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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

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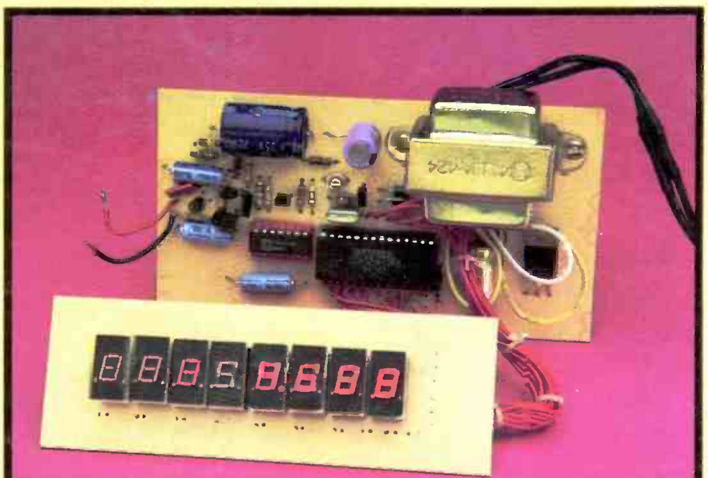
Super-Sensitive Meter Indicates Static

Meter Measures One-Trillionth Amp (p. 24)

Co... on:

- ...er Lets Computers ...gle Printer
- 'S... Cable Foolproofs Car-B...ery Jump-Starts
- A 10-MHz Frequency Counter
- Short-Time Wake-Up Alarm For Therapeutic Napping


H-P's LaserJet II Laser Printer (p. 64)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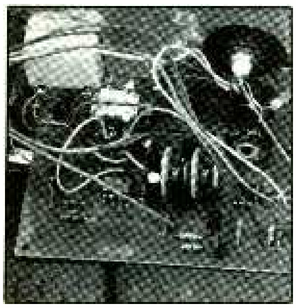

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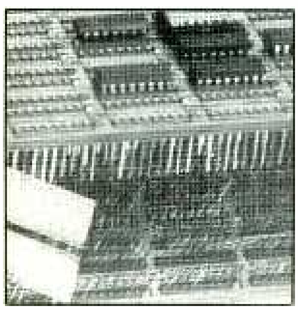

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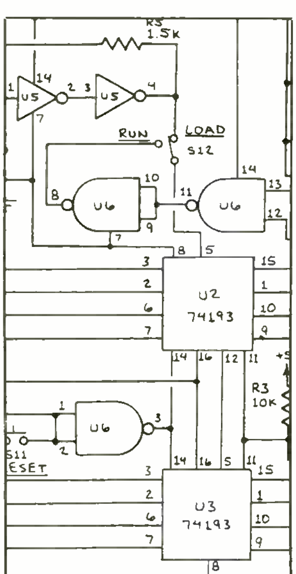

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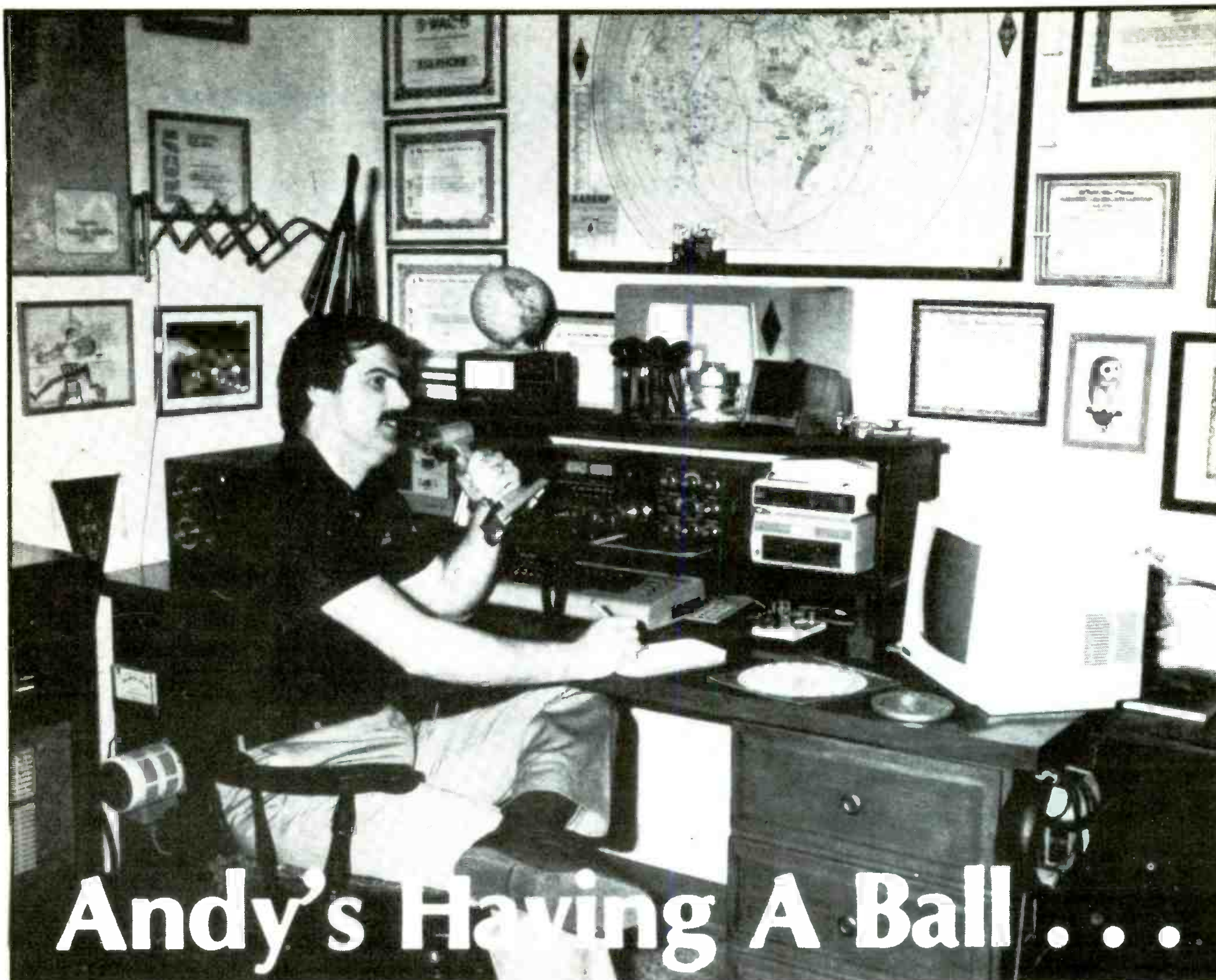

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EDITORIAL

A New Glamour Technology

Superconductivity, or zero-resistance electrical conduction, is a fascinating concept that's akin to traveling close to the speed of light. The theory was developed three decades ago by a trio of scientists, one of whom, John Bardeen, was a member of an earlier trio that developed the transistor. Nothing much happened in the "super" field for more than 20 years because the very costly need for cooling a conductor to a critical ultra-low temperature wasn't surmounted.

Only a few years ago, however, two IBM scientists (Bednorz and Muller) in a Switzerland research lab measured a much higher superconductivity transition temperature than previously attainable by using a ceramic compound, and published their findings in a West German physics journal in late 1986 without registering much interest. But it did pique the curiosity of a few enterprising scientists who investigated the claimed phenomenon.

Two of them—Ching-Wu Chu (University of Houston) and Mau-Kuen Wu (University of Alabama)—used the discovery of ceramic conductors' attributes to rock the scientific world a year later by achieving superconductivity at an appreciably higher transition temperature (95 K vs. the IBM scientists' "high" 35 K) with a yttrium barium copper oxide conductor. With a transition temperature now much above the boiling point of nitrogen, it meant that cheap liquid nitrogen could be used as the needed coolant to achieve zero electrical resistance instead of very costly liquid helium!

Not many months later, the IBM scientists who turned to ceramic conductors shared a Nobel Prize award in Physics.

Now the prospect of superconductivity at *room* temperature does not seem to be as faraway a dream as it once was. As a result, visions of its applications—magnetically levitated trains moving at breathtakingly high speeds, very cheap electrical power transmission, and other magical possibilities—have become rampant. However, the consenus seems to be that glamorous electric power applications will take a back seat to electronic devices, which do not face a host of problems that bulky material causes. So the high speed one hopes that superconductive applications will bring to us will likely first be seen in the computer and communications fields.

Forrest Mims' columns (April and May 1988 "Electronics Notebook") on superconductivity underscored the interest in this field that you readers have. We've been deluged by letters (see "Letters" below), in fact, that pointed out an erroneous conclusion he drew that's related to radioactivity while working with liquid nitrogen used in his reported superconductivity experiments. He promises to write more about radioactivity and its detection in the near future.

We were pleased to learn how sharp in eyes and minds *Modern Electronics* readers are, judging by the Letters' comments. It's no wonder, though, when one considers that about 23% of you hold Ph.D.'s or have done post-graduate work. Thanks for your time to set the facts straight.

Art Salsberg

LETTERS

Superconductor Experiment

• I thoroughly enjoy Forrest Mims' column and it is usually the first article I read. However, I would like to point out an horrendous error in his "Electronics Notebook" column, "Experimenting With Liquid Nitrogen," in the April issue. He concludes that cooling a radioactive substance to liquid-nitrogen temperature (77-degrees Kelvin) reduces its rate of radioactive decay, in essence, that cooling increases its half-life. To quote a physics textbook, "The rate at which a particular radioactive material disintergrates is a constant independent of all physical and chemical conditions." (*An*

Introduction to Atomic Physics by Henry Semat, Rinehart & Company, Inc., 1946, page 278.) This principle of constant half-life for a given isotope is the basis of all isotopic age measurements, whether it be the age of the universe or of some archeological artifact.

I believe that, while his experimental data is correct, the effect he observed is due to absorption of the radiation (shielding) by the liquid nitrogen itself, and by the container. He would notice a similar reduction in counts by filling the styrofoam cup with water or lighter-fluid at room temperature. This example emphasizes the necessity of carefully considering the experimental conditions, using proper controls and considering all possible logical explanations when interpreting experimental data!

An alternate explanation is that such a violation of basic physics would only appear in the *April* issue.

Kenneth Smouse
Ione, OR

• Please tell me it ain't so! In one brief tabletop experiment described in *Modern Electronics*, you overturned the entire sciences of geology, cosmology, and biology. All these fields have depended on the consistency of radioactive decay for dating purposes. Every test prior to yours, using the most extreme temperatures and pressures, have shown that radioactive decay is constant within 4 percent. Did Mims *really* detect a huge drop in radioactivity when he cooled a sample in liquid nitrogen?

From the procedure's description, it appears he did not account for the shielding effect of the liquid nitrogen covering the sample during the mid-part of the test. If he did account for it, maybe something else threw off the results. Possibly the fibers of the lamp mantle shrunk up around the thorium when it cooled, providing a shield.

Was there experimental error or have you won yourself a Nobel Prize?

Yale Simkin
DeKalb, IL

• Forrest Mims's observation that radioactive materials become less active at lowered temperatures (*Modern Electronics*, April 1988) is something new indeed. I believe it is generally accepted that radioactivity is governed by processes within the atom's nucleus and is not affected by such factors as temperature, chemical combinations, or the like.

Then the question becomes: What *did* Mr. Mims observe? That may not be so easy to answer, but I can hazard a guess or two. Thorium is primarily an alpha-particle emitter, and alphas don't penetrate matter very well at all. Just filling the plastic cup with liquid nitrogen should have blocked most of the radiation. Indeed, the really puzzling thing is that he got as high a reading as he did with the liquid in the way.

Several possibilities: There may have been other radioactive materials present as impurities. If any of these were beta or gamma emitters, some radiation might have penetrated the liquid and the cup. Another (and not exclusive) possibility is that not quite all of the thorium mantle was submerged. A third is simply that the count rates were all so low that "statistical noise" produced deceptive results.

May I suggest that Mr. Mims try the same experiment, using (say) water at

(Continued on page 63)

SUING & BANNING. Apple Computer filed a lawsuit against Microsoft Inc. and Hewlett-Packard Corp. for infringement of its copyrighted "audio visual computer display" as used on the Macintosh personal computer screen. This relates to the Mac's use of a mouse cursor control device and its distinctive audio visual display which Apple claims is substantially similar as used for Microsoft's Windows 2.03 and H-P's New Wave software.

Germany's Federal Office for Examination of Harmful Publications (BPS), which is a statute intended to protect youth from harmful publications, has banned or recommended banning some of MicroProse's entertainment software products, such as the U.S. company's "Silent Service," "Gunship" and "Airborne Ranger." The company is appealing the banning or recommendations. It's too late to do the same for the banned popular "F-15 Strike Eagle" because the appeal period expired before MicroProse was even aware that such action was taken by BPS. Once a product has been banned for sale to youth, it cannot be advertised in any German medium and may be sold only in retail establishments with an adults-only entrance....Intel and NEC are still battling it out in court on whether or not NEC's V-Series microprocessors consist of copied Intel 8086 code. The case began in 1984.

NEW ACQUISITIONS. Tandy Corp. announces acquisition agreement with GRiD Systems, which will become a wholly-owned subsidiary. Tandy's chairman & chief executive, John Roach, said that the new division will enhance Tandy's product development capability in laptop computers and open up new opportunities. GRiD will also continue to market under its current name....Uniden acquires Regency's Consumer Products Division, which consists of scanners and marine radios, as well as patents and trademarks.

USED MICROCOMPUTERS. Old, unused personal computers don't necessarily languish in storage rooms or closets. There is a $1.2-billion market (1987) for them, according to the National Association of Computer Dealers. This figure is expected to rise to $1.8-billion in 1988. The major selling force is the consumers, who sells to friends, co-workers and through classified ads, while companies that upgrade systems sell out-dated computers to employees before approaching the public.

The used value index (UVI) of computers, which is derived by the average selling price of Apple, IBM and Compaq computers and comparing this to the average used selling price of the same equipment, is said to be up again in the first quarter of 1988, reaching the record high of 67.86%. Compaq retained an average of 73.21% of their actual selling price (up 3.87% over last year); Apple computers had 67.23% (up 4.1%); IBM, 63.14% (down 0.29%).

This information is listed in the Computer Blue Book, which covers about 12,500 hardware and software items. The guide, published by Sybex Inc., is available at many book stores ($9.95) and a twice-a-year subscription from NACD (14925-A Memorial Drive,Houston, TX 77079) for $15.95.

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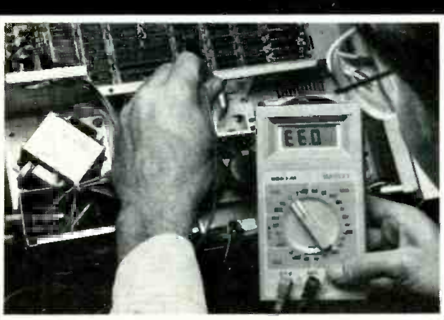
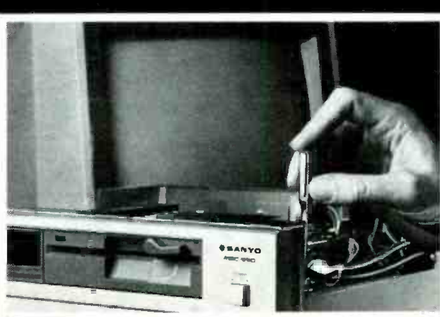


The power supply is assembled in the main unit of the computer. You check out keyboard connections and circuits with the digital multimeter included for training and field use.



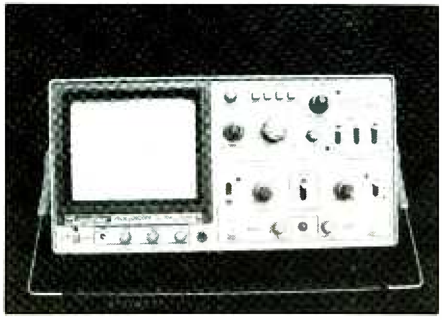
Next, you install the 5¼" floppy disk drive, learning disk drive operation and adjustment. Later, you increase your data storage capacity dramatically by installing a 20 meg hard disk drive.

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

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.

Oscilloscope Line

Two oscilloscope models are being marketed in the U.S. by Korean industrial giant Goldstar Precision Co., Ltd. (Cerritos, CA). Both provide a 6″ rectangular CRT with internal graticule, scale illumination and camera bezel. Other features com-



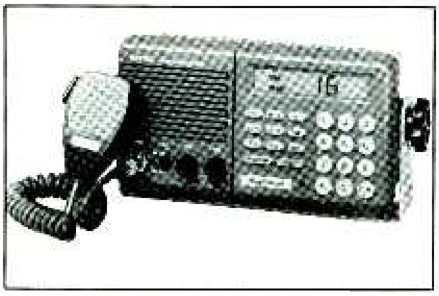
mon to both instruments include: stable, low-drift design; a TV sync separator circuit; an X-Y mode; 1-mV/division sensitivity; ±3-percent accuracy; calibration indicators; and gold contacts.

