LEDs. A relay driver that permits each output to control a much larger load than otherwise possible is shown in Fig. 9. The

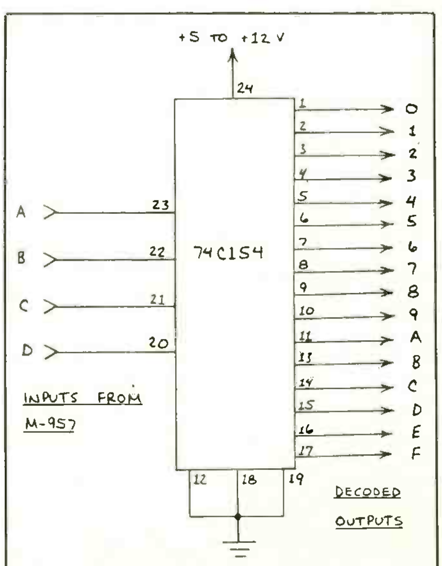


Fig. 8. A 1-of-16 decoder for Teltone's M-957 tone decoder.

four LEDs in Fig. 7 can be omitted if the outputs are connected to an alternative output device, such as the Fig. 8 decoder.

This receiver will respond to the Fig. 2 transmitter over a range of several hundred feet. If a small fresnel magnifying lens is placed in front of the solar cell, the receiver can be triggered from across a room. Since this narrows the beam from the transmitter, careful pointing will be required.

Suitable fresnel lenses are available from office supply and department stores. A wide variety of lenses of all kinds is available from Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 08007.

A high-power near-infrared AlGaAs emitter that radiates at 880 nanomoeters will give the greatest range. A super-bright AlGaAs red LED will give a shorter range, but its beam can be seen in a darkened room.

• *SSI 202P DTMF Receiver.* SSI's 202P 18-pin DIP DTMF receiver chip can be powered by 5 to 16 volts and is designed to be powered by a single 5-volt supply. Like the M-957, the 202P has several control and output functions that enhance operation. A complete description of these functions is given in the device's data sheet. These include:

The Output Enable (OE) at pin 3 that controls whether the output pins are active or placed in a high-impedance state. The Hex input at pin 2 determines whether the four output pins provide a standard 4-bit binary hexadecimal output or a 2-to-8 binary code.

The Detection Valid (DV) output at pin 14 indicates when a valid frequency pair is present at the input. Normally, pin 14 is at logic 0. When a valid DTMF signal appears at the input and is verified (decoded), pin 14 goes to logic 1.

The SSI 202P tone receiver and data sheet, complete with sample circuits is available from Radio Shack for $12.95 (Cat. No. 276-1303), as is the required 3.58-MHz crystal (Cat. No. 272-1310) for $1.69.

The Fig. 7 Teltone M-957 DTMF infrared receiver can easily be adapted for use with the SSI 202P. Though it is almost identical to the Fig. 7 circuit, the 202P circuit shown in Fig. 10 is shown to avoid possible errors.

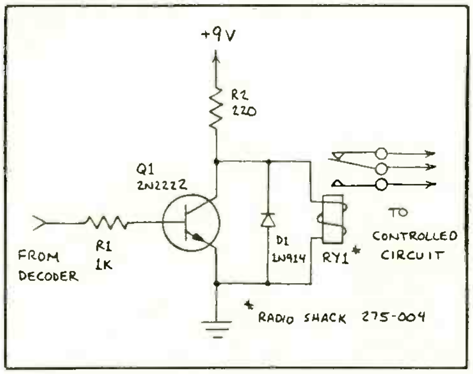


Fig. 9. A relay driver circuit for the Fig. 8 decoder chip.

Operation of the Fig. 10 circuit is essentially identical to that of the Fig. 7 circuit. Moreover, the Fig. 10 circuit can also be connected to the Fig. 8 output decoder and Fig. 9 relay driver. The most important difference between the two circuits is that the 202P chip must *not* be operated with a supply that delivers more than 7 volts.

To test the relative performance of the M-957 and 202P DTMF infrared receivers, I assembled both on a single solderless breadboard. The output from a single solar-cell receiver was connected to each chip's input so that each would receive the same signal. These tests revealed that both chips performed nearly equally well when coupled to the same infrared receiver. Though the M-957 was slightly more sensitive, the difference was so slight as to be negligible.

A more important observation was that the base of *Q1*, the LED driver in Fig. 2, required a slight readjustment for both DTMF receivers to simultaneously receive incoming signals. For other adjustments of *R1*, neither or only one of the two receivers would operate.

Going Further

The simple DTMF infrared remote-control circuits presented here can be modified to increase their sensitivity and versatility. They can also transmit signals through optical fibers.

Though these DTMF remote-control circuits use near-infrared or visible light as a transmission medium, there is no reason why a twisted-pair cable or radio cannot be used instead. In any event, the DTMF system offers a very convenient and relatively noise-immune method for achieving reliable remote control. ME

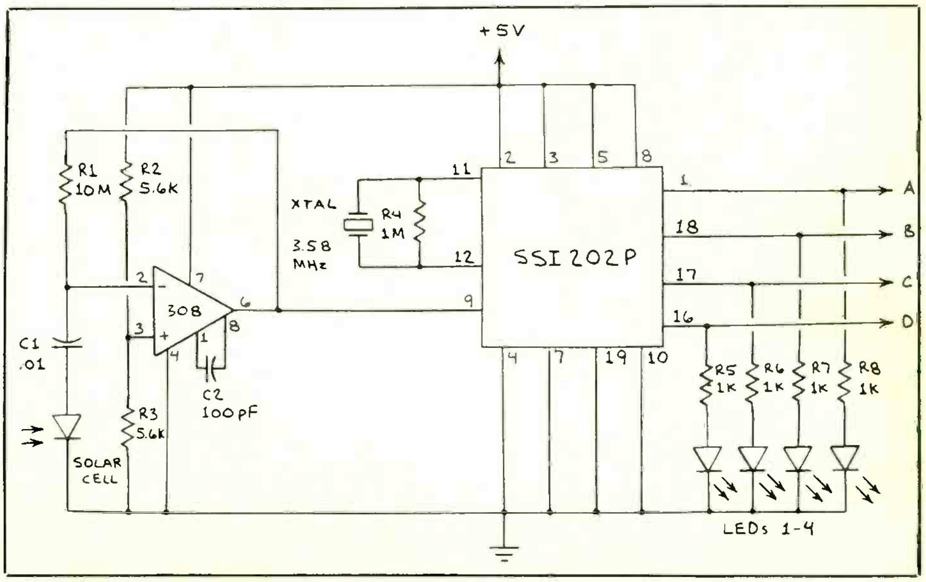


Fig. 10. A Touch Tone remote-control infrared receiver built around SSI's chip.

SOLID-STATE DEVICES

A new monthly column on semiconductor technology and developments

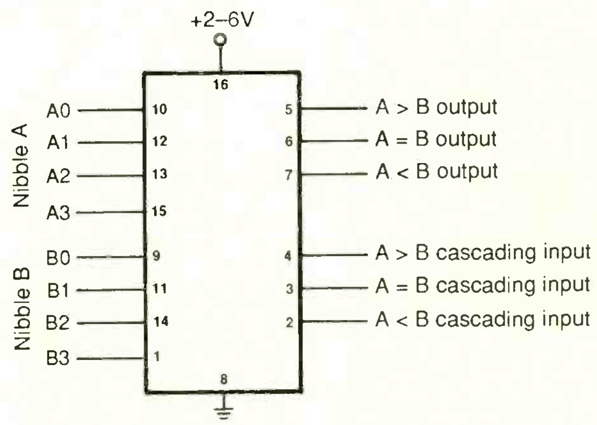
By Harry Helms

Electronics engineering journals and trade magazines today are busily beating the drum for applications-specific ICs (ASICs), the catch-all term for a host of technologies that produce custom and semicustom ICs. Indeed, many predict that by early in the next decade ASICs will capture over half of the worldwide IC market.

I happen to think they're right. ASICs *will* be a big and important part of electronics in the 1990s. But they won't be the whole show by any means. For many purposes, existing IC designs will be adequate and there will be no need to use an ASIC approach. Since ASIC devices in small quantities are an expensive proposition in small quantities, it seems likely that cost-conscious engineering managers will urge their design staffs to try to find solutions using "off the shelf" devices before going the ASIC route.

Therefore, keeping up with developments in standard ICs will continue to be highly important. A recent one I found interesting is the explosive growth in *high-speed CMOS* devices. I'm so impressed by the capabilities of this logic family and the range of devices offered in it that I'm going to go out on a limb and predict that HCMOS (as it's known) will be *the* dominant logic IC family of the next decade, supplanting standard CMOS and TTL (including advanced low-power Schottky ALS versions).

What's so special about HCMOS? Think of it as a marriage between TTL and CMOS that produced children with many of the good qualities of the parents and few of their shortcomings. For years, the tradeoffs in digital logic were clear. TTL was fast and its devices were "tougher" than CMOS but consumed globs of current, was bothered by "noise," and its power supply had to be +5 volts. In contrast, CMOS used little current and could operate over a wide supply voltage range. Unfortunately, CMOS was very slow compared to TTL. A serious problem was CMOS's susceptibility to damage from static discharge (some frustrated users felt you could "zap" a CMOS device simply by looking at it wrong!). Enhanced versions of CMOS and TTL were developed to address some of these problems, but they were more expensive and had some new limitations of their own.



74HC85 4-Bit Magnitude Comparator

Dc supply (V_{CC}): +2 to +6 volts
Dc input voltage: Not to exceed V_{CC}
Maximum quiescent mode power consumption: 8 μA
Minimum high-level input voltage: 1.5 volts for a 2-volt V_{CC}, 3.15 volts for a 4.5-volt V_{CC}
Propagation delay: 230 ns at 2-volt V_{CC}, 46 ns at 4.5-volt V_{CC}
Prime vendors: GE/RCA Solid State, Motorola
Secondary vendors: Hitachi, National Semiconductor, Signetics, Texas Instruments

Fig. 1. Pin diagram and salient specifications and information for the 74HC85 magnitude comparator.

Ahhh, but HCMOS! Now we're getting somewhere! Let's compare HCMOS to ALS, the most advanced version of TTL. HCMOS can operate from a supply voltage from +2 to +6 volts instead of the fixed +5 volts needed by ALS. ALS ICs typically have a quiescent supply current demand of 0.2 mA per gate, which HCMOS easily beats with a 0.0005-mA figure. In speed, there's no real difference between HCMOS and ALS. For example, a D flip-flop typically has a maximum speed of 35 MHz in ALS and 40 MHz in HCMOS, while a typical counter IC can operate at up to 45 MHz in ALS and 40 MHz in HCMOS.

Propagation delay times are virtually identical for ALS and HCMOS. HCMOS noise immunity is greatly superior to ALS. And HCMOS has a big advantage in fan-out capability. For example, a typical ALS IC can drive inputs of 20 other devices, while HCMOS outputs can drive over 50 inputs.

HCMOS also has remarkable compatibility with other logic families. HCMOS outputs can directly drive HCMOS, standard CMOS, or up to ten TTL inputs if all ICs use the same supply voltage. Moreover, HCMOS can accept inputs from HCMOS, standard CMOS and NMOS devices. There are even some HCMOS devices that can directly accept TTL inputs.

You can identify HCMOS devices by the "HC" or "HCT" in their part numbers. "HC" is a "normal" HCMOS device, while "HCT" indicates a device with TTL-compatible inputs and outputs. The normal format for part numbers begins with "74" (sometimes, "54"), then the "HC" or "HCT," followed by two to four numbers. One such part is the 74HC00, which identifies a quad 2-input NAND gate device. If that number looks familiar, it should; 7400 is the part number of the same device in standard TTL. Virtually all TTL devices have HCMOS equivalents identified by "HC" and "HCT." These are identical in their pin numbers and functioning. In addition, a number of standard CMOS devices are available in HCMOS versions. This means you can incorporate analog switches, multiplexers/demultiplexers, timers, and even phase-locked loops (the 74HC4046A) into all-HCMOS designs. If you're already familiar with TTL and CMOS, you won't have to learn a new variety of part numbers, devices and functions.

HCMOS isn't perfect, however. It still consumes more power and is more susceptible to noise than standard CMOS. It can't operate over as wide a voltage range as standard CMOS, and "HCT" devices must be operated from a constant +5 volts like TTL (HCT devices also consume more power than HC types). Furthermore, HCMOS is currently more expensive than most other logic families. And HCMOS still is vulnerable to damage from static discharge, requiring the same handling and use precautions that ordinary CMOS does. But these shortcomings are more than offset by HCMOS's many strengths. On balance, it's clearly the best existing logic family for most purposes.

4-Bit Magnitude Comparator

One useful new HCMOS device is the 74HC85 magnitude comparator. Figure 1 shows a pin diagram for this device, which takes two 4-bit (or "nibble") inputs and compares them. The two nibbles are labeled A and B, and three outputs (at pins 5, 6 and 7) indicate three possible relationships between them: A > B, A = B and A < B.

The output corresponding to the relationship between the two nibbles has a high logic level, while the other two outputs are low. There are three cascading inputs (pins 2, 3 and 4) that are used when two or more devices are cascaded to compare "words" larger than four bits. If you're using just one 74HC85, set the A = B cascading input (pin 3) to high and the other two inputs (pins 2 and 4) to circuit ground.

Figure 2 shows how to cascade the 74HC85 to compare two bytes. The first device is used to compare the least-significant nibbles of the two bytes and the second 74HC85 compares the most-significant nibbles. Outputs of the first device feed the cascading inputs of the second, while the cascading inputs of the first device are held to the same logic levels used with the single device. Additional devices can be cascaded in the same manner shown in Fig. 2 to compare words of 16, 32 or more bits. Though it would be easy to use an ASIC device to compare two bytes, this is one example where using standard components can be just as effective and much less expensive!

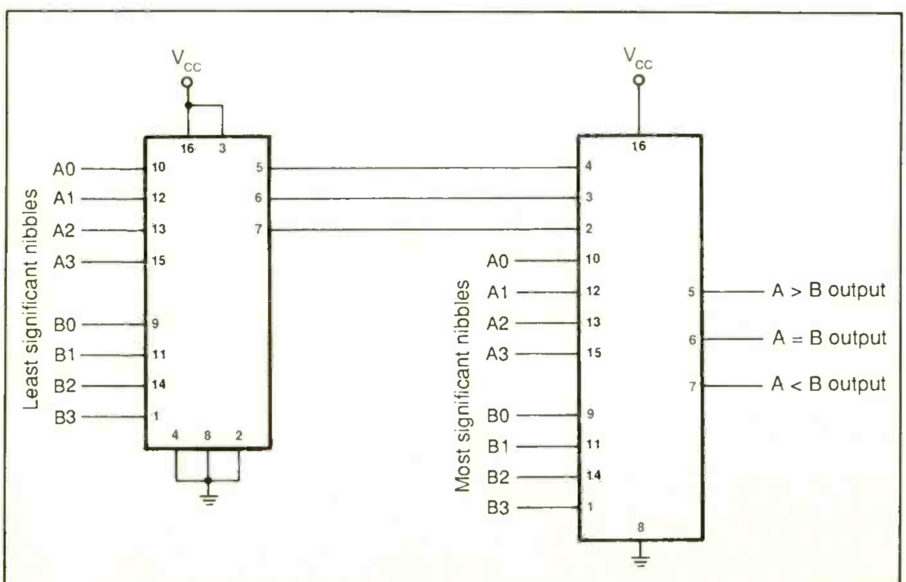


Fig. 2. Details of how to cascade 74HC85s to compare two bytes. Additional 74HC85s can be cascaded in the same manner to compare words of 16, 32 or more bits.

An 8-Bit Equality Comparator

There are often cases when all we need to know is whether or not two bytes are equal. Figure 3 shows the pin diagram for the 74HC688 8-bit equality comparator device. The inputs consist of two bytes, labeled A and B, and a single A = B output at pin 19. This output is low whenever the two bytes are equal; otherwise, it is high. There is also a cascade input at pin 1, which should be kept at a low logic level when only one device is used. (If it is at a high level, pin 19 will be high regardless of the inputs.)

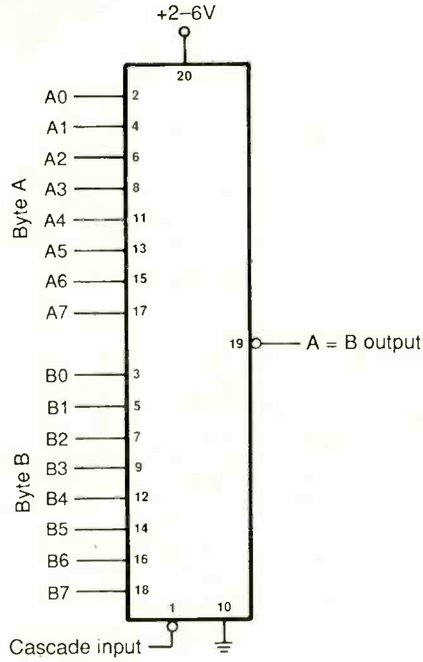
The cascade input is used if more than one 74HC688 is used to compare data "words" that are longer than one byte. This is done by connecting the A = B output of the first device to the cascade input of the second. The pattern is repeated for all other devices in the cascade chain. The cascade input of the first device must be connected to ground. The first device accepts the least-significant byte of each word, the last device in the chain accepts the most-significant bytes.

A 9-Bit Odd/Even Parity Checker & Generator

Parity checking it a technique to detect errors when data is transmitted serially from one point to another. Each data word has one bit known as the *parity bit*, and *odd* or *even parity* can be used. If odd parity is used, the number of 1 (high logic level) bits in the data word will always be an odd number. In even parity, the number of 1 bits will always be even.

The parity bit is usually the first bit in each data word; in the data word 101100011, the first "1" is the parity bit; 0 is used for even parity, while 1 is used for odd parity. Some parity-checking systems "borrow" a bit from a data word byte, leaving only seven bits for data, while other methods add an extra bit to a byte to form 9-bit words.

Figure 4 shows a pin diagram for an HCMOS device to detect the parity of a 9-bit data word input. The 74HC280 has two outputs, the even parity (pin 5) and an odd parity (pin 6). Input bit A (pin 8) is the parity bit. Depending on the parity of the input, one output will be high while the other will be low. If the number of 1 bits in the input is even (0, 2, 4, 6, 8), pin 5 will be high and pin 6 will be low. If the number of 1 bits is odd (1, 3, 5, 7, 9), then pin 5 will be low and pin 6 will be high. This allows you to not only determine the parity of an input signal, but also to "generate" a parity signal for use when comparing inputs that are larger than nine bits. To cascade 74HC280 devices, connect the odd-parity output of the first device to the A bit input of the next device in the chain. Leave the even-parity output open. Additional devices can be cascaded in this manner to handle 33- or 65-bit inputs.



74HC280 9-Bit Odd/Even Parity Checker & Generator
Dc supply (V_{CC}): +2 to +6 volts
Dc input voltage: Not to exceed V_{CC}
Maximum quiescent mode power consumption: 8 μA
Minimum high-level input voltage: 1.5 volts for a 2-volt V_{CC}, 3.15 volts for a 4.5-volt V_{CC}
Propagation delay: 205 ns at 2-volt V_{CC}, 41 ns at 4.5-volt V_{CC}
Prime vendors: GE/RCA Solid State, Motorola, Signetics
Secondary vendors: Hitachi, Mitsubishi, National Semiconductor

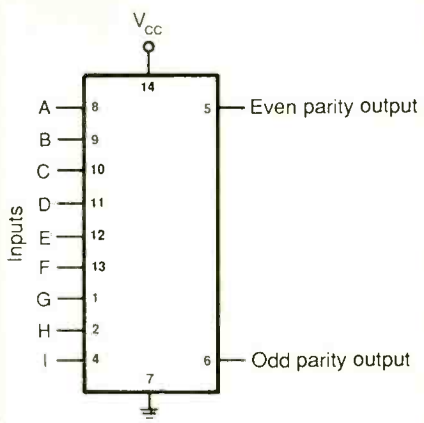
Fig. 3. Pin diagram and salient specifications and information for the 74HC688 8-bit equality generator.