The single-channel scopes are housed in low-silhouette cabinets equipped with carrying handles that serve as tilt stands on the testbench. The 20-MHz Model OS-7020 is priced at $445, the 40-MHz Model OS-7040 at $775.

CIRCLE 10 ON FREE INFORMATION CARD

VHF Radiotelephone

Raytheon's top-of-the-line Model RAY-90 vhf radiotelephone and full-function remote/intercom units permit a user to communicate with other vhf units from up to five locations on a boat. The compact remotes provide every function of the master unit, as well as being able to communicate with it. The RAY-90 offers four scanning modes and is said to provide exceptional channel discrimination on all U.S. and International (ITU) channels, including weather channels. It has 10 private channels



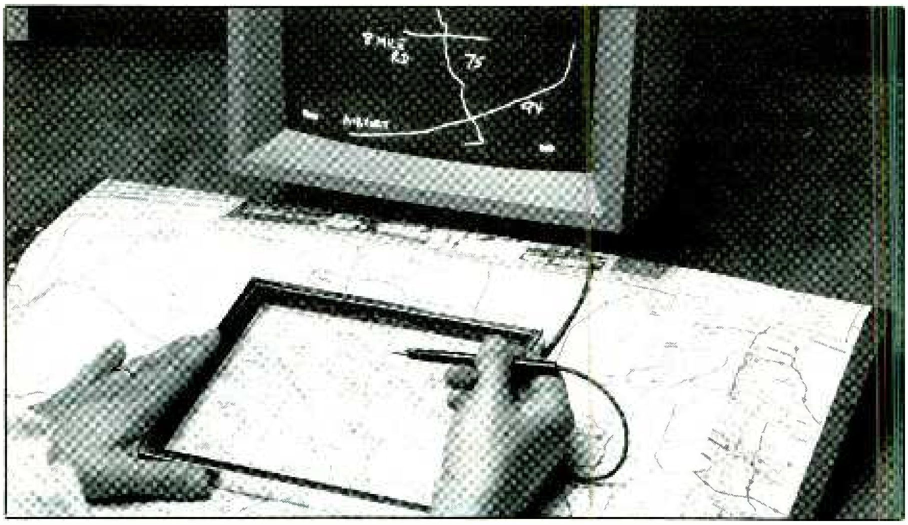
for use where permitted or for future channels that the FCC may allocate.

A user can call up as many or as few channels as he wishes, using all-scan, programmable select-scan of an unlimited number of channels, or memory-scan of up to 10 channels. Programmable weather alert keeps the user informed of weather hazards while it select-scans or dual-watches other channels. An NOAA alert automatically interrupts scanning with emergency weather broadcasts. Quick-Select Channel 16, Dual Watch of Emergency 16 and any other channel designated as priority are available as well.

Features include: 25-watt open-water/1-watt in-harbor transmit power; automatic 1-watt operation on certain harbor channels; LCD display of active channel and all operating modes; automatic photocell control of fiber-optic backlighting for controls and display; transmission verification monitor light; noise-canceling microphone; extra-loud audio; and quick-release tabletop/bulkhead/overhead bracket. A telephone-type handset is optionally available. The radio measures 10″W × 5″H × 3″D. $995.

Up to four optional Remote/Intercom units can be used with the RAY-90. Each has an LCD channel indicator and keypad controls and measures 8.7″H × 4″D × 2.2″W. $395 per unit.

CIRCLE 2 ON FREE INFORMATION CARD



Transparent Graphic Pad

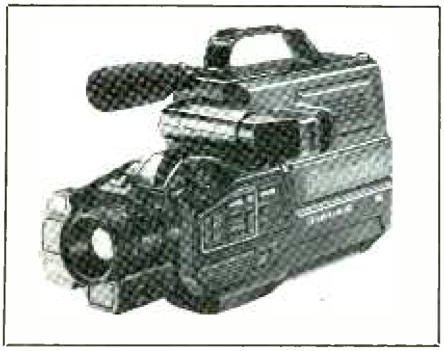
Ovonic Imaging Systems, Inc. (Troy, MI) has a transparent digitizing pad, named E-Z Image, for entering hand-written or "touch" information into digital systems of all kinds. The free-form input device is designed for use with PCs and other screen-based systems. The pad consists of a glass plate coated with a transparent resistive film over its 8.5″ × 7″ active area.

When a user writes or draws on the pad's surface with a conductive stylus, the resulting image appears on a display screen in bit-mapped form. The pad can be laid over drawings, grids, maps, light boxes, etc., to enable the user to create or trace images, enter comments and instructions, or even fill out forms electronically. It can also function as a direct-entry notepad or be used in a signature-verification system.

CIRCLE 7 ON FREE INFORMATION CARD

Digital S-VHS Camcorder

The digital Model PV-S350 S-VHS camcorder from Panasonic provides a list of technologically advanced digital special effects. With this camcorder, the user can create still-picture freeze frames. Still frames can be combined with live-action effects as well. Still pictures can be phased into a live shot by three digital effects: wipe, box wipe and overlap.

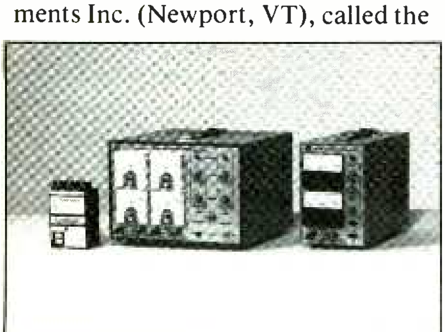


Among the camcorder's standard features are: a high light sensitivity that approaches 1 lux; a digital memory circuit that works in conjunction with a CCD solid-state image pickup device to allow recording under very low light conditions; a high-speed shutter with choice of $1/1000$, $1/500$ or $1/250$ second capability; a flying erase head; an 8:1 power zoom lens; and instant playback. The camcorder can operate in the SP and SLP modes, giving it a maximum recording time of up to 6 hours with a T120 tape. $2,400.

CIRCLE 6 ON FREE INFORMATION CARD

DC Power Supplies

A new line of benchtop regulated dc power supplies from Brunelle Instruments Inc. (Newport, VT), called the

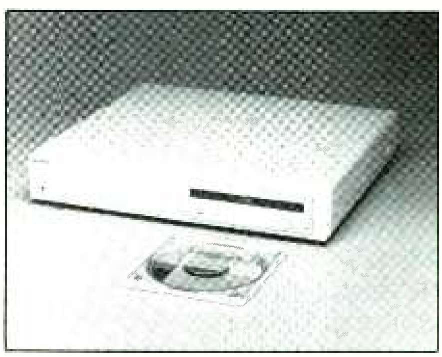


Commander Series, offer short-circuit protection, automatic constant current and constant-voltage output with very low ripple. Sixteen models, including four dual tracking models, make up the line, which offers six voltage ranges from 0 to 18 volts dc to 0 to 150 volts dc and current-delivery capabilities ranging from 2 amperes to 20 amperes. All supplies are claimed to feature excellent voltage or current regulation and are housed inside rugged metal enclosures with carrying handles.

CIRCLE 5 ON FREE INFORMATION CARD

CD-ROM Drive

On-line memory of up to 540-megabyte capacity is featured with Sony's Model CDU-7101 stand-alone CD-ROM drive. Designed to be used with IBM PC/XT/AT and compatible computers, the drive comes with a PC interface (Sony bus), connecting cable, disc caddy and MS-DOS



CD-ROM Extension. The system can access CD-ROM discs as well as conventional audio compact discs. Data transfer is rated at 150K bits per second sustained, burst transfer at 600K bits/second up to one block in length (2,048 bytes in Mode 1, 2,936 bytes in Mode 2). Access time is said to average 0.5 second.

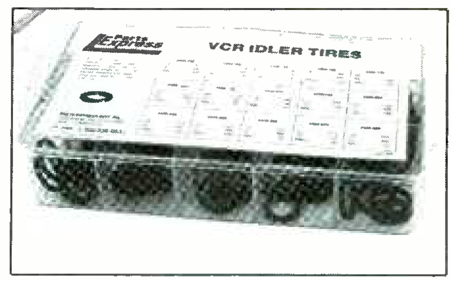
The drive's optical pickup automatically locks when the caddy is unloaded, and its auto-loading mechanism is claimed to assure easy and foolproof disc insertion. The caddy provides field-loadable media protection. Caddy ejection can be accomplished manually via a button on the front panel or automatically via the host computer. Emergency ejection is via the access hole.

Built in is Sony's L-EC (Layered Error Correction) circuit, which does not require attention from the host computer's CPU. Up to four CD-ROM drives can be daisy-chained via the Sony bus, with all units providing output capability of CD-ROM audio tracks. The system unit measures 14"W × 12⅝"D × 2⅜"H.

CIRCLE 4 ON FREE INFORMATION CARD

VCR Idler Tire Kit

Parts Express (Dayton, OH) has a VCR Idler Tire Kit that includes, free



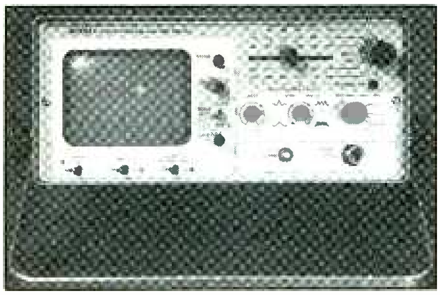
of charge, a cross-reference chart that lists more than 80 manufacturer assembly part numbers and more than 200 models. The kit contains 10 each of 15 different sizes of tires housed in a clear molded-plastic flip-top box.

CIRCLE 3 ON FREE INFORMATION CARD

Portable Spectrum Analyzer

A new portable spectrum analyzer for satellite communications, the Model PSA-35A, is available from Avcom (Richmond, VA). The analyzer has a standard center frequency band that is calibrated from 1,250 to 1,750 MHz to cover European BDC frequencies and a switch-selectable 2-dB/division or 10-dB/division sensitivity to permit peaking of antennas and other functions required on a satellite receiving system. Frequency coverage of the analyzer is 10 to 1,750 MHz and 3.7 to 4.2 GHz for checking signal strength, in-band attenuation, terrestrial interference, filter alignment, faulty connectors, LNAs, feedhorn isolation and cable loss at all commonly used satellite communication frequencies, including 12-GHz for downconverters.

Other features include a built-in dc block with +18 volts for powering LNAs and BDCs, calibrated signal amplitude display and a rechargeable internal battery with built-in charger. Input connectors are BNC on low band and type F on high band. Both input connectors are dc blocked and have provisions for insertion of +18 volts via a front-panel switch. The CRT display contains 10 horizontal and 7 vertical graticule divisions. Reference levels of 0, −20 and −40 dBm/+49, +29 and +9 dBmV are provided, and dynamic range is rated at 60 dB. Amplitude



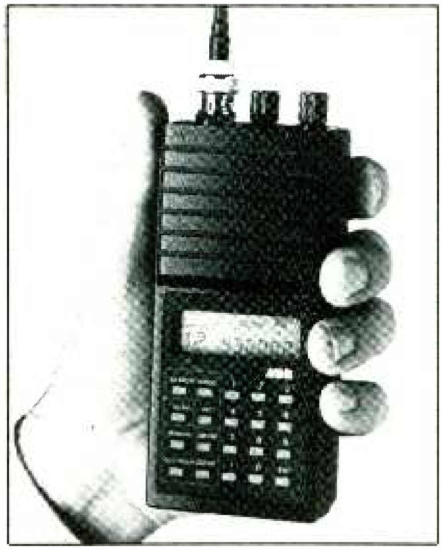
accuracy is rated at ±2 dB, resolution bandwidth at 300 kHz.

The spectrum analyzer is housed inside a low-silhouette metal case that comes with a carrying handle/tilt stand. It measures 14.5″ × 13.5″ × 5.5″ and weighs 17 pounds. $1,965.

CIRCLE 51 ON FREE INFORMATION CARD

800-MHz Scanning Receiver

A new AOR, Ltd. personal hand-held monitor receiver with 800-MHz tuning and channel-scanning capabilities is available from Ace Communications (Indianapolis, IN). The very compact receiver provides frequency coverage in the 30-to-50-MHz, 118-to-136-MHz, 140-to-174-MHz, 436-to-512-MHz and 830-to-950-MHz bands with no removed or restricted frequencies. A 20-key pad on the front panel allows the user to operate the receiver by accessing an on-board microprocessor. All operating and mnemonic functions appear in a side-lighted liquid-crystal display (LCD) window.

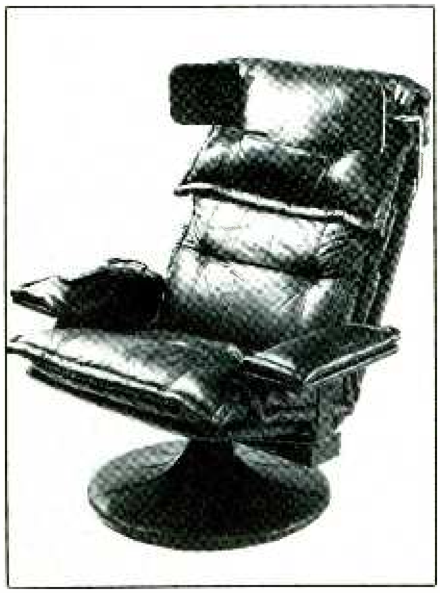


Measuring just 5 inches high, 2.25 inches wide and 1.69 inches deep and weighing just 19 ounces, the receiver is small and light enough to fit into a coat pocket. It comes with antenna, rechargeable battery pack, battery charger and carrying loop. $299.

CIRCLE 52 ON FREE INFORMATION CARD

Surround-Sound Chair

Pioneer's new Model BSS-F1 Bodysonic surround-sound chair has stereo speakers built into its headrest and a driver mounted in its seat for deep-bass reproduction. It also has a remotely controlled stereo power amplifier for the drivers. The chair can be used with any audio/video equipment with line-level outputs. When used with an existing stereo system, the chair's speakers serve as the rear sound sources in the surround-sound listening area. With other audio or video sources (even personal stereos), its speakers serve as the primary sound sources.



The 3.5-inch speakers located in the headrest can be moved vertically and angled horizontally as desired to suit the listener's taste. The bass driver employs a new damped driver design that is claimed to expand the frequency range and reproduce realistic bass effect.

Two phono input jacks are provided on the amplifier for connection to the line-level audio outputs from a stereo system or laser-disc player, videocassette recorder, etc. There is also an auxiliary output jack to connect to additional Bodysonic chairs. The umbilical-connected remote controller has a power switch, separate volume controls for the main stereo speakers and bass driver, surround-sound on/off switch, a "soft" switch (for softening the sound by filtering out high frequencies), and five indicator lights that indicate the mode selected.

Designed for comfortable sitting, the chair features black leather upholstery, padded arm rests and swivel function. It measures 40 inches high and 38 inches wide and deep. $2,000.

CIRCLE 53 ON FREE INFORMATION CARD

Self-Inking Printer Ribbons

"Sta-Blk" is the name of a new series of automatic reinking printer-ribbon cartridges from Chronos Computers (San Diego, CA). The Imagewriter/Prowriter model fits Apple Imagewriter I and II and C.Ithoh Prowriter printers. Another model, the FX-100, fits Epson wide-carriage FX/MX/RX 100/185/286e printers. (A previously announced model fits Epson FX/MX/RX 70/80/86e printers.) These automatic reinking ribbon cartridges are designed to extend the life of the typical ribbon by having the user periodically place a few drops of ink in a small reservoir built

into the cartridge housing. After that, the cartridge automatically re-inks the ribbon as it passes through it. According to information provided by Chronos, a single Sta-Blk cartridge will outlast about 80 regular ribbons. $39.95 and $49.95, depending on cartridge size (includes eye-dropper bottle of ink); $9.95 for extra ink supply.

CIRCLE 55 ON FREE INFORMATION CARD

Voltage Calibrator

Sibex Inc.'s (Clearwater, FL) Model VR-1 battery-powered, hand-held precision voltage source provides selectable output that ranges from 10

mV to 10 volts, with selections in a 1-2-5 sequence via a 10-position rotary switch. A separate toggle switch allows a user to select either positive or negative output polarity, while a second toggle switch turns on and off power to the instrument.

The calibrator, housed in a molded-plastic enclosure, is contoured for convenient gripping. Power is supplied by a standard 9-volt battery, and visible low-battery indicator is built in. $89.95.

CIRCLE 57 ON FREE INFORMATION CARD

Speeding Up Optical Isolators

Simple, inexpensive ways to get 3-MHz and greater speed from low-cost optoisolators like the 4N35

By William Melhorn

Electrical isolation between a circuit and the outside world has become a low-cost practical reality with the ready availability of optical isolators like the 4N35 and others. These low-cost optoisolators are excellent devices to use for isolation, as long as the switching rate is limited to a maximum of 22 kHz or so. For faster speeds, in the kilohertz or even low-megahertz range, you have had to resort to high-speed devices that are costly or/and difficult to find from traditional electronic component outlets.

In this article, we will explore simple, low-cost techniques for improving the speed of slow garden-variety optoisolators. Though our discussion will focus specifically on the 4N35 device, most of this discussion applies equally well to other low-speed optical isolators.