Good Reading

Manufacturer literature is one of the best ways to keep up with semiconductor applications and electronics technology. You can obtain literature from their distributors and sales representatives, or you can obtain it directly from the manufacturer if you request it on business or professional letterhead.

Integrated devices haven't totally conquered the world. For many high-power applications, it's tough to beat a MOSFET. A valuable collection of MOSFET circuits is *TMOS Power FET Design Ideas*, available from Motorola Semiconductor Products. This book includes schematics and circuit information for voltage regulators, motor speed controls, lamp switches and dimmers, audio amplifiers, modulators, power supplies, and radio transmitters. This manual runs 70 pages and proves that discrete devices are alive and well. (Motorola, P.O. Box 20912, Phoenix, AZ 85036.)

I started this month's column by mentioning how ASICs seem destined to dominate electronics. A good guide to what an engineer must keep in mind when designing an ASIC is *Practical Considerations for the Design of Semicustom ASICs* (ICAN-8740), available from GE/RCA Solid State. Some of the advice is surprising, such as suggestions to avoid using on-chip clock signal oscillators and tri-state (high, low and high-



74HC688 8-Bit Equality Comparator
Dc supply (V_{CC}): +2 to +6 volts
Dc input voltage: Not to exceed V_{CC}
Maximum quiescent mode power consumption: 8 μA
Minimum high-level input voltage: 1.5 volts for a 2-volt V_{CC}, 3.15 volts for a 4.5-volt V_{CC}
Propagation delay: 210 ns at 2-volt V_{CC}, 42 ns at 4.5-volt V_{CC}
Prime vendors: GE/RCA Solid State, Motorola, Signetics, Toshiba
Secondary vendor: Hitachi

Fig. 4. Pin diagram and specifications and information for the 74HC280 9-bit odd/even parity checker and generator.

impedance) outputs. (GE/RCA Solid State, P.O. Box 3200, Somerville, NJ 08876.)

A Personal Note...

This is my first of what I hope will be a long line of columns. I'm particularly glad to once again write for Art Salsberg, for whom I wrote over a decade ago at *Popular Electronics*, and to appear in the same magazine as Forrest Mims, who has been a good friend since my days in Radio Shacks's technical publications group. My charter is to bring you the most recent developments in semiconductor technology and news on the latest devices available. I'd appreciate your feedback and comments about what you'd like to see in this column! **ME**

LETTERS ... *(from page 7)*

Electronics can send $12 to Vontronics, 1010 Park Drive, Everett, WA 98203. Also available from the same source are an undrilled case, the pc board, the three ICs and assembly instructions for the converter for $35. Please add $2.50 for P&H and state sales tax if you are a Washington resident.

Crady VonPawlak

• In the Note at the end of the Parts List in the "Off-Hook Phone Alert" (November 1987), the pc board and kit supplier should read R&R Associates, 3106 Glendon, Los Angeles, CA 90034.

Peter A. Lovelock

• For benefit of any readers who may be confused by some typographical errors in "A General-Purpose Speech Synthesizer" (October 1987), I offer the following corrections:

In Fig. 2, eliminate the connection from pin 1 of IC4 to pin 1 of IC12; connect pin 16 of IC4 to pin 2 of IC7; connect pin 19 of IC4 to pin 1 of IC7; change C15 to 0.1 microfarad and R2 through R7 to 2,700 ohms.

If used, Data Out in Fig. 3 goes to the RX input on the computer, not CTS. Also, pressing the RESET button causes the synthesizer to vocalize "okay" but not print it on the computer screen.

Barry L. Ives

Okay

• Since Radio Shack introduced the CTS256A-AL2 speech processor, I started building the circuit. The furthest I succeeded is when I hit the RESET button and the speech processor signaled "OK," telling me that the wiring is more or less correct. The literature that came with the chip was helpful just to wire it up to say "OK." But to interface it with a computer, it was not. Happily, the October 1987 *Modern Electronics* explains how to wire and interface it to a computer using serial or parallel outputs. I used the serial output option. As I was wiring it up according to the diagram, I noticed the diagram on page 36 has a misprint. Pin 2 of DB-25 connector J1 should be TxD and pin 3 should be RxD. After making this correction, my Speech Synthesizer started vocalizing any word I typed in. I hope everyone has as much fun as I did.

John Vartanian
Garden City Park, NY

Mismatching

• In "Hardware Hacker," August 1987 issue, it's noted that the internal resistance of automobile batteries is not "carefully matched" to the impedance of the starter motors they are designed to drive. If the impedance were matched, the terminal voltage of the battery would drop to one-half the unloaded voltage. In practice, the cranking voltage is not observed to drop below about 10 volts in a 12-volt system.

Stanley W. Wilson

• Don Lancaster's statement that "... a car battery's impedance is carefully matched to the impedance of the starter ..." in your August issue with regard to delivering maximum power during cranking can be misleading. I feel certain that such matching is not the case. Although there is a correlation between the impedance of the starter and the battery, a match would infer a 1:1 impedance ratio. If this were the case, the output of the battery would fall to half its open-circuit potential, or about 6.6 volts. However, cranking potential should not fall below 9 volts during cranking, suggesting a 3:1 ratio between load and battery. Best power delivery occurs when load impedance is much greater than source impedance.

A very large battery that has essentially zero impedance would deliver about four times as much power to a fixed load as the same-voltage battery would with a matched impedance. Therefore, what car manufacturers probably look for is a reasonable tradeoff between power-delivery "efficiency" and weight to optimize cranking in practice.

Wayne Shook
Marissa, IL

In the Beginning

• Some time ago, needing more shelf space, I cast my eyes about looking for something to throw out. I settled on some old vacuum-tube TV schematics printed in blue and taken out of an old magazine called *Electronic Technician*. Guess whose name I saw on the masthead????

TL Clayton
Meridian, MS

Yes, indeed, that's where this editor started in the magazine business.—Ed.

PC CAPERS

A New Computer-Oriented Column

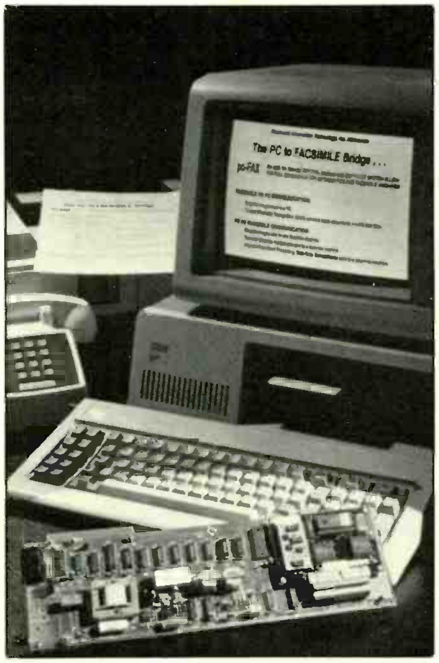
By Ted Needleman

Welcome to the first installment of "Computer Capers," which is intended to help you keep up with the pulse of the small-computer field that so many of us are active in. I've been using a variety of computers (in a variety of sizes) for almost 20 years as a programmer, systems analyst, DP manager, consultant, and an accountant in public practice.

I love gadgets and gizmos, and enjoy a love/hate relationship with computers. Over the years, I've accumulated a variety of computers. My main working machines are three PC compatibles, but I also use a 512K Mac, and occasionally my Apple IIe. There's a DEC Rainbow over in the corner running a FIDO Bulletin Board and a DEC Pro 380, which is as impressive a door stop as you'd ever want to see. The Apple /// got pawned off on my brother (he doesn't know much about computers, and was thrilled to get it), while a Commodore C-64 is in the care of a cousin. Add several printers (one for each system), a variety of review systems, and several hundred software packages, and you'll understand why my wife makes me work down in the basement.

What this eclectic collection means to you, as a reader, is that I won't concentrate on one particular computer system. And you can expect to occasionally see me cover some out-of-the-ordinary applications here, as they strike my fancy. Of course, much of this depends on your feedback to me. As the feedback loop increases over time, a column tends to evolve and take on almost a life of its own. As I can't call each one of you individually, this leaves the matter in your hands.

I'll list a couple of ways you can contact me at the end of this column, but I'm going to try and improve and expand my computer bulletin-board system over the next couple of months. Right now, it's primarily for use by owners of Digital's Rainbow systems, but I hope to be adding sections for PC and Mac owners. In a couple of months, when it's ready, I'll give you the details. It will be the best way to get in touch and will also offer a selection of downloadable public-domain software and shareware.



Facsimile boards like E.I.T.'s gives PCs receive/transmit facsimile functions.

In the meantime, you can drop me a note, or E-mail me on my CompuServe account. One word of warning, though. If you'd like to hear back from me, please include a phone number. Like many writers, I'm terrible about answering mail. I'd much sooner pick up the phone than fire up the word processor.

Bulletin Boards

As the operator (sysop) of a Bulletin Board System, and an early user of commercial information services like CompuServe and The Source, I'm sometimes surprised at how many people don't know about the tremendous number of BBS systems out there. It doesn't take much to set up a BBS; just a computer, a modem, some software, and an open telephone line. As a result, lots of people tend to jump right in.

Naturally, when the amount of work needed to keep the board up begins to dawn on them, or they realize that they can only use their own computer when someone's not on the board, lots of people jump right out again! This tends to keep the BBS situation fluid. New boards are always popping up, and established boards disappear overnight. Still, even with all this coming and going, BBS (and the commercial services) are a great place to do two things—solve problems and find software.

Many Bulletin Boards, especially the commercial services with their Special Interest Groups (SIGs), serve as forums where users, both experienced and new, can exchange information. If you're having a problem with a piece of hardware or software, it's possible that another member has also had the same problem and solved it (or found out that it is unsolvable). There are boards and SIGs for most major computers. Moreover, several software companies, such as Microsoft, Borland, and Aldus, maintain their own areas on CompuServe. You'll often get a faster response by leaving a message on one of these forums than calling the company. If your message isn't a private one to the system operator, other folks will readily put in their two-cents worth.

The BBS network and SIGs on the commercial services function as a para-user's group. Throw a modem and some communications software in your machine, and fellow users are as near as your telephone. This by itself is enough to make me strongly recommend them. A tremendous side benefit of most BBS's are their download libraries. These are sections that contain *lots* of free (or almost free) software. There are all kinds of software programs on these boards, including programming utilities, spreadsheet templates, word processors, database managers, etc. Some of these programs are real dogs, but some are as good as their commercial equivalents. Most are free, except for the cost of the phone call to download them. With others, the author asks that you voluntarily send them payment, if you like.

Considering the amount of time that goes into writing, testing, and debugging a program, you might be a little skeptical about the quality and/or utility of something for nothing. After all, we all know that there ain't no free lunch. Maybe so, but at the same time, sometimes you get treated to lunch by a friend. And there still are at least a few people out there who are willing to share the fruits of their labor. In many instances, a program is just as much a work of art to its creator as paintings or sculptures are to their creators. And most of us like to feel that our work is appreciated.

For others, who ask for a nominal registration fee, the "donations" are a way of funding on-going support and improvement. After all, it's hard to keep pouring time into something you "finished" a year and a half ago. For a few, the number of users who actually pay for the software is enough to fund a full-time business. Quicksoft, the people who put out PC Write, is a successful, on-going business, as is Headlands Press, with its PC-TALK III communications package. In fact, Headlands has been so widely accepted as a software publisher that PC-TALK IV, its latest version, is no longer shareware—it's strictly commercial now.

Along with the gems, you sometimes get rocks. Some of the downloads are just plain poor. You might even get a program with a worm in it. These are innocuous-looking programs that can trash your hard disk's contents. (For example, a hidden FORMAT command isn't inconceivable.) Most BBS operators are cautious about weeding these out, but never say never. Therefore, if you're going to download software, make sure your hard disk is backed up. But this is good practice anyway, isn't it?

Public-domain software and shareware are worth looking into. I'll talk more about this in future columns and tell you about some of my favorites. I'd also like to hear from any of you who use downloads and find out what you're using and your experiences.

What's the best way to find a BBS? Lots of sources. Some computer-only publications list them, and local user's groups may run their own. You can start with a commercial service and just ask about them in the various SIGs.

Another place to inquire is the International FidoNet Association (IFNA). FidoNet is a network of over 1,000 FIDO Bulletin Board systems. Most of these are "public" boards, which are more or less (depending on the system operator) open to the public. There are special-interest

A video screen generated by Z-SOFT's Publisher's Paintbrush program.

boards for motorcycle riders, fishermen, the handicapped, and many others. FIDO BBS's are also running all over North and South America, Europe, Africa, Asia, and even a few behind the Iron Curtain. For more information on the FIDO "movement," write to Ken Kaplan, President, IFNA, P.O. Box 41143, St. Louis, MO 63141. And if you have a favorite board that's something special, drop me a note and I'll spread the word.

The Best-Laid Plans . . .

One of the benefits of working in the computer press is being able to review lots of hardware and software (and get paid for it to boot!). And it's a great ego enhancer when people come to you with their problems because they consider you "an expert." At least it is until I remember my own definition of the word expert —someone who has fallen flat on his face enough times that he has developed calluses on his nose.

On this note, about a month or so ago, I received a pc-FAX board and ps-2000 scanner from E.I.T., Inc. This board and software combination turns an IBM compatible into a facsimile machine, which scans a document and converts it into a form that can be transmitted over the phone lines. The receiving fax machine reconstitutes the document and prints it out.

E.I.T.'s pc-FAX can send and receive fax's to and from any other fax machine that meets Group I, II, or III standards. These standards determine what speed (up to 9,600 baud) the system will transmit information at. The scanner allows documents with text and/or graphics to be captured as fax documents, just like a standard desktop fax. It sounded great, so I rushed to install it in my main system, an ITT Xtra with an 80-meg Tallgrass hard disk.

Installation was simple: drop in the pc-FAX modem board and the scanner controller board, close up the machine, run the install program to transfer software to the hard disk, and run the set-up program to tell the software what kind of system it was running in. Bingo . . . it didn't work! The scanner, which is supposed to scan at 200, 240, or 300 dots per inch (dpi) resolution would only work at 200. And the modem refused to talk to any other fax system. It would dial a number and then ignore the other system's "Hello there" tone.

A call to the company elicited the opinion that it might be that I was using an older version of the software, or it might be the outboard hard disk on the ITT, or it might be . . . . It turned out that one of the E.I.T. people lives about two miles from me, so she was nice enough to stop off at my home the next day with a new set of disks.

Another two weeks went by (never let it be said that I rush into these things), and I transferred the boards to an old PC compatible. When I went to install the software, I realized that I had only three disks, while the installation routine expected four. Another call to E.I.T. produced the fourth disk in the mail two days later. The software was quickly installed and, Bingo . . . it still didn't work! This time the scanner refused to even peek at the document, and the modem, likewise, is incommunicado.

I had the feeling that the problem was caused by either a) the fact that the Columbia has an incompatible BIOS (after all, it's four years old); b) the TOPS network card I installed the week before; c) the E.I.T. equipment needs to be repaired/replaced; or d) the moon is in the seventh house and Jupiter is aligned with Mars or some such nonsense.

The next step was to move the modem and controller cards to the other ITT. This system has a built-in hard disk, and I

PC CAPERS . . .

hadn't gotten around yet to installing the TOPS network card in it. The results of the move should narrow the above choices down somewhat, I thought.

When I couldn't get *anything* to work, I decided to take another tack. E.I.T.'s ps-2000 scanner is basically the same unit as the Shape scanner. I recently reviewed a great package from Z-SOFT called Publisher's Paintbrush. Z-SOFT is well known for its PC-Paintbrush graphics program, and Publisher's Paintbrush is an extension of this. The program lets you do almost anything you might want with a graphic image, including shrinking or blowing it up and rotating it. It also supports a variety of scanners, including the Shape.

Dragging the software package home from the office, I installed it on the *Columbia's* hard disk. The next step was to install a device driver for the Shape into my MS-DOS config.sys file. Easy enough, except the driver wasn't on any of my disks. A call to Z-SOFT uncovered that I had one of the first set of disks shipped, and that driver probably wasn't available at that time. I shipped the disks back for updating, and two weeks later I was back in business.

Now, however, there is also an install program for the Shape scanner that has to be run once the device driver has been installed. Want to guess on what set of disks it *wasn't*? Shannon, over at Z-SOFT's tech support, promised me he'd mail it right out. Maybe by next column I'll have some success (or at least some answers).

The whole point of this tale is not to convince you what a rough life we reviewers have. Rather, it's just to remind you that being on the edge of technology means that you sometimes get a few cuts. It's frustrating when things don't work right the first time out. And more than that, it's time consuming. But it's also a lot of fun most of the time.

I can't help thinking that if it's taking me all this time to straighten things out when the companies involved know I'm a reviewer, it chills me to think of what some of you must be going through. I'd really like to hear about some of the tips and techniques that you've developed to handle troubleshooting. I'll pass the best of them on here. It may not make you rich, but at least you'll be famous.

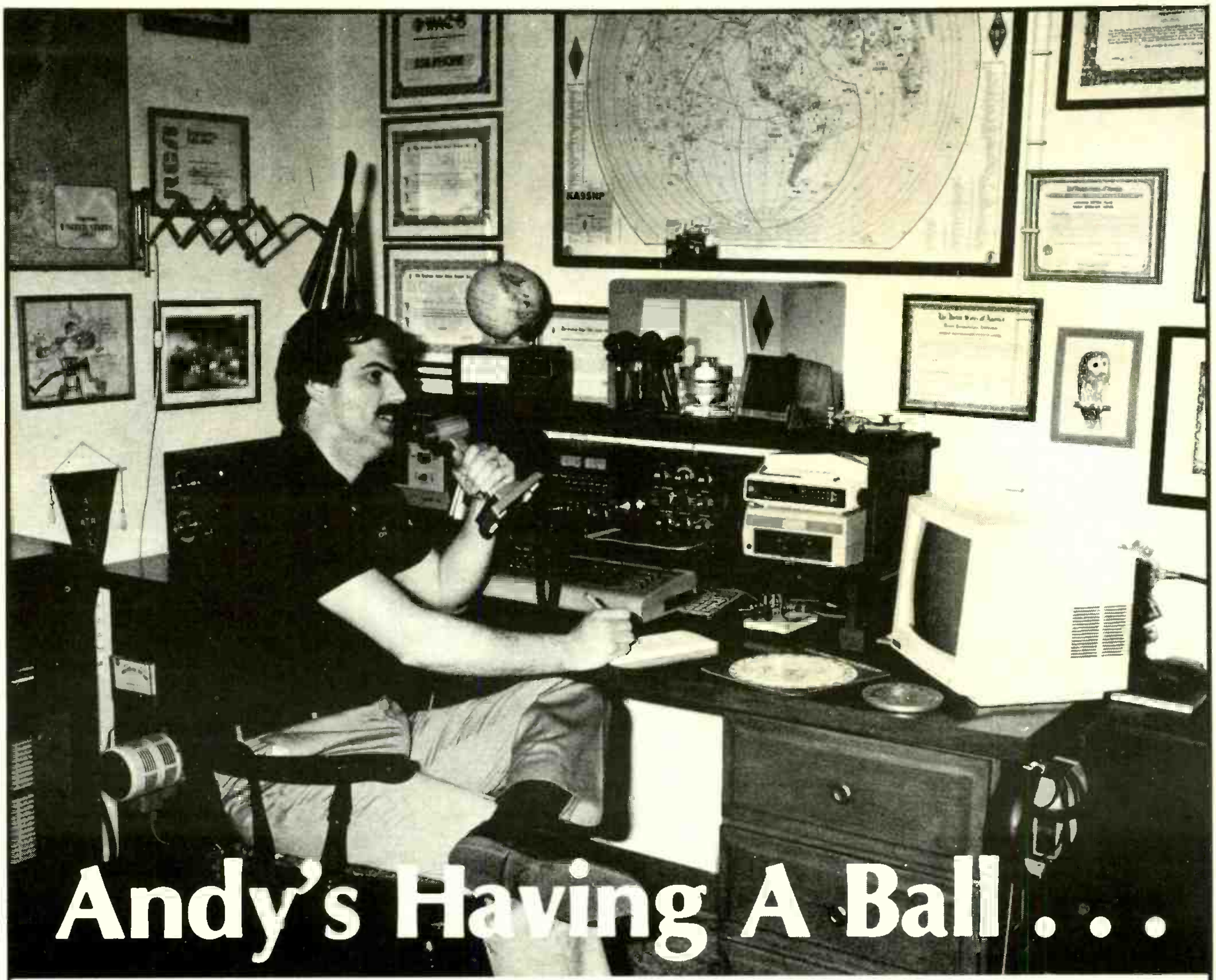
In Times To Come

I don't need a crystal ball to know what's coming up in near-future columns. All I have to do is look at the pile in my "lab." Apple's Hypercard, OWL's Guide for the PC, Centrum's TOPS network and some nice utilities are all here. And, of course, there's the on-going story with the E.I.T. pc-FAX as well as another fax card from Gammalink. I'll also tell you about a nice 80386 machine I've been playing with, the ACER 1100, as well as the PC-MOS/386 multi-user, multi-tasking operating system. And, of course, there's always something new showing up.