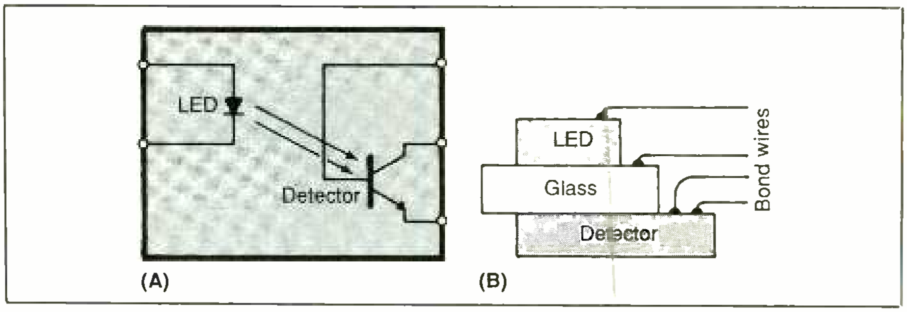


Fig. 1. Schematic (A) and physical construction (B) details of typical optoisolator.

Background

An optoisolator can take many physical forms. The low-cost variety commonly available to experimenters and hobbyists, however, usually comes in a six-pin dual in-line package (commonly known as a "DIP") similar to that used for most integrated circuits. Contained within this package are a light-emitting diode, or LED, and a photodetector, the latter usually being a phototransistor. This internal arrangement of a typical optoisolator is shown schematically in Fig. 1(A).

As illustrated in Fig. 1(B), the LED and photodetector are separated inside the package by a thin sheet of optical glass. The glass serves as an efficient medium for coupling the light energy from the LED to the sensitive base of the phototransistor. It also establishes electrical isolation between the two elements. Commonly available low-cost DIP-type optoisolators, such as the 4N35, have an isolation capability that is usually rated at 2,500 volts.

When current flows through the optoisolator's LED diode junction in the forward direction, the LED generates photon energy, or light, as in Fig. 2(A), by a process called "junction luminescence." Excess electrons in the n-type junction material jump the gap of the diode's pn junction and combine with excess holes in the p-type material, as in Fig. 2(B). When these "carriers" re-

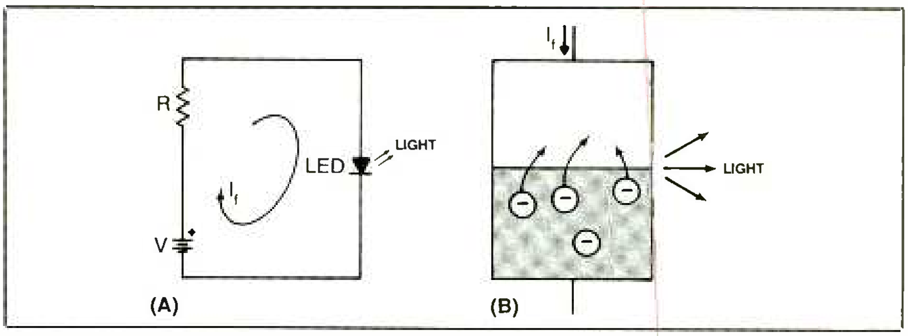


Fig. 2. Forward current flow through a LED results in light-energy output (A). Excess electrons in n-type material jump the gap of a LED's pn junction and combine with excess holes in p-type material to produce light (B).

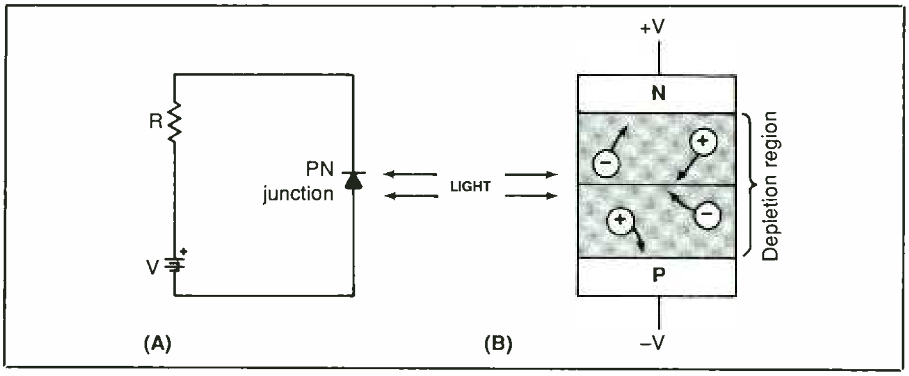


Fig. 3. Reverse-biased phototransistor junction (A) when struck with light from LED generates electron/hole pairs (B) to cause a photocurrent to flow through the phototransistor.

combine, photon energy is released. In the typical optoisolator, this energy is at near-infrared wavelength.

The phototransistor inside the typical optoisolator is sensitive to the infrared energy generated by the on-board LED. When photons strike the reverse-biased collector-to-base junction of the phototransistor, as in Fig. 3(A), electron/hole pairs are generated. As illustrated in Fig. 3(B), these electrons and holes are swept away by the electric field generated by the reverse-bias voltage. The result is a "photocurrent" flow that is proportional to the amount of IR energy striking the junction. The base current in the transistor created by this photocurrent is amplified by the transistor's current gain.

It is at this point in the process that the problem with low-cost general-purpose optoisolators lies. Increasing the phototransistor's junction also increases the sensitivity of the detector simply by making it possible for the detector to collect more photons. However, the larger junction also increases the transistor's inherent capacitance and storage time, which greatly slows switching speed.

A good way to think of this speed-robbing capacitance effect is by reviewing the charging and discharging formulas for the capacitor in a simple RC circuit. The formula for charging a capacitor is:

$$V = V_{max}(1 - e^{-t/RC}),$$

where V is the transistor's collector voltage; V_{max} is supply voltage; R is a resistance whose value is set by the amount of light striking the transistor's collector-base junction; and C is the reverse-biased phototransistor's junction capacitance. According to the data sheet for the 4N35 optoisolator, collector-to-base junction capacitance is about 100 picofarads.

The formula for discharging a capacitor is:

$$V = V_{max} \times e^{-t/RC}$$

In this formula, the terms are determined by the same factors that apply in the charging formula, except that R is now set by the phototransistor's base input resistance. Base input resistance for the Fig. 4(B) circuit is the value of the collector resistor multiplied by the transistor's current gain (typically about 100).

For this discussion, the "on" switching time is defined as the difference in time between the point at which the V_{in} input signal switches high and that at which the V_{out} output reaches 90 percent of the supply voltage (see Fig. 5).

The "off" switching time is defined as the time between the points at which the V_{in} input signal goes low and the V_{out} output reaches 10 percent of the supply voltage.

Solving the Problem

To demonstrate how a typical low-cost optoisolator performs, let us conduct an experiment using the commonly available 4N35 device. Assuming the circuit for this experiment is as shown in Fig. 6(A), a 10-kHz signal is applied at V_{in} and

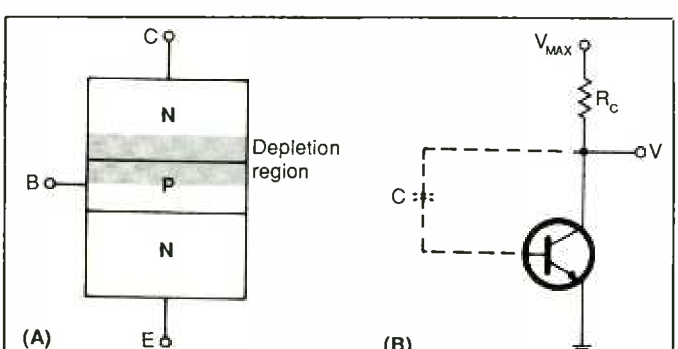


Fig. 4. Physical (A) and schematic (B) capacitance speed-robbing effects of increased junction area.

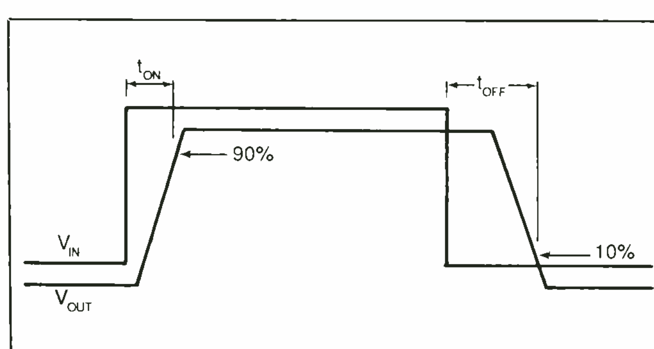


Fig. 5. Graphic illustration of turn-on (t_{on}) and turn-off (t_{off}) times of a typical low-cost optoisolator.

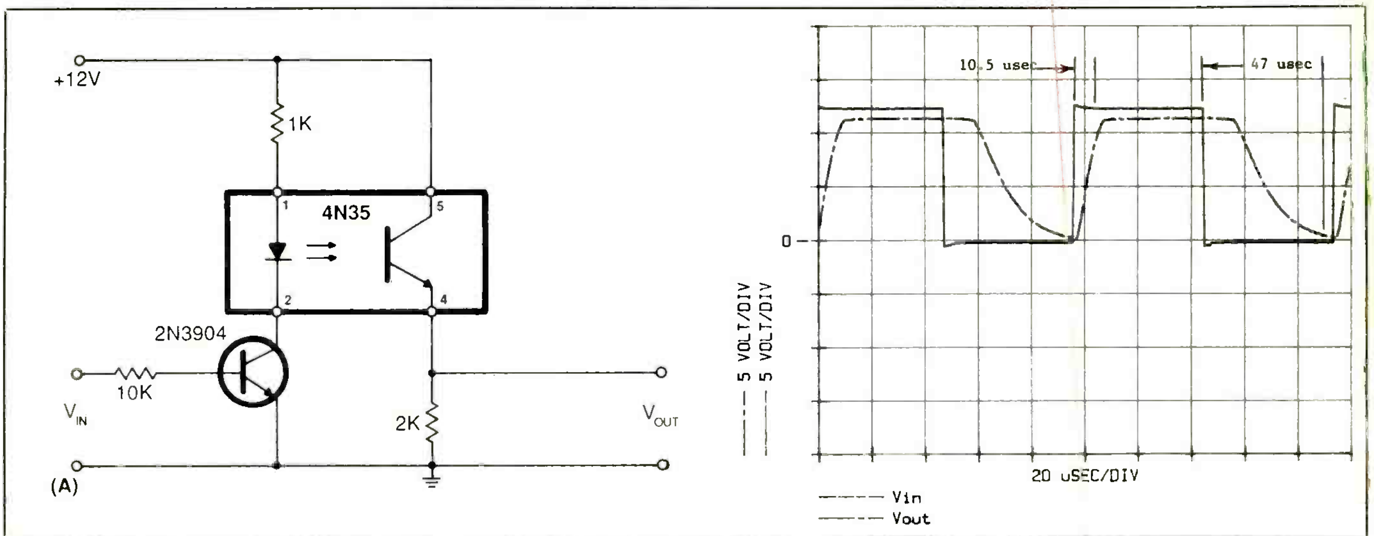


Fig. 6. Schematic of an unassisted 4N35 optoisolator circuit (A) and its switching-speed response (B).

the input signal to and output signal from the optoisolator are monitored on the screen of an oscilloscope.

When V_{in} goes to + 12 volts, the 2N3904 transistor conducts and causes current to flow through the LED inside the 4N35 optoisolator. With current flowing, the internal LED emits IR energy that is, in turn, coupled to and turns on the 4N35's phototransistor. When the phototransistor turns on, its emitter is pulled up to the collector voltage and produces a high output condition at V_{out}.

When V_{in} goes to 0 volt, the 2N3904 transistor turns off and, in turn, shuts off the current through the 4N35's internal LED. With the LED now off, no IR energy is available to keep the internal phototransistor conducting. With this cutoff condition at the output of the optoisolator, a low output condition exists at V_{out}.

For the circuit shown in Fig. 6(A), the length of time needed for turn-on was 10.5 microseconds, and the time for turn-off was 47 microseconds, as illustrated in Fig. 6(B). Notice here how the output waveform has the characteristic shape of a charging and discharging capacitor in an RC circuit.

Trying to improve switching speed, you can add an output transistor to the circuit, as shown in Fig. 7(A). With this stage added, IR energy from the 4N35's internal LED strikes

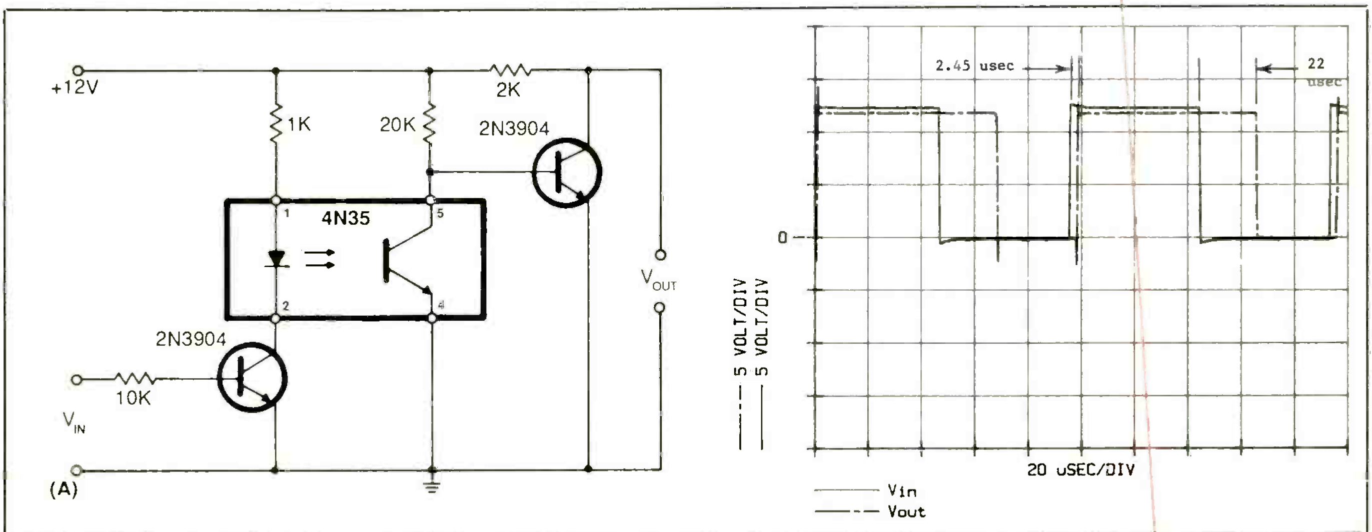


Fig. 7. Adding an output transistor to a 4N35 (A) increases switching-speed time over unassisted circuit (B).

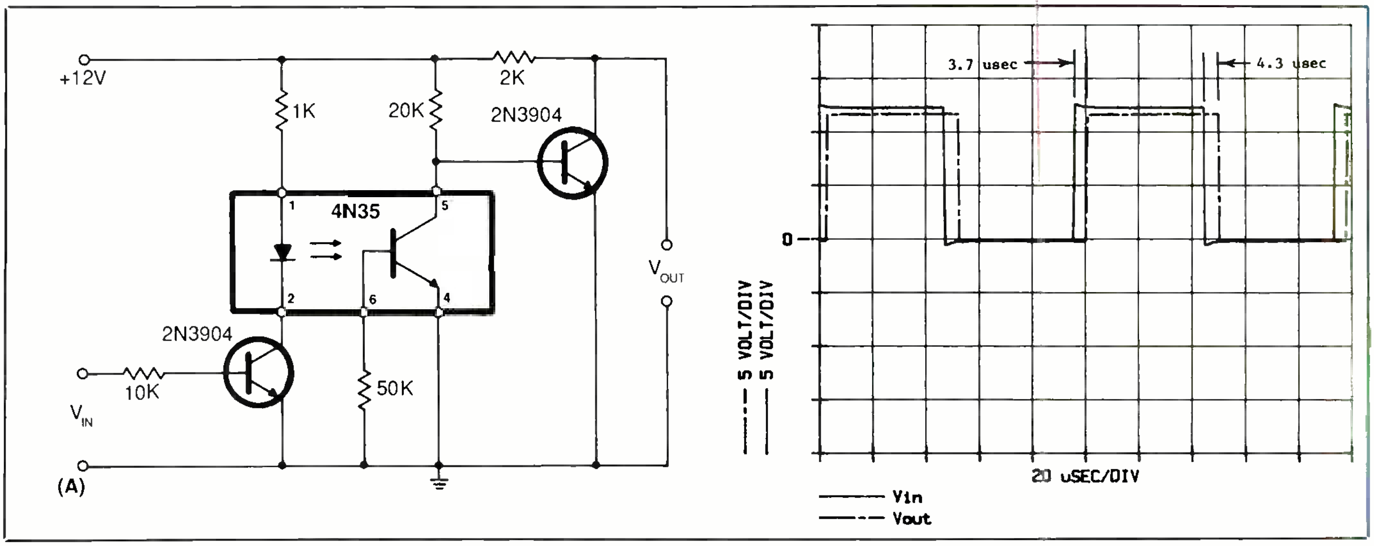


Fig. 8. A 50k-ohm resistor in base-emitter circuit (A) improves turn-on and turn-off times of 4N35 (B).

the base of the internal phototransistor, turning it on and shorting the base to the emitter of the 2N3904 output transistor. When this occurs, the output transistor turns off and produces a high condition at V_{out}.