If there's something specific you'd like to see covered here, drop me a note. If I can get it, and if it will be of general interest, I'll give it a shot. There are several ways to get in touch. The easiest, though not necessarily the best, is U.S. Snail. A card or letter to P.O. Box J, New City (not *NY City*), NY 10956 will generally make it through. Electronic mail can be sent via CompuServe 72777,3041.

If you want to log onto FIDO BBS, Rainbow Corner, the phone number is (914) 425-2163. When my system answers, wait five seconds and hit RETURN a couple of times. Before you dial, though, set your communications package to emulate a VT-100 terminal. The sign-on screen uses VT-100 graphics. You can access the board without this ability, but the first 20 seconds or so will be garbage.

Once you get to the point where the system asks your name, you'll be OK. The first time you sign on, you won't be allowed in the file area. However, you can go to the message area, look around, and leave me a message. If you'd like file download privileges (there is some IBM software up on the board), let me know that you're a *Modern Electronics* reader and I'll upgrade your access. Be speaking to you. **ME**



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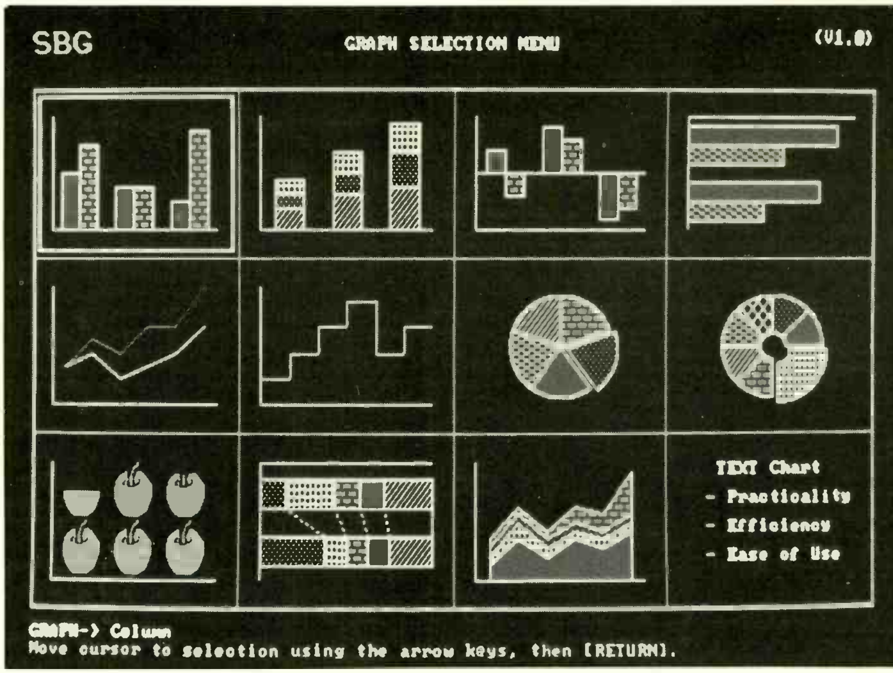
Quick Charts By Stella

By Art Salsberg



Stella Business Graphics' chart selection screen makes it easy to look at the same data in a variety of different ways and allows you to get your first chart in five minutes.

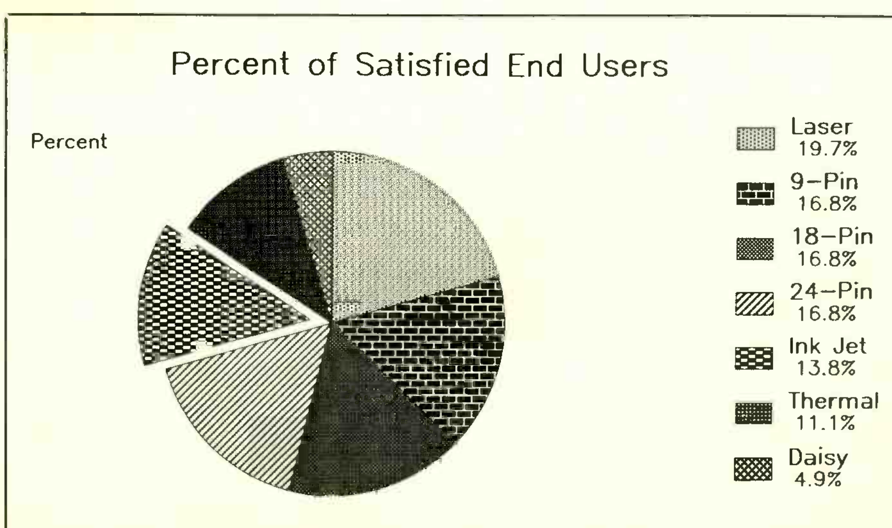
Stella Systems (Cupertino, CA) upgraded its Stella Business Graphics package to version 3.01 and, at the same time, announced that its U.S. management bought the company from its Japanese owners. Moreover, the $199 package was reduced in price to $99. This was followed by the introduction of a second Stella graphics software product, called Business Graphics II, ver. 2.0, priced at $199. Both are for use with IBM and IBM compatible computers, come with two disks, and are not copy protected.

The graphics packages work similarly, with the latest one providing more flexibility. BGII, for example, adds the capability to work with more graphics boards, such as IBM's new PS/2 and Vega Deluxe PGA, as well as EGA, CGA and monochrome ones. Further, the latest, more expensive (though less costly than most other graphics packages) software expands its print device capability, allowing setup for color and ink jet printers, as well as a wider choice of laser printers, plotters and dot-matrix printers. Furthermore, the newer package enables a user to position the created graph on one of nine different page locations, offers a choice of three different graph sizes, and portrait or landscape orientation (vertical or horizontal paper positioning).

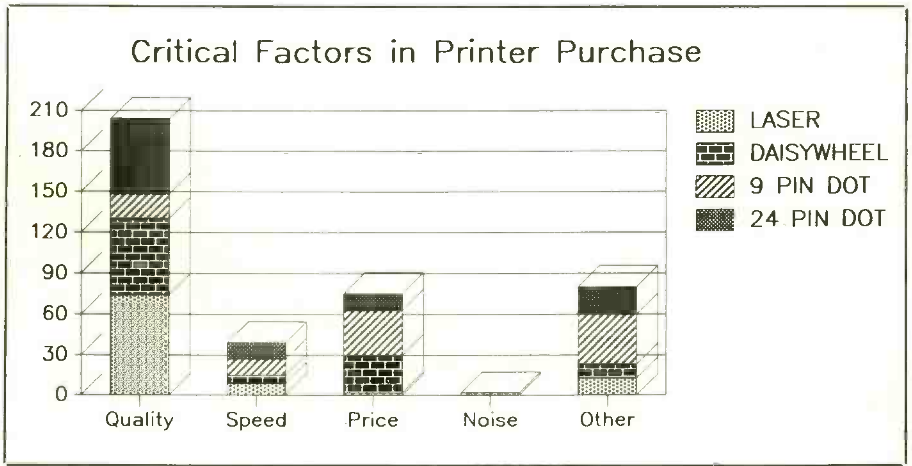
Additionally, the more costly program allows one to choose alternate paper sizes to as large as 11 × 14 inches, choose the number of copies, and produce color printer output from monochrome monitor systems. Default outputs are in high resolution regardless of what graphics card is in the system, with a draft resolution option. A variety of file formats can be imported, including ASCII and .WKS and .WK1 Lotus 1-2-3 files. In contrast, the earlier package required DIF file conversion for Lotus. BGII now provides extensive Help screens; 100K worth.

In Use

Setup is a snap, giving the user a choice of menus from which submenu-listed selections are made for printer choice, graphics card, etc. Loading either program, the first screen display that one sees is a pictorial bevy of 12 graph types (actually, one is all text that can be modified) that can be chosen by simply moving the cursor to the selected one, which displays a blinking line frame, and pressing RETURN. These range from bar, column, pie, donut (with hole in the center that



A BG2-developed pie chart with exploded section, printed with Epson's GQ-3500 laser.



Example of a stacked-bar type graph created with Stella systems' BG2 program.

can accommodate two lines of up to 8 character text), and a library of symbols (such as a car, a simulated bag with a large dollar sign, etc.) that can be modified if the user wishes to do so. A new symbol can be created, too.

Once a chart selection is made, the user is directed to input data by pressing function-key F4. Doing this sets up legends for choosing data input by keyboard or type of file for, say, Lotus, dBase, WordPerfect files. Each choice has a number for quick selection. Pressing the number "1," for Keyboard, displays a spreadsheet format for entering data. This includes Title, Footnotes, Column and Row names, and numeric information. For each, a choice of large or small type is offered, as well as a choice of color that is selected by typing the color's first letter.

The graph is subsequently displayed by pressing ESC. Appropriate legends at the side of the graph identify each data portion, which likely has different cross-hatchings, color, solid or dotted lines, etc. Should a change be desired, you can quickly go back to the spreadsheet and make it, pressing ESC again to view how the modification looks graphically. One can even quickly change the graph format by going back to the opening pictorial choices, and view the data in its new graphic coat.

When the graph is displayed, the user has an opportunity to insert additional text anywhere he wishes, which is an especially welcome feature.

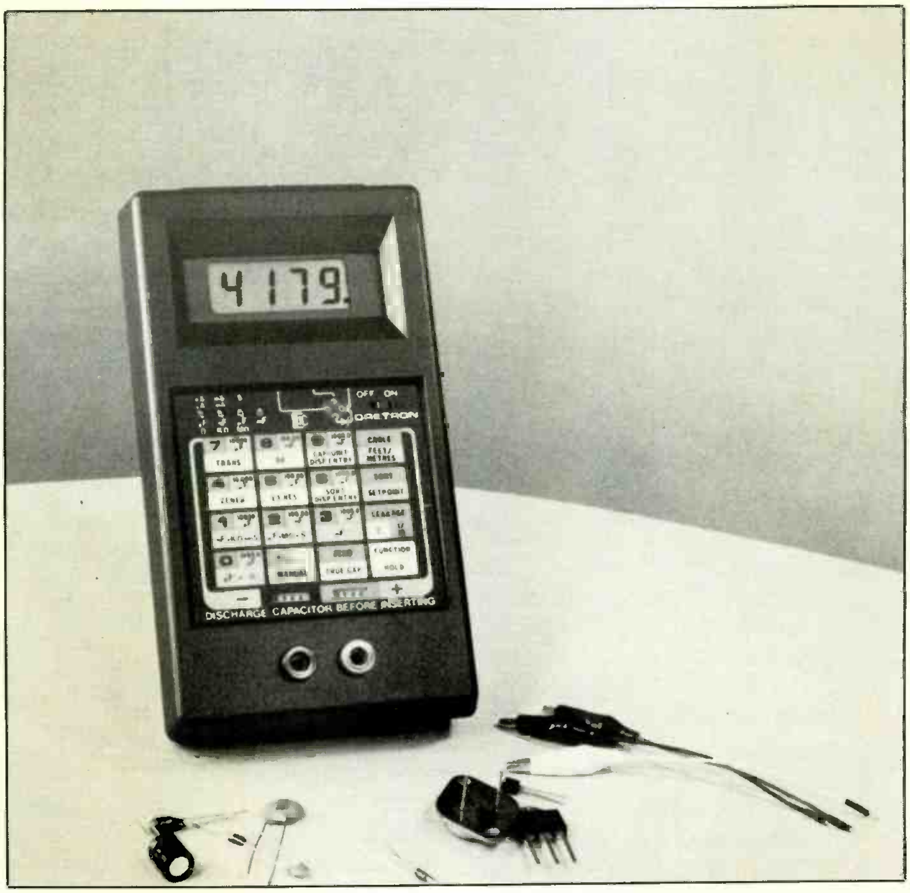
Conclusions

The earlier SBG graphics package is certainly a great buy at its reduced $99 retail price. It's simple to use, which means quick graph-making without the complicated hurdles of many similar programs. Though it does not compare in breadth and depth with many of the presentation graphics programs on the market, which allow you to do animation work and a variety of drawings, among other features, for owners of older IBM-type PCs who merely wish to make some quick and neat-looking graphs and have a variety of them to easily choose from, this low-cost, non-copy-protected one is a winning work.

The later package, BGII, expands on what the earlier one offers by working with the latest IBM-type machines and with a variety of color printers and more laser printer-oriented features, as well as easier transfer of files from Lotus and other popular business software. At $199 retail, it too represents a good value. If you don't need all the versatility provided by the $695 presentation packages, it will serve you very well on the latest type of personal computer equipment without the added operating complexities that the more sophisticated ones have. ME

CIRCLE 2 ON FREE INFORMATION CARD

The Daetron MC300: More Than Just a Capacitance Meter



The Daetron MC300 Digital Capacitance Meter belies its name. It's not your garden-variety capacitance meter, as you shall see. Nor is it limited to the typical capacitor checks. At $169.95, the powerful and flexible battery-powered instrument is one of the better bargains around. (An optional carrying case is $16.95; an ac adapter, $9.95.) Surprisingly, the meter isn't made in Japan or Korea; it comes from Canada.

The unit is packaged in a handsome black square-edged 7 × 4 × 1¾-inch case that appears to have a terrifyingly complex four-color 16-key keyboard. However, reading the manual and fiddling with the MC300, it becomes considerably less imposing.

To start with, the basic function of the MC300 is fully autoranging measurement of capacitance, with a range from 0.1 picofarad to a whopping 1 farad (1,000,000 microfarads). To measure most capacitors, you simply turn on the unit and poke the capacitor's leads into the instrument's push-in sockets. The MC300 responds with a four-digit ½-inch-high LCD display, and one of four LEDs lights to indicate the range in use. To measure capacitors with values greater than 10,000 microfarads, the unit must be turned off, the capacitor inserted (or, more likely, connected via short cables to the two banana jacks), and the unit is then turned on. The larger the capacitor, the longer the wait for its value readout. The manual indicates a wait of about 50 seconds for a 180,000-microfarad capacitor, and this was borne out in my testing. (The largest capacitor tested was 220,000 microfarads, which turned out to be 214,700 mikes—pretty close, all things considered.)

Accuracy of the unit was excellent up through about 33 microfarads, that being the largest precision capacitor in my stock. Accuracy on the smaller 1-percent and better capacitors was within their tolerance ranges.

In addition to full autorange capability, the MC300 allows you to select any of 10 fixed test ranges by pressing the blue MANUAL key, followed by one of 10 range-select keys.

The MC300 goes far beyond the foregoing. While you might not ever want to measure a capacitor with a value greater than 1,000 microfarads, you may wish to know a few of its other electrical characteristics, such as its leakage rate and dielectric absorption. The MC300 measures both directly!

The highest test voltage for leakage tests is about 15 to 18 volts. A lower test voltage, down to about 3.5 volts, can be chosen. The display will indicate either nonE (if leakage is negligible) or bAd (if leakage is severe), or will indicate leakage in kilohms. To exit the leakage testing mode (actually, to exit any of the special test modes), you press the FUNCTION key two or three times.

Knowing the dielectric absorption of a capacitor is critical in timing circuits, since a high DA can throw the calculated time periods off. To measure a capacitor's dielectric absorption, you charge the capacitor for a certain period of time, discharge it for a like period of time, and then measure its residual voltage—that's the DA. With the MC300, all you do is plug the capacitor into the push-in socket and press FUNCTION, followed by the white DA key. The display changes to dA, and pressing the DA key again starts the test. The display indicates UAIt (that is, wait) and the mF range LED lights to indicate the stabilization period. After about a minute total, the capacitor's DA is displayed, expressed as a percentage ratio of the charging voltage to the residual voltage. A reading of 0 indicates no absorption.

The MC300 can be used to quickly sort a pile of capacitors in a variety of ways. The simplest way is to enter the upper and lower ranges you want. Thus, if you want to select all of the 1-percent devices from a pile of 1-microfarad capacitors, you would enter .99 and 1.01 microfarads, then press SORT and poke the caps into the socket one by one. The display will show LOU, hiGh or GOOd, depending on whether the capacitor's value is below, above or within the range.

Since the MC300 allows you to enter a zero value, you can also sort capacitors by entering the nominal value, say, 1,000 microfarads. The display will then show the *difference* between this value and the capacitor's actual value. For example, a 1.215-microfarad capacitor would read 0.215, etc.

Among other features are *true capacitance* (which tells you the actual capacitance of a leaky capacitor), *extended resolution* (which allows you to shift the display to read a capacitor's value to one extra decimal place), and *time constant* (which allows you to enter a resistance value and determine a capacitor's time constant with that resistance in seconds).

One semi-capacitive function that is worth noting is the MC300's ability to measure cable length, up to a theoretical limit of 10,000 miles. This is done by entering a known or measured value of picofarads per foot (or meter), then connecting the MC300 to the cable to be measured. It's uncertain how useful this feature is, as many things can influence the accuracy of the reading. When it works, though, it would be a useful substitute for a very expensive time-domain reflectometer.

In addition to all of the above, the MC300 tests transistors, zener diodes, and rectifiers. To extend its zener testing range, the MC300 has a dc-to-dc voltage converter that produces up to 25 volts, even though the unit is powered from a single 9-volt battery. The voltage isn't regulated, though, and drops as battery voltage declines. To see what peak testing voltage is at any given time, all you have to do is press the ZENER key again with no diode in the socket, and the display will show the voltage. With a zener inserted into the transistor socket, the display will show the diode's breakdown voltage with a resolution of 0.1 volt.

Testing rectifiers is a similar procedure, except that the diode is inserted in reverse fashion. Any reading from 0.2 to 1 volt means the diode is good; a reading of 0 means a short, and a higher reading (usually the maximum) means the diode is open.

Lastly, we come to the MC300's attractive ability to test bipolar transistors. "So what?" you say, "you can get a transistor tester for as little as twenty bucks!" That may be true, but you first have to know the pinout of the transistor, and often have to know whether it's npn or pnp. The MC300 not only tells you what type the transistor is and whether it's good or bad, but it also identifies all three leads for you!

Transistor leads fit into the top three holes of the tester's transistor socket. If the transistor is good, the display will indicate either nPn or PnP; if it's not, you'll get bAd. A second press of TRANS (if the device is good) produces a reading of EbC, CbE, bCE, etc., and lines run between the display and the socket to tell you which lead is which. Now, is that incredible or what?

This function isn't perfect: the display indicates bAd when the transistor is good about 25 percent of the time. Switching around the leads often helps produce a reading from the MC300. However, some transistors, particularly power types, just won't generate a reading. A fresh battery or the use of the ac adapter will produce the most good readings, but as the battery weakens the number of bAd indications will increase. Even so, this is one of the MC300's useful functions.

Since many transistors have leads that are too large to fit into the socket, Daetron provides three short leads with alligator clips on one end and pins that slip into the socket on the other. These can also be used in the capacitor socket to accommodate large capacitors, but they tend to fall out, so regular banana jack-to-alligator clip leads are a better bet for testing more than one or two large capacitors at a time. (Such leads are not provided with the MC300 but can easily be bought or you can make them yourself.)

All roses have thorns, and the MC300 is no exception. For all of its power, the unit has a few annoying drawbacks, the most glaring of which is the keyboard action. The keyboard is a flat membrane type, which wouldn't be too bad except that no feedback, either tactile or audible, is provided. The only feedback comes from the four range LEDs, which flash briefly when the pressed key is read into the microprocessor. The flash is hard to see under the best of circumstances, and the keyboard polling rate is very slow, Therefore, it's best to hold down a key for a half-second or more to assure a response. (According to a Daetron spokesman, an audible feedback indicator is soon to be added to the unit.)