When IR energy ceases to be generated by the LED, the phototransistor turns off. Now the base of the output transistor is pulled up by the 20,000-ohm collector load resistor and the output transistor turns on, causing a low output condition to appear at V_{out}.

As illustrated in Fig. 7(B), this extra output stage shortens switching time for turn-on down to 2.45 microseconds, a big difference from the 10.5-microsecond time of the unassisted Fig. 6(A) circuit. It also shortens the turn-off time down to 22 microseconds, compared to the 47-micro-second time for the unassisted circuit.

The reason for the improvement in turn-on response is that the load for the phototransistor inside the optoisolator is now 20,000 ohms, instead of the original 2,000 ohms. By reducing the amount of photon energy necessary to support the load current, more photocurrent can be used to charge the collector-base capacitor and get the phototransistor to turn on.

Turn-off time has been reduced because the phototransistor must now turn off to only 0.7 volt (instead of 0.1 volt) to send the output transistor into conduction and produce a low condition at V_{out}. Turn-off time is hindered somewhat, however, because the phototransistor's load has been reduced by the 20,000-ohm resistor. With this high-impedance load, the phototransistor's storage time is increased because its base region is flooded with excess photons and is free of electrons, a condition referred to as "hard saturation." The phototransistor will not even start to turn off until these extra electrons are used up.

The circuit in Fig. 8(A) is the same as that in Fig. 7(A), except that a 50,000-ohm resistor has now been added between the base and emitter of the phototransistor inside the 4N35. This resistor provides a path for the collector-base capacitor of the phototransistor to discharge and provides a dump for the excess electrons that caused the hard-saturation condition in the Fig. 8(A) circuit.

Addition of the 50,000-ohm resistor changes switching response time to 3.7 microseconds for turn-on and 4.3 microseconds for turn-off, as illustrated in Fig. 8(B). Turn-on time has now been increased by 1.25 microseconds over that for the Fig. 7(A) circuit because the sensitivity of the phototransistor has been spoiled somewhat by this resistor. Photon-generated current must now be used to turn on the output transistor, supply the 50,000-ohm load and charge the phototransistor's collector-base capacitor. Turn-off time has been improved by 17.7 microseconds, however. This improvement is well worth the slight loss in turn-on speed that was the penalty of adding the 50,000-ohm resistor.

In Fig. 9(A), a circuit has been added to the LED side of the 4N35 optoisolator to regain the lost phototransistor sensitivity during the turn-on period. This sensitivity is regained by "blasting" a current that is ten times the steady-state current into the internal LED for a sufficient period of time to get the phototransistor turned on.

The amount of time the current blast is present is set by the 0.01-mi-

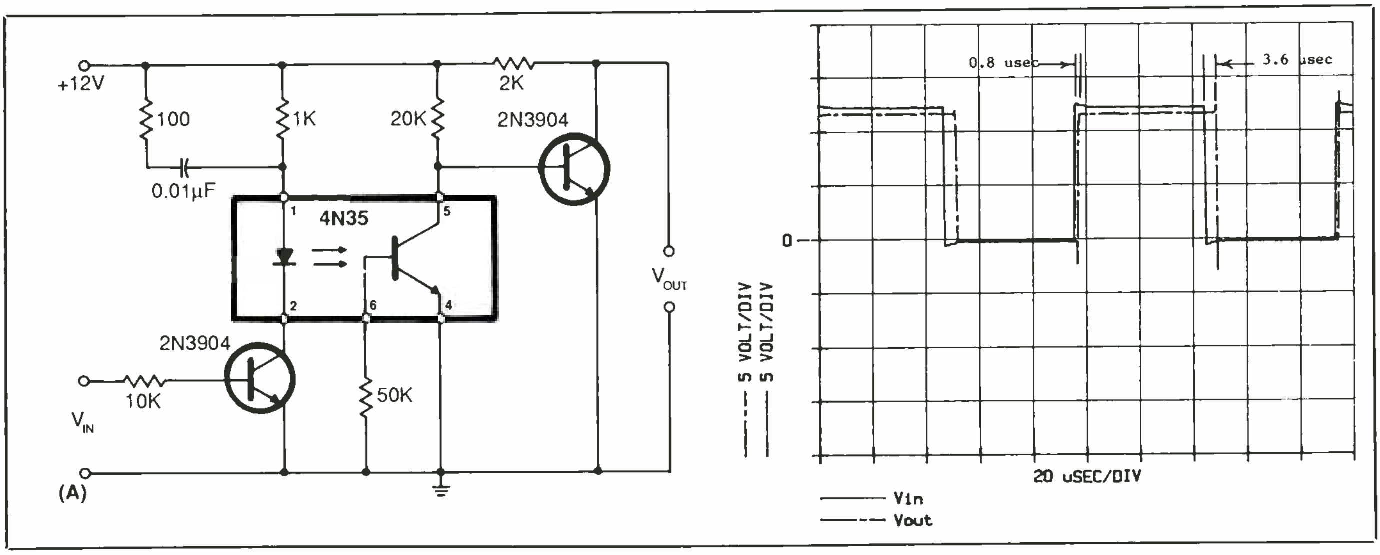


Fig. 9. Adding 100-ohm resistor and 0.01-microfarad capacitor to optoisolator's LED circuit (A) restores phototransistor's sensitivity that was lost with previous fix, as illustrated by the response curves in (B).

crofarad capacitor and 100-ohm resistor. With these values, blast time is 0.01 microfarad × 100 ohms = 1 microsecond. Care must be exercised to avoid exceeding the surge rating of the internal LED when using current blasting.

This change helped to restore the short turn-on time of the Fig. 8(A) circuit, as illustrated in Fig. 9(B). Turn-on time has now been reduced to 0.8 microsecond, while turn-off time is unaffected by this change.

Final Configuration

In optimizing the design of a fast-switching circuit built around a low-cost optoisolator, we come to the circuit shown in Fig. 10(A). In this circuit, a 1N5818 Schottky diode is shown connected across the terminals of the base and collector of the phototransistor inside the 4N35. This diode prevents the collector-base capacitance of the phototransistor from slowing down the device by limiting its charge and discharge range. The inherent capacitor can now charge only in the range from 0.7 to 0.5 volt.

(Continued on page 90)

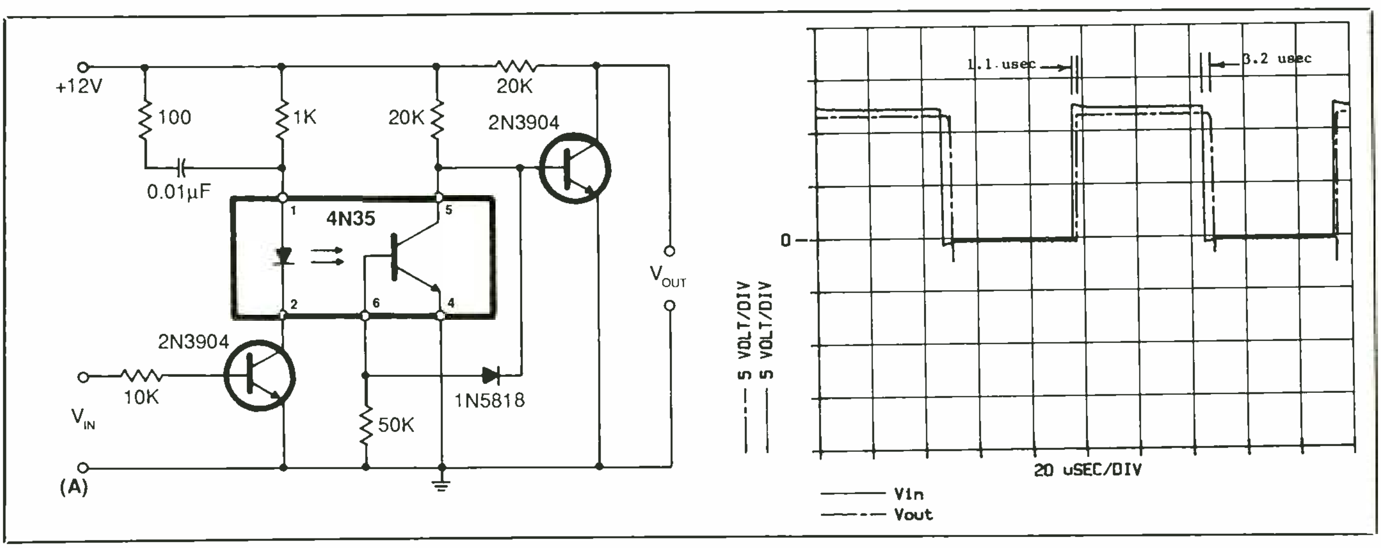
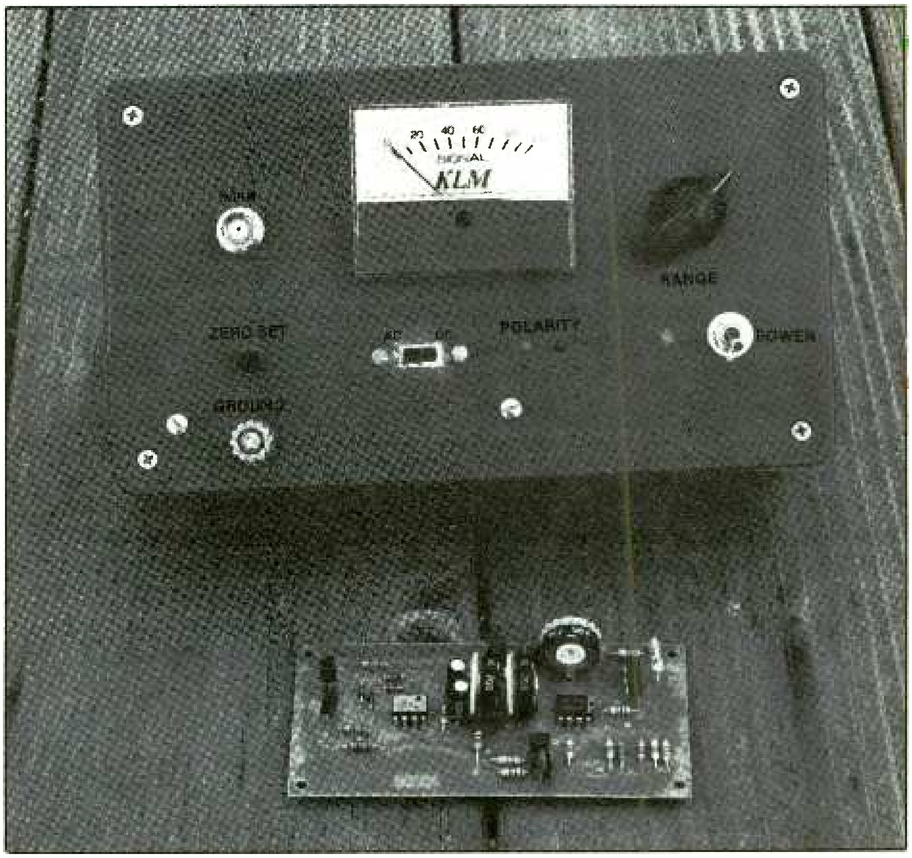


Fig. 10. Schottky diode between 4N35's collector and base (A) prevents collector-base capacitance from slowing down internal phototransistor, greatly improving turn-on and turn-off times (B) over those of unassisted circuit.

100,000-Megohm-Input Meter Indicates Static Electricity

Ultrasensitive picoammeter/electrometer expands your measurement world to one-trillionth of an ampere and a trillion ohms

By Rudolf F. Graf & William Sheets



Typical volt-ohm-milliammeters, even 10-megohm FET VOMs, are useless when it comes to measuring minute electric charges or very-high-impedance sources such as ionization gauges, Geiger-Muller tubes, MOSFET gates, electrostatic devices, and comparable devices. They always place too high a load on the circuit. To make such measurements, you're usually forced to use an expensive laboratory instrument. Now there is a $50-or-so alternative you can build to obtain relative indications, as follows.

Our inexpensive electrometer-type voltage/current meter employs no unfamiliar assembly techniques or difficult-to-find components. It uses basic printed-circuit wiring and a commonly available 1-mA analog meter movement (you may also use your DVM or an old tuning meter as a relative level indicator), among other readily available components. Yet, its sensitivity is so great that it can even detect a person's movement in a room, let alone the relative level of static electricity at your work station!

About the Circuit

Shown schematically in Fig. 1 is a basic electrometer amplifier that has an input impedance of about 100,000 megohms. MOSFET-input operational amplifier *IC1* serves as a variable-gain dc amplifier. In this circuit, *R1*, *R2* and *R3* provide dc returns for the input circuit of the op amp, while *C1* and *R4* provide static protection for the IC.

A voltage divider made up of *R5* through *R8* and tap-selectable by the rotary switch provides gains of 1, 3.3, 10 and 33 times so that a +1-volt output swing is available with 1, 0.3, 0.1 and 0.03 volts ac or dc at the op amp's input. BALANCE control *R21* is included in the circuit to allow the zero point to be set.

The inverting (−) input of the op amp is kept at a voltage that is very close to the potential of the ac or dc input signal on the op amp's noninverting (+) input. Note that a "Guard" surrounds the components and conductors between INPUT jack

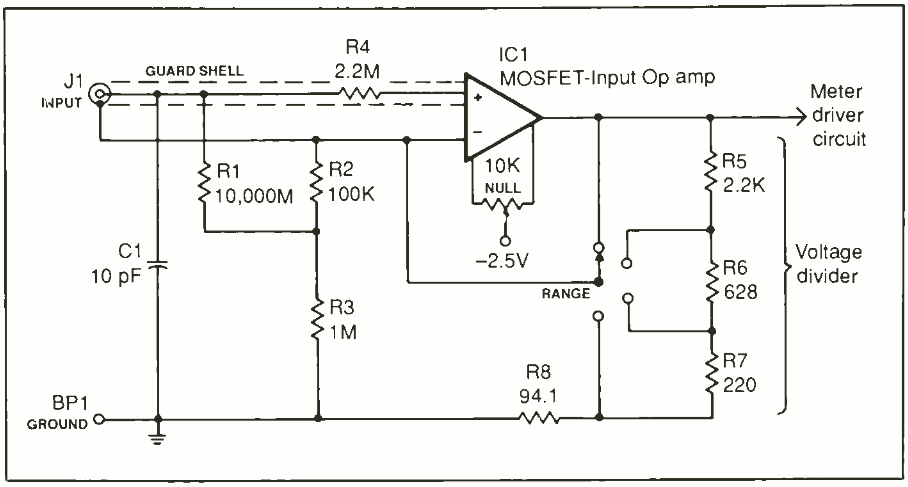


Fig. 1. The basic electrometer circuit uses a MOSFET-input operational amplifier and a special input network to minimize loading down a circuit under test.

J1 and the + input of *IC1*. This "Guard" is *not* a mesh shield; rather, it represents a shield formed by the copper conductor pattern on the printed-circuit board on which the project's circuitry is assembled. Because the potential difference between the inverting and noninverting inputs to the op amp is very small, equal to the output of the amplifier divided by the open-loop gain (typically more than 1,000 times), leakage across the surface of the pc board as a result of dirt, humidity, etc., is minimized by this "guarding" arrangement.

Guarding is a technique commonly used for measuring very high resistances and very small currents and capacitances, and where undesired or stray effects may mask quantities to be measured. It generally makes use of a voltage or current or another signal to cancel out the unwanted effects. Several examples of the guarding technique are illustrated in Fig. 2. Note that guarding is used for *shielding* purposes only; the guard must *not* be connected to circuit ground!

Returning to Fig. 1, the output of the op amp goes to a metering circuit that gives an indication of the magnitude of the parameter being measured. Potentials of up to 1 volt peak of positive or negative polarity can be measured by this circuit. Use of an ac metering scheme allows ac voltages to be measured by this circuit.

Input resistor *R1* is a special device that has a value of 100,000 megohms. It is returned to the junction between *R2* and *R3* so that about 90 percent of the input voltage applied via *J1* appears at the junction. This arrangement has the effect of raising the apparent resistance of the electrometer's input by a factor of ten times, effectively to 1,000 megohms.

Some dc stability is sacrificed by the input-network arrangement shown in Fig. 1. If the value of *R2* is reduced to 10,000 ohms, 1,000,000 megohms can be obtained, although doing this would cause troublesome drift in the operating point. Therefore, for most purposes, 100,000 megohms is sufficient. By using the most sensitive range (0.03V) in the metering circuit, input currents of 0.1 picoampere (0.1 micro-micro ampere) are detectable with acceptable stability.

Shown in Fig. 3 is the schematic diagram of the entire electrometer circuit, including its dual-polarity battery-type power supply. As in the Fig. 1 circuit, *IC1* is a MOSFET-input op amp. Input to the project is applied through *J1* across *R1* to the + input terminal at pin 3 of *IC1*. The functions of *S1* and *R5* through *R8* are exactly the same as in the previous circuit.

Note here that *R6* and *R8* each consist of two separate resistors, labeled *R6A/R6B* and *R8A/R8B*, respectively. The reason for these parallel-resistor arrangements is that single precision resistors of the values needed in these two instances do not exist and, therefore, must be obtained by appropriate parallel combinations of available values. In these two cases, the values required are 628 and 94.1 ohms for *R6* and *R8*, respectively.

After undergoing amplification by *IC1*, the signal at the pin 6 output is coupled back to the pin 2 inverting input of the op amp through RANGE switch *S1*. Independent of the setting of this switch, the amplified pin 6 output of *IC1* should always be between 0 and +1 volt. Test point *TP1* on the output line provides a means for connecting a voltmeter into the circuit to externally monitor, via a pin jack or other device, the voltage at this point during calibration.

Transistors *Q1* and *Q2* and their associated components serve as simple voltage regulators that supply a "stiff" +2.5 volts to *IC1* from the power supply made up of batteries *B1* and *B2*, without the need for zener diodes and inefficient shunt regulator circuits. The result of this powering arrangement is minimal drain on the battery supply.

Resistor *R12* couples the pin 6 output from *IC1* to the pin 4 input of *IC2*, which functions as the meter circuit's rectifier/driver circuit. Switch *S2* permits selection of either ac or dc for measurement purposes. In the DC position, *C6* and *C7* restrict the circuit's frequency response and reduce noise pickup. Diodes *D1* through *D4* make up a bridge rectifier for 0-to-1-milliampere meter movement *M1*. Capacitor *C8* shunts ac signals to bypass *M1*.

Since *D1* through *D4* are in the feedback path, nonlinearities of the

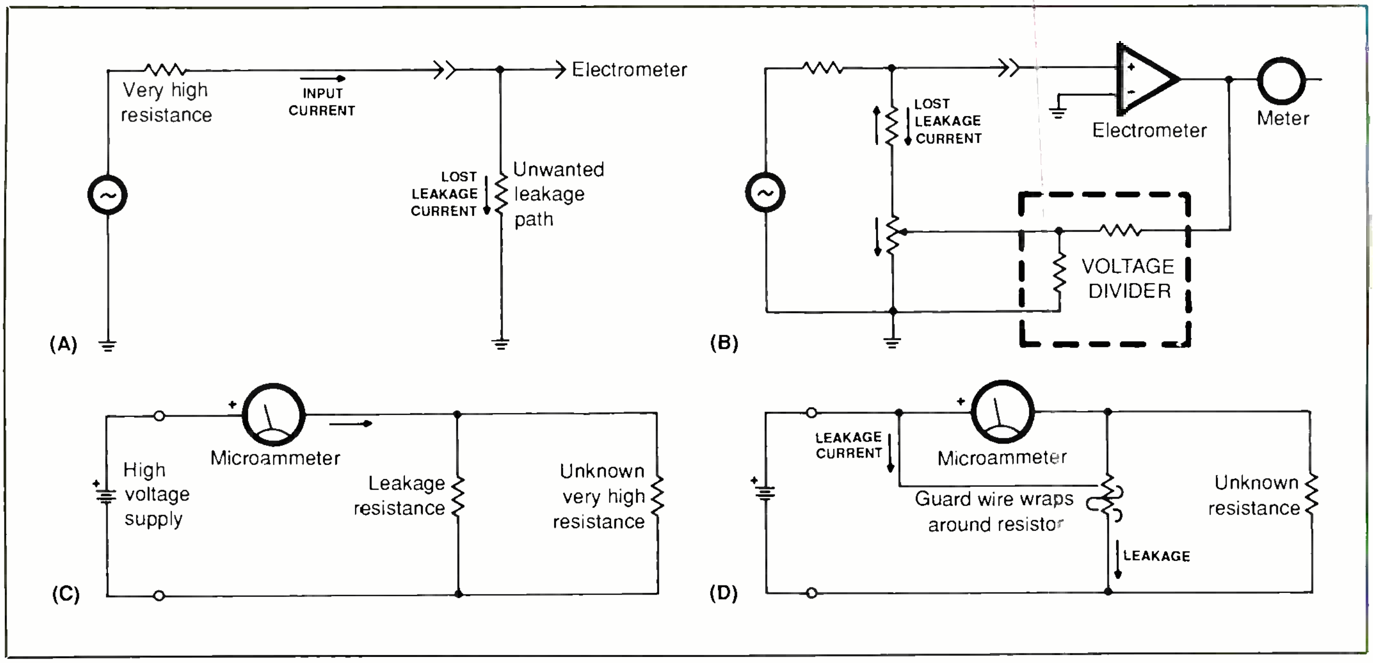


Fig. 2. Unguarded (A) and guarded (B) systems. In (B), a portion of the electrometer's output is tapped off and used to cancel the leakage path. High-resistance measurements with unguarded (C) and guarded (D) setups. Microammeter in (C) indicates sum of currents through an unknown resistance and leakage along the surface, while microammeter in (D) shows resistor current, as leakage current bypasses the meter.

diodes are compensated for and *M1* will indicate the absolute average dc value of the input signal applied to pin 3 of *IC2* on its linear scale.

AC CAL and DC CAL controls *R9* and *R10*, with *R11*, provide the means for calibrating the ac and dc functions, according to the position to which *S2* is set. These controls must be set so that 1 volt ac or dc, as indicated on the meter connected between *TP1* and circuit ground, will cause full-scale deflection on *M1*.

The output of *IC2* also drives *Q3* and *Q4*, through *R17*. If *IC1*'s output is positive, *Q3* conducts and lights red light-emitting diode *LED1*, indicating a positive (+) input voltage. Conversely, a negative input voltage will cause *Q4* to conduct and light green *LED2*. The *LED1/LED2* arrangement glows alternately red and green for ac inputs.

BALANCE control *R21* is used to null *IC1* to set *M1*'s pointer to its 0 index.

Power is applied to and disabled from the circuit via POWER switch *S3*. Drain on the battery supply is about 10 to 15 milliamperes. Yellow light-emitting diode *LED3* is an optional power-on indicator that has nothing to do with circuit operation. This LED and current-limiting resistor *R20* can be eliminated if you wish to save on component cost or/and battery drain.

Construction

Due to the stability requirements for this project's circuitry, printed-circuit construction is mandatory. You can etch and drill your own pc board using the actual-size artwork shown in Fig. 4 (use only G10 epoxy-fiberglass pc blank) or purchase a ready-to-wire, silk-screened pc board from the source given in the Note at the end of the Parts List. Before beginning to wire the board, thoroughly clean it with isopropyl alcohol and, if possible, acetone to remove all dirt, grease, etc. (If you are using a silk-screened board, do *not* clean the screened side with acetone or allow acetone to get on it; if you do, the screened legends will wash off.) These are volatile materials; so work in a well-ventilated location and away from open flames!

Begin wiring the board by installing and soldering into place the resistors, followed by the capacitors, diodes, transistors and, finally, the integrated circuits, as illustrated in Fig. 5. Make absolutely certain that the diodes and electrolytic capacitors are properly oriented before soldering their leads to the copper pads on the bottom of the board. Clip away all excess component lead lengths. Similarly, make sure the ICs are plugged into the holes in the proper locations and that they are properly oriented before soldering their pins to the pads.

Prepare suitable-length wires for BP1, J1, both holes for all LEDs, M1+, M1−, S1,1 through S1,5, S2,1 through S2,6 (note that there is no hole for S2,4, which is not used), S3,1 through S3,4, and TP1. If you are using stranded hookup wire, strip ¼ inch of insulation from both ends, tightly twist together the fine wires and sparingly tin with solder. Plug one end of each wire into the indicated holes and solder into place.

Carefully check all soldering. Reflow the solder on any suspicious connection. Also, use solder wick or a vacuum-type desoldering tool to remove any solder bridges you might have created between closely spaced pads and/or traces. When you are sure your soldering is okay, clean the bottom of the board with flux remover or isopropyl alcohol.

This extremely sensitive project must be housed inside either an all-metal enclosure or a *foil-lined* plastic project box. The first thing to do is drill the mounting holes for the circuit-board assembly through the floor of the enclosure.

Next, machine the enclosure as needed for mounting *BP1*, *J1*, *LED1* through *LED3*, *S1* through *S3*, and a pin jack (for connection to TP1) on the front panel. A suggested layout is shown in the lead photo. When suitable holes have been made, temporarily mount the circuit-board assembly in place, with the adjustment shaft of *R21* facing toward the front panel, using ½-inch spacers and 4-40 × ¾-inch machine screws and nuts. Determine exactly where on the front panel the hole for this trimmer control's shaft must be drilled and mark that location. Remove the circuit board assembly and then drill the hole in the marked location.

The four-cell holders for *B1* and *B2* should be mounted on the rear wall of the enclosure. To accomplish this, drill the holes according to the pattern on the holders. This done, mount the holders on the rear wall. Then remount the circuit-board assembly in its location with the same hardware you previously used.

Mount rotary RANGE switch *S1* in its hole in the front panel, making the hardware only finger tight. Place a pointer-type knob on the switch's shaft and, without allowing the switch itself to move, rotate the knob through all four positions. As you do this, observe where the index on the knob points for the first and last positions. If these are not symmetrical, readjust the positioning of the switch until they are. You may have to remove the knob to do this.

Once the RANGE switch is properly positioned, tighten its hardware and replace the knob on the shaft. Once again, rotate the knob through all four positions. This time, make a

Background

For most electronics work, the loading effect of a VOM is not a critical factor. However, when it is necessary to measure minute charges or sources that have very high impedance, they will not suffice.

Of course, it is possible to use electrostatic instruments that are voltage operated without drawing any current from the circuit or source being measured. Unfortunately, though, these devices are suitable for only relatively high voltages (beyond about 50 to 100 volts). One such device, invented more than a century ago, is the electroscope, which operates on the principle of electrostatic repulsion. In the electroscope, two very light metallic leaves made of gold foil are suspended from a wire. A charge placed on the wire causes the gold leaves to repel each other by a given amount. It is theoretically possible, but hardly practical, to calibrate such an instrument.

Invention of the vacuum tube made it possible to use the tube as an amplifier in which the grid theoretically draws no current. Tubes for this application must be operated at very low voltages to avoid causing unwanted electrons from collecting on the grid and interfering with the measurement. This type of device can detect and measure very small currents, down to a picoampere (micromicro or 10^{-12} ampere). A disadvantage is that commercial electrometers are priced beyond the means of most home experimenters and many professional service shops.

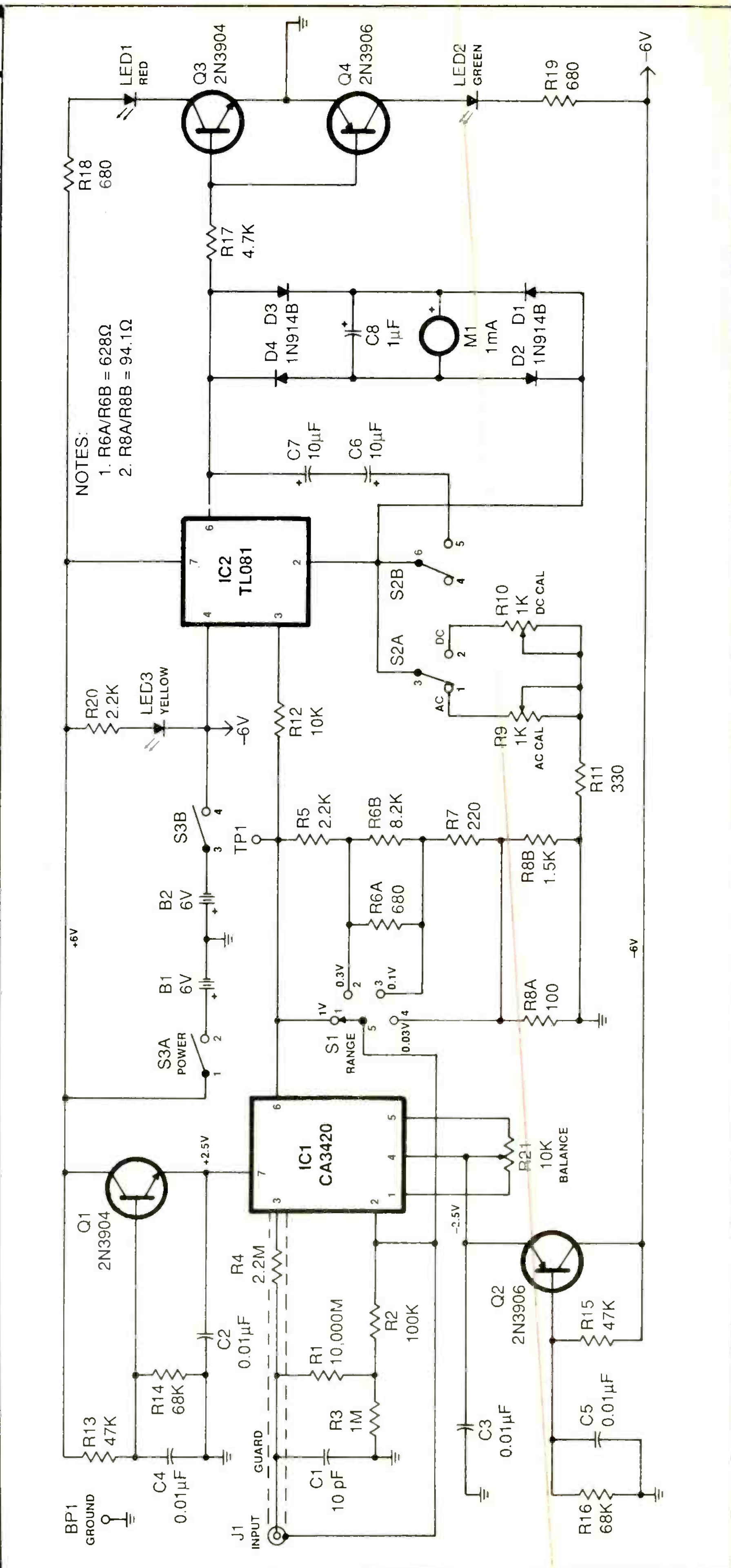
The metal-oxide field-effect transistor (MOSFET), conceived in the 1920s by a man named Lilienthal, finally became a practical reality in the 1960s. The MOSFET modulates the surface conductivity of a semiconductor with an electric field, applied via a gate electrode. In theory, and quite close in practice, the MOSFET's gate draws no current because it is insulated from the semiconductor structure. The MOSFET has become a basic building block of modern electronics and is the heart of VLSI (very-large-scale integrated-circuit) devices.

The MOSFET has the potential of being an ideal device for electrometer applications. Though early MOSFETs were unstable and noisy, the modern MOSFET-input operational amplifier has overcome most of the problems. MOSFET-input op amps now make it possible to measure very small electrical charges and currents and to use these signals to control very large currents. Individual power MOSFET devices can now switch 10 to 30 amperes at 100 volts or more while being controlled by megohm-level impedance sources, an ability not presently possible with bipolar devices.

The project presented in the main article takes advantage of a commonly available, inexpensive MOSFET-input op amp, the CA3420, to produce a low-cost picoammeter/electrometer instrument that can measure currents as low as 1 picoampere and resistances as high as 1M megohm.

Now just about anyone who is interested in electronics, whether as a hobby or as a career, can have this type of instrument without having to spend many hundreds or even thousands of dollars for a similar commercial instrument. With it, one can now seriously check the relative level of static electricity that might damage an electronic or computer component, the effectiveness of insulation, determine the static-charge polarity of different materials, and other tasks beyond the capability of common test instruments.

Fig. 3. The diagram of the complete electrometer, including metering circuit and AA-cell dc power supply.



light pencil mark at the location where the knob index stops to indicate where to put the range legends for the switch. Remove the knob.

Now label the front panel according to the legends detailed in Fig. 3. If you use a dry-transfer lettering kit for this, wrap the shaft of the rotary switch in masking tape. Then spray at least two *very light* coats of clear acrylic over the entire front panel to protect the lettering. Be sure to allow each coat to completely dry before spraying on the next.

When the acrylic spray has completely dried, mount the pin and banana jack, BNC connector, meter movement and switches in their respective holes in the front panel.

Referring to both Fig. 3 and Fig. 5, connect and solder the free ends of the appropriate wires to the indicated lugs on the switches and pin jack. Do the same for the wires coming from the J1 CENTER and BP1 holes. Locate the free end of the M1 + wire and connect and solder it to the + terminal on *M1*. Do the same with the free end of the M1 − wire and − terminal on *M1*.