A second complaint is that it's sometimes difficult to get out of a special test mode and back to the regular capacitance-testing mode. According to the manual, two presses of the FUNCTION key will return you to the initial mode at any time. In practice, three or four presses are sometimes required, and some portions of the special test modes must be first exited by pressing the relevant test mode key before pressing FUNCTION. It's easy to forget which test mode key was last pressed, of course, meaning you're locked up until you figure it out. I often found myself powering the unit off and then on to get it back to the capacitance-measuring mode.

Finally, the manual that accompanied the MC300 was less than ideal. The usage information presented is somewhat unclear and sometimes inexact despite a careful listing of which keys to press and when. Although nicely printed, the text of the manual was produced with a non-letter-quality dot-matrix printer and is difficult to read.

Despite these drawbacks, the Daetron MC300 is an impressive piece of equipment, with a host of imaginative functions that are not ordinarily available at its price. Lastly, after three weeks of using it on my (well-equipped) bench, I refused to part with it, and ended up buying the test sample. I think that says it all!

—J. Daniel Gifford

CIRCLE 1 ON FREE INFORMATION CARD ME

BOOKS

Handbook of Practical I.C. Circuits by Harry L. Helms. (Prentice-Hall. Hard cover. 163 pages. $34.95.)

Here is a book for everyone who has a professional, experimenter or hobby interest in electronics. Rather than being a mere "handbook" that lists some IC devices and a few typical applications circuits, this book is collection of "recipes" that let the reader get right to work in breadboarding and building devices without resorting to deep theory, heavy mathematics and component-by-component analyses. As such (as the author states) it is a "cookbook" that is ready to be used as soon as a reader opens it.

Emphasis is on using readily available IC building blocks rather than on designing circuits from scratch. It capitalizes on available building blocks that perform specific functions instead of the old-fashioned method of reinventing each circuit as it is needed.

The book beings with an introduction to integrated circuits with discussions on IC packaging, pin-numbering schemes, IC types, logic symbols and construction and powering IC circuits. Following chapters individually discuss operational amplifiers, linear ICs, TTL devices and CMOS devices. Each chapter includes basic theory, pinouts and tables for the specific devices mentioned and a number of practical schematic diagrams that can be built.

If you are a professional, serious experimenter or just an occasional tinkerer, you should find this book to be a handy source of information and ideas.

Free (and Almost Free) Software for the Macintosh by Robert C. Eckhardt. (Dilithium Press. Soft cover. 413 pages. $19.95.)

Free software? You bet! and this large-format book (it measures 8.5 × 11 inches) tells you what it is and how and where to get it for the Apple Macintosh computer. Among the free (and almost free) software items that can be obtained are hundreds of applications and files ranging from sophisticated games to utilities to templates for commercial programs. There is even a complete catalog of nearly 300 free fonts, most printed out as they would appear on paper.

This book is more than just a catalog of software titles. Though it does list hundreds of titles (arranged according to category, like desk accessories, fonts, communications, graphics and animation, music and sound, games, utilities and everything else), it goes much further in offering quality and value ratings in addition to description. Each entry is accompanied by the program title, where it is available from and for how much (*almost* free, remember?) and screen printouts where appropriate.

Up front, the first chapter tells the reader where and how to get public-exchange software. The where includes users groups, commercial disk libraries and over the wires. This chapter closes with a section on how to use the book.

This is a fun book through which to browse. Its contents make fascinating and sometimes amusing reading. If you own a Mac, you should have this book near it.

Build Your Own Working Fiberoptic, Infrared and Laser Space-Age Projects by Robert E. Iannini. (Tab Books. Soft cover. 262 pages. $15.95.)

Leafing through this book is like scanning an electronics technical manual from the future. Its 14 chapters are chock full of plans for building devices one usually associates with a physics research laboratory and some even with science-fiction movies and books. Here you will find such items as solid-state, helium-neon and CO_2 lasers, even a ruby-laser gun. Other items that will pique your interest are a high-speed laser-light pulse detector, an IR night-time viewing device, a fiber-optic communication system, and a plasma tornado display lamp/sculpture lamp, among others. All projects are fascinating, to say the least.

Many of the projects are also dangerous if not built and operated properly. Thus, the author leads off the book with prefaces on laser safety and general precautions and project descriptions and special precautions.

Each project presented has a chapter of its own. All chapters contain theory of operation sections and detailed construction procedures, including assembly drawings. Full schematics and parts lists are also provided. Where circuitry is to be assembled, printed-circuit board layouts are given, and where perforated-board construction is called for fully detailed drawings are provided. Whenever a point in construction or operation is reached where safety precautions must be taken, that portion is highlighted with a tint block.

NEW LITERATURE

SWL Catalog. The 1988 edition of the Electronic Equipment Bank SWL Catalog is now available. It contains complete listings, including descriptions, technical and physical specifications and prices for a wide variety of tabletop and portable shortwave receivers, converters, antennas, accessories and literature. Brand names like Grundig, ICOM, Japan Radio, Kenwood, Magnavox, Sony, Ten-Tec, Toshiba and Yaesu are represented. Each product listed is accompanied by a photograph. For a copy, write to: Electronic Equipment Bank, 516 Mill St., Vienna, VA 22180.

Test Equipment Catalog. Beckman Industrial's new 52-page test instruments catalog describes the company's full line of heavy-duty digital multimeters, oscilloscopes, telecommunications test gear, function generators and frequency counters. In addition to providing detailed specifications and full-color photos of each product, the catalog includes a special section on the company's new line of digital temperature-measuring instruments, including hand-held thermometers, multiple-input digital bench-top thermometers and temperature calibrators. For a copy, write to: Shelly Vickery, Beckman Industrial Corp., 3883 Raffin Rd., Dept. ME, San Diego, CA 92123-1898.

Interconnection Products Catalog. A 60-page Interconnection Products Catalog from L-Com lists and describes more than 2,000 products, many of them new to this issue, for computer, communications and electronics applications. Information supplied includes: unit/quantity pricing, full specifications, drawings and photos of the products, dimensions and other pertinent details. Product categories include: molded coax and data cable assemblies, baluns and multiplexers, data line and surge protection systems, telecommunications cables/accessories, RS-232 devices and testers, IEEE-488 cables and accessories, and more. For a free copy, write to: L-Com Data Products, 1755 Osgood St., N. Andover, MA 01845.

Electronic Instruments Brochure. A full-color brochure published by Hewlett-Packard presents information on 22 basic instruments used to make electronic measurements. Instruments covered include digital multimeters, counters, pulse and function generators and power supplies. Brief descriptions, specifications and prices are provided by each product. For a copy of Publication No. 5953-7040, call any Hewlett-Packard sales office listed in the white pages of your telephone directory.

Optoelectronics Selector Guide. Motorola's fourth edition of the "Optoelectronics Selector Guide" lists more than 20 product families in sections on Emitter/Detectors, Optoisolators, Optointerrupters and Fiber Optic Components. Product families new to this edition include Motorola's first hermetic-packaged optoisolators (4N22,A Series), the industry's first 200-volt zero-cross triac driver (MOC3080 Series) and the company's first visible light-emitting diode (MLED76). Also included are a cross-reference guide and a section on reliability for both Motorola OPTO 400 and optoisolator "dome" packages. For a copy of the No. SG87R4/D guide, write to: Motorola Literature Distribution Center, P.O. Box 20924, Phoenix, AZ 85063.

Test Equipment Catalog. A new eight-page, two-color catalog that lists and fully describes the company's low-cost test equipment is available from Mercer Electronics, Division of Simpson Electric. Among the items listed are recently announced multifunction frequency counters and 20-MHz sweep/function generator; 3½- and 4½-digit hand-held DMMs; a volt-ohm-ammeter; a high-accuracy, full-range 3½-digit capacitance tester; and a variety of other digital test instruments and probes. For a free copy, write to: Mercer Electronics, 859 Dundee Ave, Elgin, IL 60120-3090.

Test Instruments Catalog. An 88-page test and measurement instruments catalog from Leader Instruments details complete features, specifications and applications for more than 100 products, including 18 new ones in this latest edition. New entries include a combination DMM/storage oscilloscope, 60- and 20-MHz portable scopes, several types of signal generators and waveform monitors, and six power supplies. Included is a new section that gives information on programmable RGB generators. For a free copy, write to: Leader Instruments Corp., Dept. ME, 380 Oser Ave., Hauppauge, NY 11788.

ASIC Design Manual. National Semiconductor's 1987 ASIC Design Manual provides designers with guidelines for using the company's application-specific integrated circuits and describes circuit functions available in gate arrays and standard cells. Packaging data, including package types, physical dimensions, pin counts and thermal resistance, are also supplied. A general information section lists the features of National's ASICs, illustrates the gate array cell structure and helps designers calculate delays and "size" chips. Selection tables and alphanumeric and function indexes are provided. For a free copy, call Carmen Valles at 408-749-7372.

MODERN ELECTRONICS
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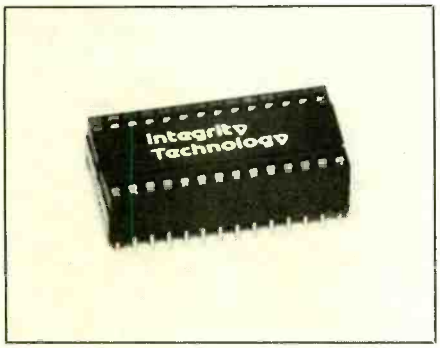
ule plugs into any available 28- or 24-pin ROM IC socket on the computer's motherboard. If no empty socket is available, the Module can be piggybacked with any ROM BIOS IC on the motherboard.



Included with the module are DOS programs to Get, Set and Show date and time. Adding the GETIME command to the AUTOEXEC.BAT file allows the computer to automatically set DOS date and time at power-up or during booting. The programs are on non-copy-protected 5.25- or 3.5-inch diskettes. Also included on-disk are install programs with full instructions and illustrations.