Now locate the wires coming from the LED1 through LED3 holes and slip over each a 1-inch length of small-diameter heat-shrinkable or plastic tubing. Cut the cathode leads of all three LEDs to a length of ½ inch and form a small hook in each. Crimp the free end of the LED1 K wire to the cathode lead of *LED1* and solder the connection. Do the same with the LED2 K and LED3 K wires and the cathode leads of *LED2* and *LED3*, respectively. Then repeat the procedure with the anode wires (not identified in Fig. 5) and anode leads of each LED in turn. When this is done, push the tubing up over the connections to fully insulate them and

PARTS LIST

Semiconductors
D1 thru D4—1N914B silicon switching diode
IC1—CA3420 MOSFET-input operational amplifier (RCA)
IC2—TL081 operational amplifier (Motorola or Texas Instruments)
LED1—Red light-emitting diode
LED2—Green light-emitting diode
LED3—Yellow light-emitting diode (optional—see text)
Q1,Q3—2N3904 or ECG123A silicon npn transistor
Q2,Q4—2N3906 or ECG159 silicon pnp transistor

Capacitors
C1—10-pF, 10% silver mica (do not substitute)
C2 thru C5—0.01-μF, 50-volt disc
C6,C7—10-μF, 16-volt electrolytic
C8—1-μF, 50-volt electrolytic

Resistors (¼-watt, 10% tolerance)
R1—10,000 megohms
R4—2.2 megohms
R11—330 ohms
R12—10,000 ohms
R13,R15—47,000 ohms
R14,R16—68,000 ohms
R17—4,700 ohms
R18,R19—680 ohms
R20—2,200 ohms (needed only if LED3 is used)
R2—100,000 ohms, 5% tolerance
R3—1 megohm, 5% tolerance
R5—2,200 ohms, 1% tolerance
R6A/R6B—628 ohms, 1% tolerance (680 and 8,200 ohms, both 1% tolerance, in parallel; matched resistor pairs are supplied in kit—see text)
R7—220 ohms, 1% tolerance
R8A/R8B—94.1 ohms, 1% tolerance (100 and 1,500 ohms, both 1% tolerance, in parallel; matched resistor pairs are supplied in kit,—see text)
R9,R10—1,000-ohm upright pc-type trimmer potentiometer
R21—10,000-ohm upright pc-type trimmer potentiometer with shaft

Miscellaneous
B1,B2—Eight AA cells
BP1—banana jack (preferably black)
J1—Female panel-mount BNC connector
M1—0-to-1-mA meter movement
S1—4-position, 1-pole nonshorting rotary switch
S2,S3—Dpdt slide or toggle switch
TP1—Pin jack (see text)
Printed-circuit board; suitable enclosure (see text); two AA cell holders (4 cells each); pointer-type knob for S1; material for making test cable for J1 (UG-88 or similar male BNC connector, good-quality RG-58U coaxial cable, etc.—see text); materials for making ground cable for BP1 (banana plug, test-lead cable, etc.—see text); small-diameter heat-shrinkable or plastic tubing for LEDs; labeling kit; suitable machine hardware; hookup wire; solder; etc.

Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, NY 10804: All components, including etched, drilled and silkscreened pc board, C8 and R10 but *not* LED 3 or any items under Miscellaneous, $37.50 plus $2.50 P&H; pc board only, $10.00, plus $2.50 P&H. New York residents, please add state sales tax.

shrink into place. This done, plug the domed cases of the LEDs into their respective front-panel holes.

Prepare two wires of sufficient length to reach from *S3* to the battery holders. Crimp and solder one end of each wire to the indicated lugs on the switch and the other ends to the indicated lugs on the battery holders. Crimp but do not solder the free end of the wire coming from the GND hole on the board to the + lug on the holder for *B2*. Finally crimp and solder a short length of hookup wire between the − lug on the *B1* and + lug on the *B2* holders. Check battery polarity before proceeding.

If you are using a plastic enclosure for your project, make certain that you fully line it with aluminum foil before mounting any components in place. Also, make sure you do not ground the shell of INPUT connector *J1*; this is a guard—*not* a ground connection. If your are using a metal enclosure, use insulating hardware to mount this BNC connector on the panel. Keep the wiring to *J1* as short as possible and as far away from other wires.

To use this instrument, you need a pair of input cables, one to connect from the INPUT BNC connector to the point of interest in and the other to connect from the GROUND banana jack to ground in the circuit under investigation. Both should be no longer than 36 inches.

Start with the input lead. As illustrated in Fig. 6, to make this lead you need a male BNC connector that mates with *J1* and a length of good-quality RG-58U coaxial cable. Prepare one end of this cable by removing 1¼ inch of outer plastic jacket. Then carefully trim away ¾ inch of the exposed shield mesh. Next, strip ¼ inch of insulation from the inner conductor. If this conductor is made up of stranded wire, tightly twist together the wires and sparingly tin them with solder. Use heat judiciously to prevent the inner insulation from melting and causing the inner conductor and shield to short to each other.

This end of the cable can be finished in any of several ways. For example, you can terminate it in a pointed probe, a ball connector or leave it as is.

If you use a probe, solder to the inner conductor about a 1-inch length of bare solid hookup wire. Use a probe whose handle can accommodate the coaxial cable. Use only a *plastic* probe—not a fiber one! Slide the cable into the handle until the wire exits the hole at the point end. Then wrap the wire around the neck of the probe tip and screw on the retaining ring. Use a similar arrangement if you use a ball-type connector. To use the cable as is, slip a 2-inch length of heat-shrinkable tubing over the prepared end and position it so that it completely covers the mesh shield and only partially covers the insulator for the inner conductor. Shrink the tubing solidly into place. When you are done, ⅛ inch of the inner insulation and all of the exposed inner conductor should be visible.

Prepare the other end of the coaxial cable as detailed with the instructions supplied with the BNC connector. Install this connector on the cable end exactly as detailed by the manufacturer. If no instructions are supplied, prepare the cable end and secure it as you normally would for any other BNC connector.

Preparation of the ground cable is much simpler. All you need for this cable are a length of stranded wire, preferably the type used for test-instrument cables, and a banana plug. Remove ⅜ inch of insulation from both ends, tightly twist together the fine wires and sparingly tin with solder. Terminate one end in the banana plug by the usual means and the other with a small insulated alligator clip or ball-type connector.

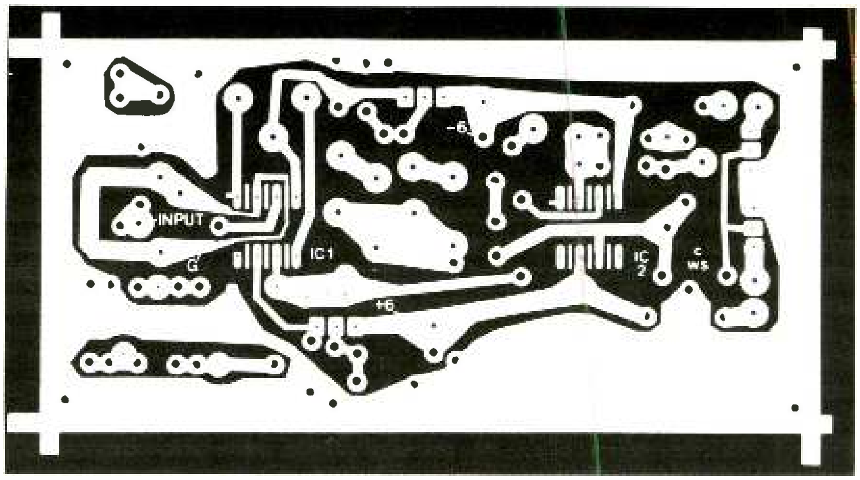


Fig. 4. The actual-size etching-and-drilling guide for the printed-circuit board to be used in this project.

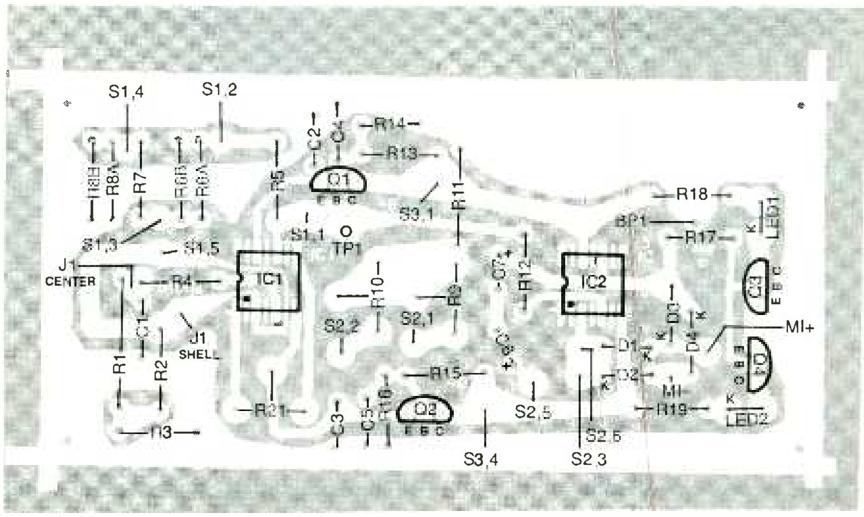


Fig. 5. The wiring diagram for the pc board.

Checkout & Calibration

With no AA cells installed in the battery holders, perform the following resistance check. First, clip the common lead of your ohmmeter to either the − lug on the *B1* holder or the + lug on the *B2* holder and leave it there. Then touch the ohmmeter's "hot" probe to first pin 7 and then pin 4 of *IC2*. In both cases, you should obtain a meter reading of more than 300 ohms. If your readings are less than 300 ohms, try reversing the connections of the ohmmeter. Whichever way you connect the ohmmeter probes, the higher reading should exceed 300 ohms. If you do not obtain the proper readings, recheck all wiring, component orientations and values or part numbers. Do not proceed until the problem has been rectified.

When you are satisfied that everything is okay, set POWER switch *S1* to OFF and install the AA cells in the battery holders. Make sure each cell is installed in the correct orientation. Then set *S1* to ON and immediately check to see if the yellow LED is on. You may also notice at this point that either the red or the green LED or both alternately are on as well.

If everything appears to be okay up to this point, use a dc voltmeter

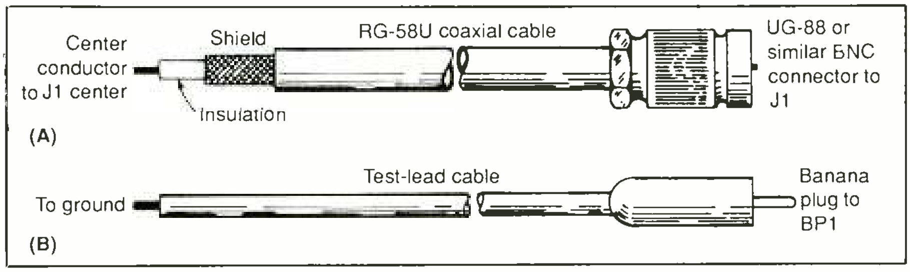
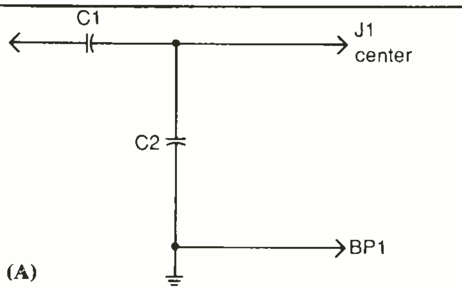
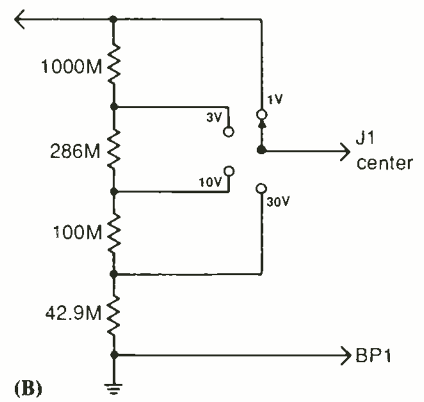


Fig. 6. Fabrication details for the two test leads required by the electrometer.



Full-Scale Range (Volts)	Value of C1 (pF)	Value of C2 (p = pF; μ = μF)
10	110	1,000 p (mica, if possible)
30	33	1,000 p
100	11	1,000 p
300	33	10,000 p (Mylar) or 0.01 μ
1,000	10	0.01 μ
3,000	3.3	0.01 μ
10,000	1	0.01 μ

Notes: C1 must be rated at *twice* maximum measured voltage.
C2 should be low-leakage type and have 5% tolerance.
Use extreme care on 300-, 1,000-, 3,000- and 10,000-volt ranges.



Resistive Divider shown is for low voltages only. Any resistor values can be used if correct ratios can be obtained. Values given are illustrative only, though they can be used if desired.

Fig. 7. Examples of external capacitive (A) and resistive (B) voltage dividers that can extend the project's measuring range.

(or multimeter set to dc volts) to verify the following:

IC1 pin 7: +2 to +3 volts
IC1 pin 4: −2 to −3 volts
IC1 pin 6: −1 to +1 volt (may vary)
IC2 pin 7: +6 volts
IC2 pin 4: −6 volts

These voltage checks should be made with the meter's common probe connected at all times to a convenient circuit-ground point. If you do not obtain one or more of these voltage readings at the indicated points, power down the project, remove the cells from the battery holders, and rectify the problem.

Next, temporarily connect a wire between the *R1/R4/C1* junction and circuit-ground trace on the circuit-board assembly. Set the RANGE switch to 1V and adjust the setting of the BALANCE control for a null reading on the meter. If the meter's pointer will not adjust to the null (zero) point, power down and, once again check your construction work. If you find no wiring or installation fault, check out *IC1* and *IC2*.

Set *S1* to DC and check to see if the BALANCE control will null the meter in each setting of the RANGE switch. Note that on one side of the null setting the red LED should be on and on the other side the green LED should be on. If you do not obtain these indications, check *IC2*, *Q3*, *Q4*, *LED1* and *LED2*.

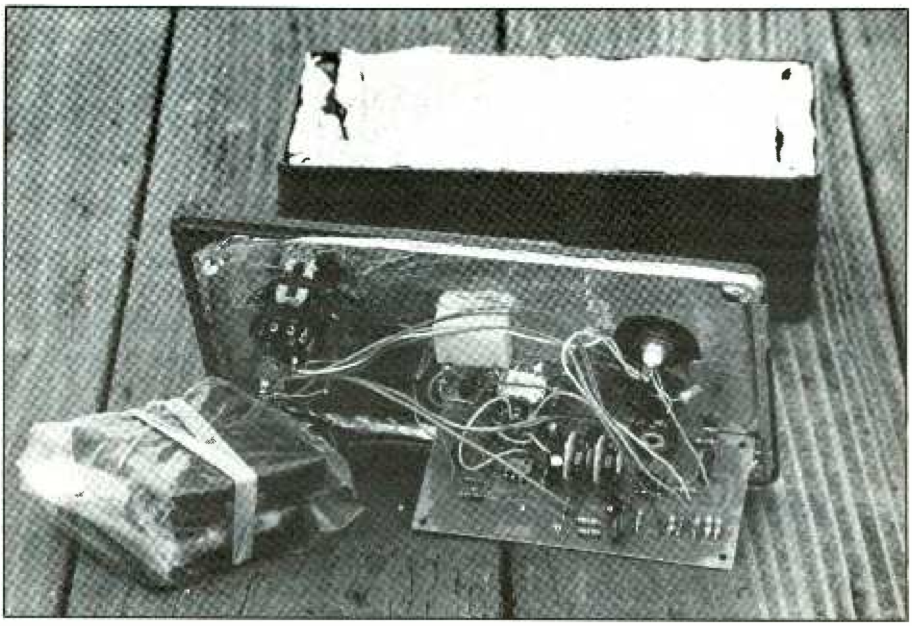
Next, set S1 to 1V and apply an exact +1-volt dc source to the center conductor of INPUT connector *J1* and *BP1* GROUND. Do *not* connect the shell of *J1* to anything for this test. Adjust the setting of *R10* for a full-scale meter pointer deflection. Now apply a 1-volt rms ac signal (60 Hz is okay) in place of the dc signal and adjust the setting of *R9* for full-scale meter pointer deflection. Your instrument is now calibrated. Mount the front panel in place to complete construction.

Using the Project

You will find this instrument to be extremely sensitive, even if you use an unwound paper clip instead of an antenna or input cable. To measure potentials greater than 1 volt ac or dc, you must use an external voltage divider. You can make such a divider with either high-value resistors or capacitors, the latter being preferable. Do *not* attempt to directly measure potentials that exceed 1 volt; if you do, *IC1* may be damaged. Also, do *not* touch the input cable to objects that are charged to a high voltage. In some cases, it may be advisable to connect the ground cable to an earth ground like a cold-water pipe.

Simple voltage dividers that can be

(Continued on page 91)

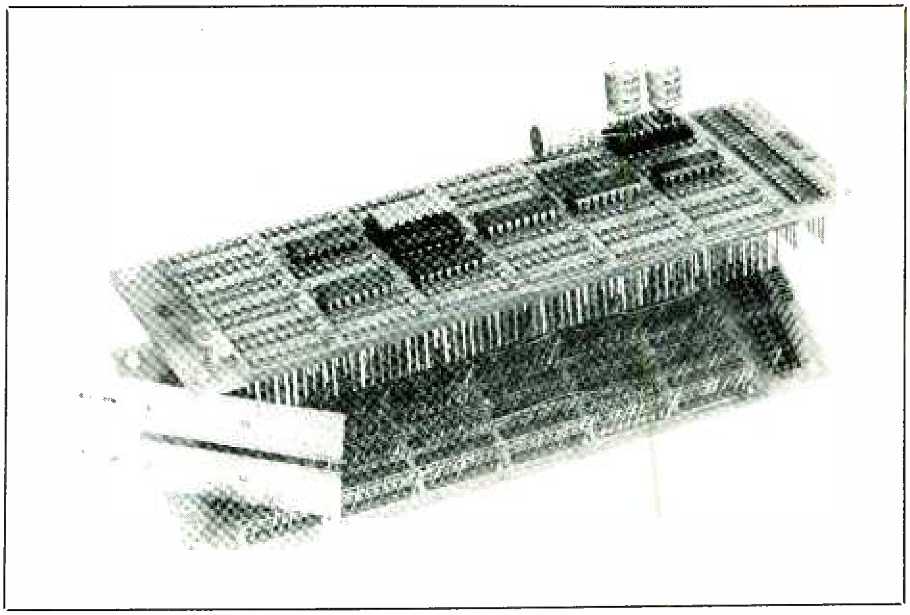


This prototype of the finished project is housed inside a plastic box. Note that aluminum foil on all interior surfaces of the enclosure provides the required shielding.

A Printer Multiplexer

Lets two computers share a single printer

By Brian B. Beard



Because printers are rarely used continuously by a single computer, it makes sense to have more than one computer share a single printer. What does not make sense is to have to physically move a printer from computer to computer. And though a common A/B switch might simplify the transfer process, it still requires physical action on the part of the user.

Ideally, switching a printer between computers should be fully automatic. The Printer Multiplexer project to be described does just that. Relatively low in cost, it allows two computers to share one printer. An install-and-forget device, it automatically powers up and is ready to use when you turn on your printer. (If you installed in your system the "Automatic Printer Power Controller" featured in the December 1987 issue of *Modern Electronics*, you do not even have to remember to turn on the printer!) Power for the project comes from the printer with which it is used, or from a separate built-in power supply if your printer does not have a +5-volt line on its I/O connector or cannot deliver the required current if it does. The project can also be used with any external printer buffer as well.

Parallel Interface

The *de facto* industry-standard Centronics parallel printer interface is based on a 36-contact Champ series connector manufactured by Amp Inc. Signals commonly assigned to the contacts on this connector are listed in the Table. (All signal voltages are assumed to be at the standard 0- and +5-volt TTL logic levels.) As with most other standards, however, there are exceptions to the contact assignments of the Centronics standard connector arrangement. Some computers and printers use fewer signals than those listed, others more. The signals given in the Table provide basic printing compatibility for all printers. Because of their rare usage, some exotic control and status lines have been omitted from the Table.

Ten lines go from the computer to the printer. Eight are for data, the ninth is for the DATA STROBE and the tenth is for the RESET signals. The DATA STROBE line is normally held high by the computer, which pulses it low only when data is ready to be sent to the printer. The RESET line can be pulsed low to clear the printer and return it to its default settings.

Five lines return from the printer to the computer. Two are for handshaking and carry the ACKNOWLEDGE and BUSY signals. The three remaining lines are for status indication: PAPER OUT, printer SELECTED (on-line), and ERROR. The handshake lines control data transfer; the ACKNOWLEDGE line pulses low to confirm that the last byte has been received; and the BUSY line goes high whenever the printer is unable to receive data. Whenever the BUSY line is high, data transfer from the computer is inhibited. Every byte sent to the printer causes the BUSY line to go high until the printer has had time to print or store that byte.

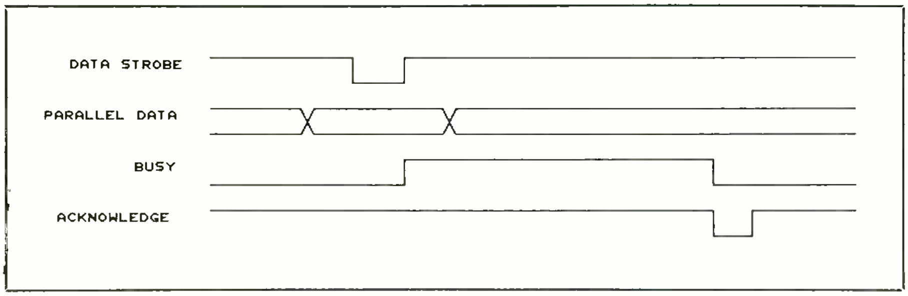


Fig. 1. Timing of data and handshaking lines in typical parallel printer interface.

The status lines from the printer are not synchronized with the transfer of data to the printer. They simply represent events that can occur independently of the printing operation, such as the printer being taken off-line or the paper running out or being removed from the printer.

Examining the Table, you will note that pin 18 of the connector is the printer's +5-volt supply line. This line can be used to power an external circuit as long as current drain remains less than the specified limit for the printer. The computer's parallel connector normally has no connection made to pin 18.

About the Circuit

Shown in Fig. 2 is the complete schematic diagram of the Automatic Printer Multiplexer. This project allows two computers to share a single printer. Instead of the mechanical switches commonly used in commercial printer switch boxes, our Multiplexer employs electronic switching to route data between the computers and printer. No power switch is provided for the Multiplexer for the simple reason that it is not needed. This is because the +5 volts dc required by the circuit is provided by the printer and is automatically switched on and off when the printer is powered up and turned off. Once the Printer Multiplexer is installed in a computer system it can be forgotten.

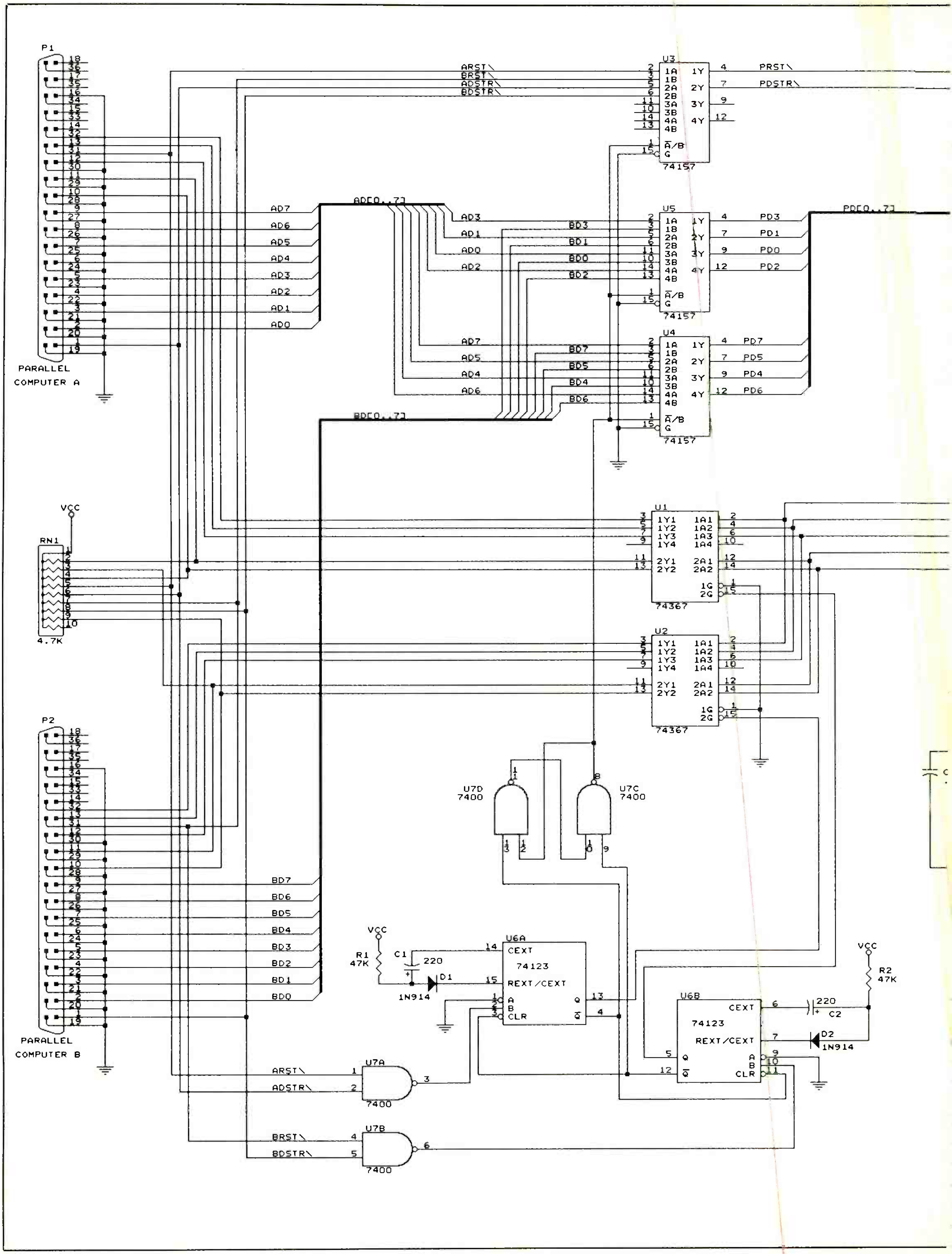
As shown in the schematic diagram, signals sent to the printer are selected by 74157 2-to-1 multiplexers *U3*, *U4* and *U5*. Signals that are sent back to the computer from the printer are handled by 74367 tri-state buffers *U1* and *U2*. Proper control of these integrated circuits is the key to the Printer Multiplexer's versatility.

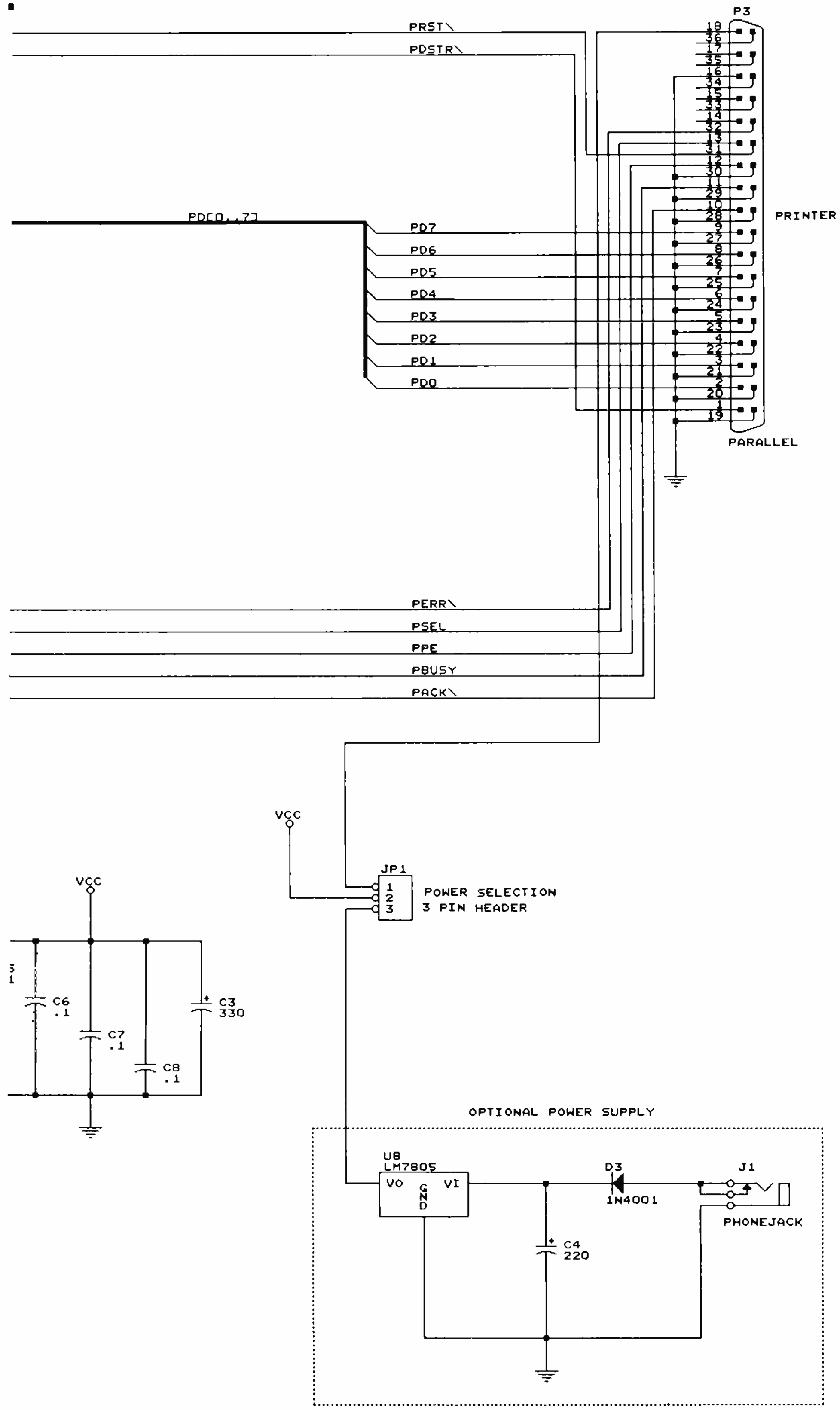
Only two lines from each computer call for a response from the printer. The DATA STROBE line tells the printer to accept the byte currently on the data lines, while the RESET line tells the printer to initialize itself. By combining these two lines in a NAND arrangement, an activity indication signal that is thus generated goes high whenever the DATA STROBE or RESET is active. Gates *U7A* and *U7B* generate the activity signals for computers A and B, respectively. (The computers connect to the Printer Multiplexer via *P1* and *P2*.) This activity output goes to the positive trigger of one section of 74123 dual retiggerable monostable multivibrator *U6*, with computer A triggering *U6A* and computer B triggering *U6B*.

The output of each section of *U6* connects to the CLEAR input of the other section so that if *U6A* is triggered, *U6B* cannot be triggered until *U6A* has timed out. Since the multivibrator is retriggerable, it can be kept in a triggered state as long as trigger pulses are present before the time constant expires. With the 220-microfarad value for timing capacitors *C1* and *C2*, each multivibrator section has a time constant of approximately 3 seconds. Hence, if computer A sends data at least once every 3 seconds, it will maintain control of the Printer Multiplexer.

Typical Parallel Printer Connector Contact Assignments

Pin No.	Signal	Computer	Printer
1	Data Strobe	Out	In
2	Data Bit 0	Out	In
3	Data Bit 1	Out	In
4	Data Bit 2	Out	In
5	Data Bit 3	Out	In
6	Data Bit 4	Out	In
7	Data Bit 5	Out	In
8	Data Bit 6	Out	In
9	Data Bit 7	Out	In
10	Acknowledge	In	Out
11	Busy	In	Out
12	Paper Out	In	Out
13	Selected	In	Out
14	N.C.	N.C.	N.C.
15	N.C.	N.C.	N.C.
16	Signal Ground	—	
17	Chassis Ground	—	—
18	+5 Volts	N.C.	Out
19 thru 30	Ground	—	—
31	Reset	Out	In
32	Error	In	Out
33	Ground	—	—
34 thru 36	N.C.	N.C.	N.C.


P1
PARALLEL
COMPUTER A
P2
PARALLEL
COMPUTER B
RN1
4.7K
VCC
U3
74157
U5
74157
U4
74157
U1
74367
U2
74367
U7D
7400
U7C
7400
U6A
74123
U6B
74123
U7A
7400
U7B
7400
R1
47K
R2
47K
C1
220
C2
220
D1
1N914
D2
1N914
ARST\
BRST\
ADSTR\
BDSTR\
PRST\
PDSTR\
AD[0..7]
BD[0..7]
PD[0..7]
CEXT
REXT/CEXT
CLR



PARTS LIST

Semiconductors

D1,D2—1N914 or similar silicon switching diode

D3—1N4001 or similar silicon rectifier diode

U1,U2—74367 tri-state buffer

U3,U4,U5—74157 2-to-1 multiplexer

U6—74123 dual retriggerable monostable multivibrator

U7—7400 quad 2-input NAND gate

U8—7805 +5-volt regulator

Capacitors (16 WV)

C1,C2,C4—220-µF electrolytic

C3—330-µF electrolytic

C5 thru C8—0.1-µF disc

Resistors (¼-watt, 10% tolerance)

R1,R2—4,000 ohms

RN1—4,700 10-pin SIP resistor network

Miscellaneous

J1—Power jack (to match plug-in dc power supply's connector)

JP1—3-position shunt jumper with 2-position header

P1,P2—36-contact Champ male IDC printer connector (can be part of commercially made printer cable—see text)

P3—36-contact Champ female IDC printer connector (can be part of commercially made printer cable—see text)

Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap hardware (see text); sockets for all DIP ICs; 36-conductor ribbon cable (see text); suitable enclosure; lettering kit and clear spray acrylic; machine hardware; wire; solder; etc.

Note: All components listed above, except printed-circuit board, are available from Digi-Key Corp., P.O. Box 677, Thief River Falls, MN 56701. Telephone: 1-800-344-4539.