The PC-Clock Calendar module has a built-in (not user-replaceable) long-life lithium battery that, in a normal environment, should last at least five years. $38.

CIRCLE 22 ON FREE INFORMATION CARD

PC Digital Logic Analyzer

Heathkit's new Model IC-1001 logic analyzer lets IBM PCs and compatibles or standard terminals be used as a versatile 16-bit logic analyzer. It can be used to troubleshoot or verify proper operation of digital circuits that contain sequential and/or combinational logic. Sixteen data lines permit checking a 16-bit-wide data bus or 16 separate logic test points. The analyzer also has a clock input

and two clock qualifier inputs, and it is compatible with TTL and 5-volt CMOS logic.

Acompanying software provides state and timing displays, including hex/octal and ASCII equivalents, an address relative to triggering and other information, which can be saved on disk. Also included is a checksum capability with bit selection for easy comparison of acquired data and the ability to search this data for a specific bit pattern. On-screen help, prompting, status and error reporting are available. A number of versatile positioning commands determine how data captured in the 2K × 16-bit acquisition memory are displayed.

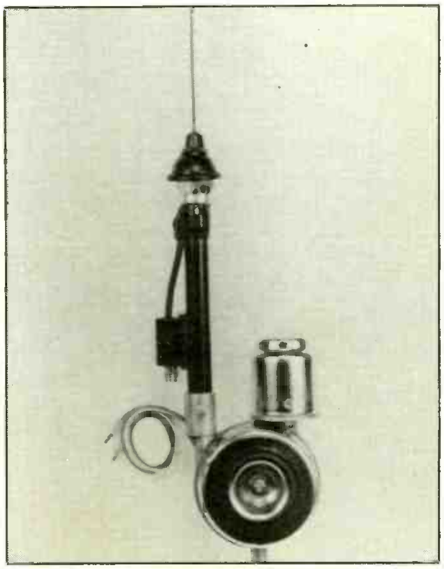
The logic analyzer can be configured to capture a specific sequence of pulses. A single or repeating trigger with selectable time delay can be used to capture a window of pulses. The delay mode can acquire data up to 50,000 clocks after trigger, and non-delay mode can be used to view events 2,000 clock pulses before trigger. Clock speeds of up to 10 MHz can be accommodated.

Supplied with a standard RS-232 serial cable, the logic analyzer features automatic 300- to 19.2K-baud rate selection; trigger outputs for use with an external oscilloscope; high-impedance inputs; and 9.25"W × 8.5"D × 1.75"H size. $269.

CIRCLE 23 ON FREE INFORMATION CARD

Motorized Cellular Antenna

A hideaway, fender-installed power cellular antenna with automatic switched motor, the Model CMR1000, is now available from ORA Electronics (Chatsworth, CA). It offers the same convenience as a power AM/FM radio antenna while eliminating the potential of damage resulting from car washes, environmental conditions and vandalism.

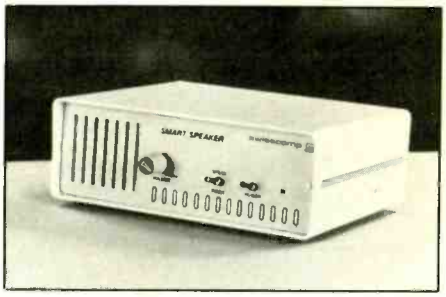


The antenna uses a ½-wave, voltage-feed design and delivers a rated gain of 2.5 dB. Its frequency range is 820 to 895 MHz, with a VSWR of 1.7:1. The CMR1000 cellular antenna can also be used as an AM/FM radio antenna when used with the CMR-FM/AM coupling box. $159.

CIRCLE 24 ON FREE INFORMATION CARD

Text-to-Speech Converter

Smart Speaker from Swisscomp Inc. (Tampa, FL) is an advanced text-to-speech converter that is said to offer features not available on other converters. Smart Speaker connects to



any computer that has standard serial or parallel ports and works with any software that puts out ASCII code to drive a printer. Because it shares the printer port via a built-in A/B switch, the converter does not require an additional I/O port slot. A serial port is provided for those applications that require RS-232 compatibility. A parallel cable is supplied.

Smart Speaker converts ASCII text to speech and accurately speaks it through its own built-in speaker. It also has a line output for driving an external audio device and a facility for connecting an external speaker. No programming is required. Numbers and text separated by spaces or periods are spelled out. Advanced text-to-speech algorithms make the converter so easy to use that no special software is needed. Data is accepted in the same format as that is required by printers.

The converter is available in the basic stand-alone version with parallel cable and dc power supply and as a Smart Connection package, for industrial and office applications, that comes with 1,200-baud internal or external modem for IBM PC/XT/AT and compatible computers. The Hayes-compatible modem recognizes Touch Tones, has a clock/calendar and comes with an 8K buffer. $229.95 for stand-alone unit; $549.95/$599.00 for Smart Connection with internal/external modem.

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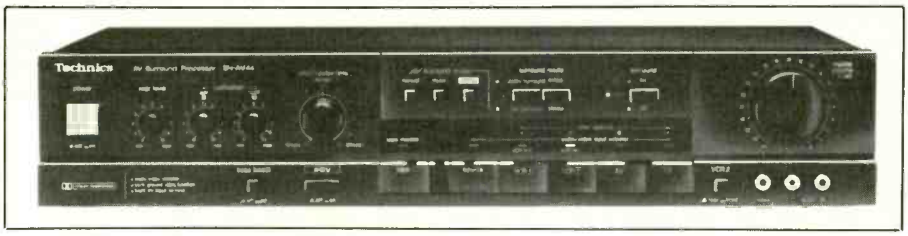

A/V Surround Processor

Technics' Model SH-AV44 audio/video surround processor simulates ambience effects. It has the Dolby Surround system used in motion pictures and on videocassettes. It also has Technics' own system that extracts reverberant soundinformation from the original signal, adds phase shift and then selectively sends it to the main and surround speakers. The Technics system can be used with mono and stereo signals and has different modes for customizing the ambience to the user's taste.

An A/V selector with BGV (Background Video) allows up to four sets of audio and video signals to be switched in simultaneously and has tape and source selectors for switching between audio-only signals. The built-in power amplifier drives rear speakers and provides a mono front-center signal that drives a separate amplifier or can be piped into the audio input jack of a TV receiver. The user's stereo system drives two front speakers, the SH-AV44 the rear two speakers.

Included are calibration controls with LED indicators for optimizing Dolby Surround effect; a control for adjusting the surround effect; LED input source indicators; VTR inputs on the front and rear panels; and a bass-boost switch. $320.

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ELECTRONICS

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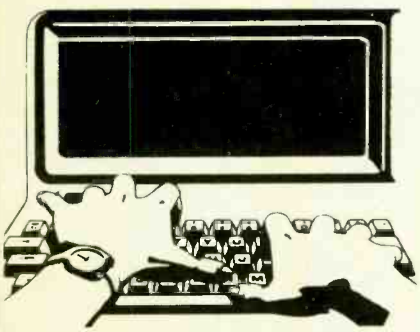
ADVERTISERS' INDEX



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LED Beacon

(from page 39)

For the positive battery terminal, strip ⅛ and ¾ inch of insulation from opposite ends of a 1¾-inch length of No. 26 solid hookup wire. Plug the end from which the ¾ inch of insulation has been removed into the board from top to bottom and solder it at point A, as shown in Fig. 2. Now position the No. 357A cell, positive electrode up, against the IC socket and hold it in place as you bend the wire over the top of the cell and around the outer edge of the board. Route the wire and solder it to pin 5 of the IC socket. The hookup wire should solidly "sandwich" the cell in place but still permit easy removal of the cell. ME

Wireless Microphone

(from page 31)

phone's r-f carrier loud and clear. Then very carefully adjust the spacing between the turns of *L1*. Use an *insulated* tuning wand for this—*not* a metal object like a screwdriver or capacitive effects will give false results. Just a slight movement of the coil's turns is needed. A word of caution is in order here: Under no circumstances should you attempt to tune your wireless microphone to a frequency beyond 108 MHz. Such frequencies are reserved for aircraft services and must not be used for any other purpose or be interfered with for any reason.

You can house your wireless microphone in any enclosure that suits your tastes. For general-purpose use to pick up sounds at a distance, a small plastic box with a hole or slot cut in it directly in line with the microphone element will do fine. For up-close announcing applications, as in a PA system arrangement, use an enclosure that is small enough to be conveniently hand-held, such as an inexpensive microphone housing or a small project box. Another alternative is to mount the circuitry inside of a box that has a clip on it to permit hanging the electronics from your belt and locating the microphone element on a tie bar or pocket clip at the end of a shielded cable.

To obtain long operating life, use a high-energy alkaline battery to power the wireless microphone. A single fresh alkaline battery will power the microphone continuously for about 30 hours. If your anticipated applications call for intermittent use, such as in paging over a PA system, you might want to place a normally open pushbutton switch in series with the +9-volt line to power the circuit only on demand. This will considerably extend battery life. Yet another alternative is to use a common spst slide or toggle switch that will allow you to turn off power whenever the microphone is not being used. ME

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Optional Accessories:

• VC-20 VHF converter for 108-174 MHz operation • YK-88A-1 6 kHz AM filter • YK-88S 2.4 kHz SSB filter • YK-88SN 1.8 kHz narrow SSB filter • YK-88C 500 Hz CW filter • YK-88CN 270 Hz narrow filter • DCK-2 DC power cable • HS-5, HS-6, HS-7 headphones • MB-430 mobile bracket • SP-430 external speaker • VS-1 voice synthesizer • IF-232C/IC-10 computer interface.

R-2000 150 kHz-30 MHz in 30 bands • All modes • Digital VFOs tune in 50 Hz, 500 Hz, or 5 kHz steps • 10 memory channels • Programmable scanning • Dual 24-hour digital clocks, with timer • 3 built-in IF filters (CW filter optional) • All mode squelch, noise blanker, RF attenuator, AGC switch, S meter • 100/120/220/240 VAC operation • Record, phone jacks • Muting terminals • VC-10 optional VHF converter (118-174 MHz)

Specifications and prices are subject to change without notice or obligation.

More information on the R-5000 and R-2000 is available from Authorized Kenwood Dealers.

KENWOOD

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CIRCLE 64 ON READER SERVICE CARD