Fig. 2. Overall schematic diagram of Printer Multiplexer designed to allow two computers to share a single printer. Project can obtain +5-volt dc power from printer or its own on-board power supply, choice depending on availability of former and proper installation of jumper on JP1.

NAND gates *U7C* and *U7D* are wired as an RS flip-flop to control multiplexers *U3*, *U4* and *U5*. The RS flip-flop is reset when computer A is active and is set when computer B is active. It will keep the data lines connected to the last active computer when data transfer has ceased.

Each 74367 tri-state device buffers the printer signals to a different computer. That is, *U1* buffers computer A and *U2* buffers computer B. The three status lines from the printer are always buffered to both computers. On the other hand, the handshake lines are controlled by the activity of the computers. If computer A is sending data to the printer, you do not want computer B to "see" its handshaking lines changing in response to computer A. To prevent this from happening, the buffers for the handshake lines are controlled by the outputs from the monostable multivibrators.

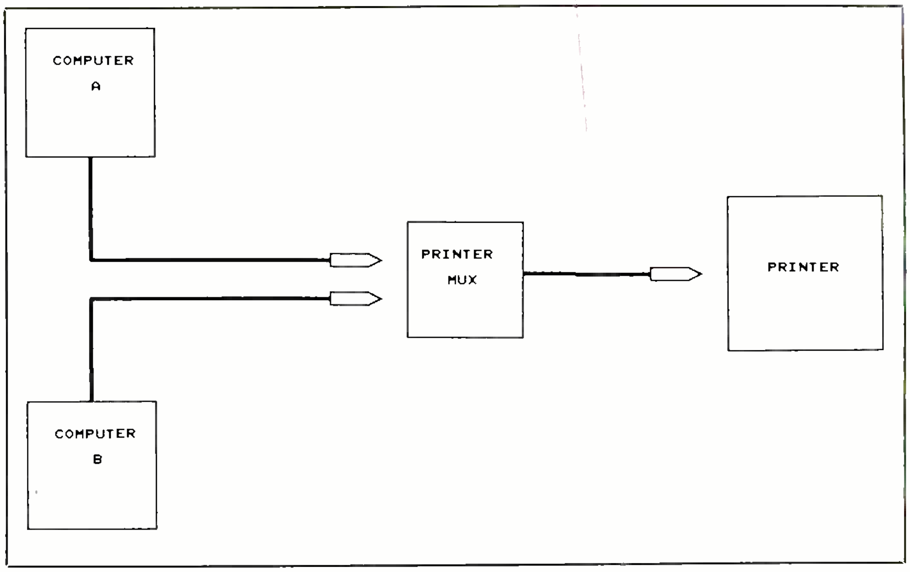


Fig. 3. Printer Multiplexer connects into system via three ribbon cables.

When computer A is active, triggering section A of the monostable multivibrator, the BUSY and ACKNOWLEDGE buffers to computer B go tri-state. Since all handshake lines have pull-up resistors, computer B "sees" them as high and inhibits data transfer from computer B. This computer will remain inhibited for as long as computer A maintains control of the Printer Multiplexer. In identical fashion, computer A is inhibited when computer B is active.

This project is designed to operate from the +5 volts present on pin 18 of the printer's parallel connector. Total current drain is about 170 milliamperes when the circuit is built using the specified standard TTL devices. If you wish, you can substitute 74HC devices of the same numbers as those specified to reduce current drain to less than 50 milliamperes. An optional regulated power supply is included in the circuit (shown at lower-right in Fig. 2) in the rare event that your printer does not provide +5 volts on pin 18 or, if it does, cannot deliver the required current. A plug-in ac adapter that supplies 9 volts dc at 200 milliamperes or more plugs into the power-supply circuit via miniature phone jack *J1*.

Construction

Unless you are really ambitious and design and fabricate your own printed-circuit board (it should be double-sided to eliminate a very large number of jumper wires), the best way to wire this project is on perforated board with the aid of Wire Wrap hardware. This is exactly what was done for the prototype shown in the lead photo. If you arrange the layout properly, you can have the input (*P1* and *P2*) and output (*P3*) ribbon cables exit the enclosure through slots cut into opposite ends.

Wiring the board takes lots of patience and a great deal of care, due to the large number of wire runs that must be made. Be sure to use sockets for all ICs except *U8* and Wire Wrap posts for all other components. Wiring is not particularly difficult, just time-consuming.

Install only the sockets—*not* the ICs themselves—during initial wiring. As you make each wire run, mark it off on Fig. 2 (or a photocopy of same) to keep track of what you have done. Install the resistors, capacitors and diodes by soldering their leads to the tops of Wire Wrap posts. Make sure that the electrolytic capacitors and diodes are properly oriented before soldering to the posts.

When you finish wiring the circuit-board assembly, carefully check it against Fig. 2. Check particularly for proper connection into the circuit of electrolytic capacitors *C1* through *C4*, diodes *D1* through *D3*, and +5-volt regulator *U8*. Place the jumper on any two of *JP1*'s pins.

Connections to the printer and two computers with which the project will be used are made via standard 36-conductor ribbon cable with 36-contact printer connectors at the external ends of the cables. You can use commercially made cables for these or separate ribbon cable and IDC connectors as needed. If you use commercial cables, they should be not longer than 6 feet in length. You need two such cables, which when cut in half yield four 36-inch cables, each with a connector at one end.

Whichever way you go with the cables, prepare one end of each by separating the conductors at the unfinished end for a distance of about 1½ inches. Strip ³⁄₁₆ to ¼ inch of insulation from all conductors of three of the four cables. (You need only three cables for this project. Reserve the fourth cable for use in another application or project.) Tightly twist together the fine wires in each conductor and sparingly tin with solder. Use heat judiciously to avoid damaging the insulation.

Cables made from scratch should also be kept to a length of 36 inches or less. Install a connector at the opposite end of each ribbon cable such that conductor No. 1—usually identified by a stripe that is a different color from the insulation on the cable—makes contact with contact No. 1 of each connector.

You can use any type of enclosure to house the project, the only condition being that it be large enough to accommodate the circuit-board assembly and power jack *J1* without crowding. Because of the wide ribbon cables used in this project, you must cut three 2 × ³⁄₁₆-inch slots for them. If you have a nibbling tool or/and Moto-Tool, you might want to use a metal enclosure. Otherwise, consider using a plastic enclosure made of two shell halves, cutting shallow slots in the joining edges of both halves (only wide enough to solidly clamp onto the cables to mechanically secure them when the enclosure is assembled).

After cutting the slots for the ribbon cables, drill mounting holes through the floor of the enclosure for the circuit-board assembly and through the rear wall for power jack J1. Before mounting the circuit-board assembly or jack, label the two input cable slots COMPUTER A and COMPUTER B and the jack hole 9V TO 12V DC. If you use dry-transfer letters, spray two or more *light* coats of clear acrylic on them to protect the legends. Allow each coat to dry before spraying on the next.

When the acrylic spray has completely dried, mount the power jack in its hole. If you are using a metal enclosure, line the cable slots with some insulating material to prevent sharp edges from cutting through the cables' insulation and shorting out conductors. Use a 4-inch length of small-diameter plastic tubing or plastic grommet material for each slot. If you use tubing, carefully slit it down the center to form open channels that can then slip over the metal edges of the slots. If you are using a plastic enclosure, of course, there is no need for tubing or grommets to protect the cables.

Route the cables into the enclosure through the slots and, referring to Fig. 1, connect and solder the various conductors to the specified points in the circuit. Repeat for the power jack. Then use suitable-length spacers and machine hardware to mount the circuit-board assembly into place.

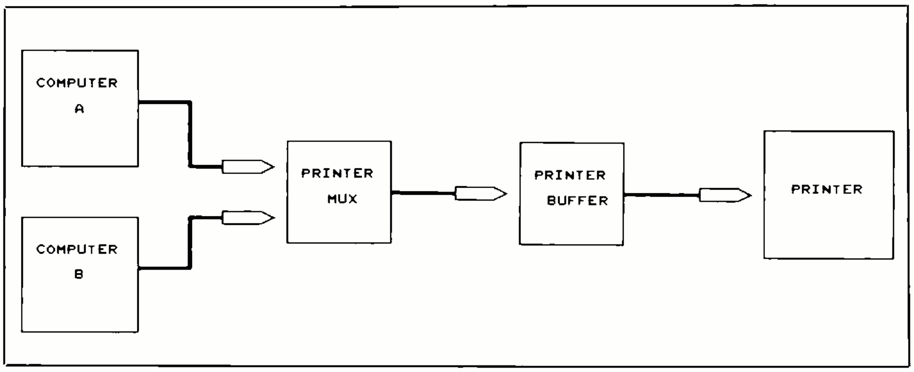


Fig. 4. Project can also be used with external printer buffer, installed between Printer Multiplexer and printer.

Checkout & Use

With the DIP ICs still not installed in the sockets, plug the dc power supply into *J1* and place the jumper on *JP1* so that it shorts together pins 2 and 3. Plug the power supply into any convenient ac outlet.

Connect the common lead of a dc voltmeter or a multimeter set to dc volts to a convenient ground point in the Printer Multiplexer's circuit. Then touch the meter's "hot" probe to the OUT pin of *U8* and note that the reading is about +5 volts on the meter. If you obtain this reading, touch the "hot" probe tip to pin 16 for the U1 through U6 sockets and pin 14 for the U7 socket. At all these points, the meter reading should be the same +5 volts. If it is not, power down the circuit and carefully check all wiring, soldering and component installations. Do not proceed until you have corrected the problem.

Having checked the on-board power supply, you should also check to make sure that the +5 volts from your printer can get through to the project on line 18 of the ribbon cable. With the project's on-board power supply disabled, move the jumper so that it bridges pins 1 and 2 of *JP1* and plug the PRINTER cable into your printer. Turn on printer power and perform the same voltage checks described for the on-board power supply.

Once you are certain that the power buses have been correctly wired, power down the project and allow the charges to bleed off the electrolytic capacitors. Then plug the ICs in their respective sockets, taking care to properly orient. Also, make sure that no pins overhang the sockets or fold under between ICs and sockets.

Connect the Printer Multiplexer into your computer system via its cables. It does not matter which com-

(Continued on page 90)

A "Smart" Car-Battery Booster Cable

Simple project makes jump-starting a motor vehicle nearly foolproof

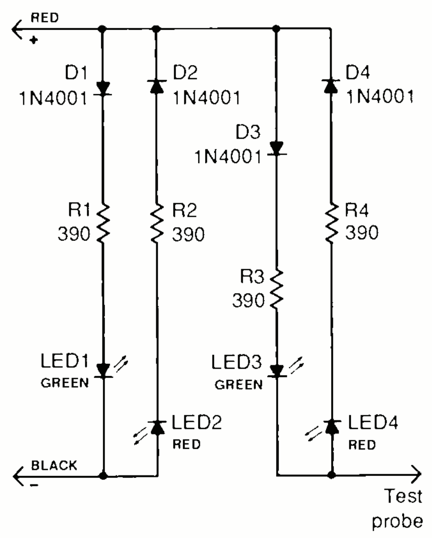
By Thomas R. Fox

Starting up a car that has a weak or dead storage battery by using cables to boost the latter with another car's good battery is commonplace. None of us do this regularly, though, so which polarity goes to what polarity can be vexing at the moment. Even if someone is rock-sure about this, a dark night without benefit of a flashlight with fresh batteries will give the best of us some pause. The same will be true if a battery's polarity markings are obscured.

Guessing which connection points to use can be dangerous since wrong connections can damage a vehicle's electrical system or even harm one's flesh. The "Booster Smarts" device we are about to describe, however, will clearly guide you so that you just cannot make a mistake even if you make the wrong connections! Moreover, it is cheap to build and permanently attaches to existing booster cables.

About the Circuit

Before describing how the Booster Smarts circuit works, let's understand just what jump-starting a vehicle is all about. Jump-starting is a method of getting a motor vehicle's engine operating when it will not start because of a weak or dead battery. To get the engine running, you connect the positive terminal of a good battery to the positive terminal of the weak or dead battery and the negative terminals of both batteries together.



PARTS LIST

- D1 thru D4—1N4001 or equivalent silicon rectifier diode
- LED1,LED3—Green light-emitting diode
- LED2,LED4—Red light-emitting diode
- R1 thru R4—390-ohm, ½-watt, 10% tolerance resistor
- **Misc.**—Printed-circuit board; suitable enclosure (optional; see text); pc encapsulating compound (see text); automotive booster cables (see text); test probe or alligator clip (see text); stranded hookup wire; solder; etc.

Fig. 1. Schematic diagram of Booster Smarts reveals that its circuit is very simple, consisting of just four each light-emitting diodes (in two different colors), current-limiting resistors, and protection rectifier diodes.

Jumper (or so-called "booster") cables are the means by which the two batteries are linked to each other during the operation (hence the name "jump-starting"). Care must be taken to assure that positive is connected to positive and negative is connected to negative. Then, with the engine of the vehicle that contains the good battery running, the ignition of the car whose engine is not running is turned on. The object is to have the good battery supply sufficient power to crank the other car's engine until it can run on its own. That is all there is to jump-starting a vehicle, assuming of course that the problem is with its battery and not the engine itself.

Using the Booster Smarts circuit with your jumper cables takes the guesswork out of possible incorrect connections. It assures the user that when a green LED lights on the project the proper connections are being made and warns him with a red LED that tells him when a wrong connection is being made *before* the final connection is made.

Shown in Fig. 1 is the schematic diagram of the Booster Smarts circuit. The light-emitting diodes (*LED1* through *LED4*) serve as polarity indicators. Rectifier diodes *D1* through *D4* serve as protection devices for reverse-biased LEDs, while resistors *R1* through *R4* limit current flow through the LEDs to a safe level.

You can see that if connections to two batteries are properly polarized only green light-emitting diodes *LED1* and *LED3* will light. Conversely, if improper connections are made, only red light-emitting diodes *LED2* and *LED4* will light. In no case will all four LEDs be on simultaneously.

If the test probe is connected to the wrong (positive) terminal of the "dead" battery, red *LED4* will light, assuming there is enough residual charge in the battery to light it.

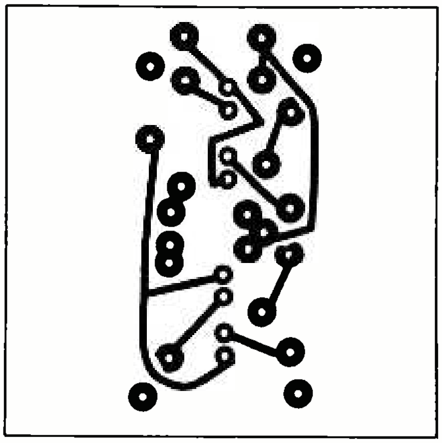


Fig. 2. Actual-size etching-and-drilling guide for project's printed-circuit board.

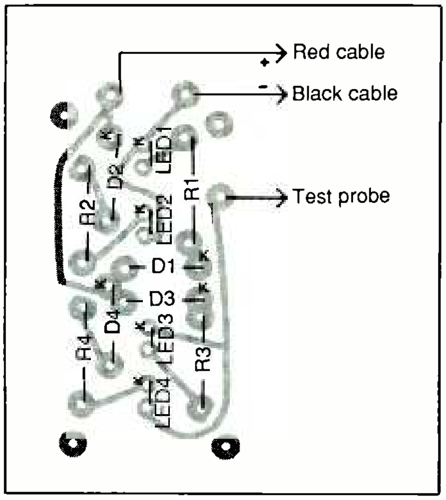


Fig. 3. Wiring diagram for pc board.

Construction

Despite the circuit's simplicity, a printed-circuit board on which to mount and wire the components that make up Booster Smarts is recommended. A pc board not only serves as a convenient wiring medium, it also provides much greater mechanical strength than does a perforated board. Since jumper cables, on which the project will be mounted, are usually kept in the unfriendly environment of a vehicle's trunk, you want the maximum in mechanical strength.

Fabricate your pc board using the actual-size etching-and-drilling guide shown in Fig. 2. When the board is ready, install and solder into place first the resistors, then the diodes and, finally, the light-emitting diodes. Make sure you properly polarize the diodes and LEDs before soldering their leads to the pads on the bottom of the board. (Note: If you wish to mount the project's circuit-board assembly inside a durable plastic or metal enclosure, the LEDs should mount on the enclosure and be connected to the board with short lengths of well-insulated stranded hookup wire.)

Strip ¼ inch of insulation from both ends of two black-insulated and one red-insulated 24-inch or so *stranded* hookup wires. Tightly twist together the fine conductors at both ends of the wires and tin with solder. Terminate one end of one black-insulated wire in an alligator clip or pointed test probe. Plug the other end of the wire into the hole labeled TEST PROBE and solder it into place. Plug one end of the red-insulated wire into the + hole and the black-insulated wire into the – hole in the board and solder into place.

No enclosure is required for the project, though you do have the option of housing in a small metal or plastic box. If you decide not to use a box, however, to assure the maximum in ruggedness, it is a good idea to protect the circuit-board assembly from rough handling. This can be accomplished by partially encapsulating the assembly. Ideally, the only components that should be left exposed should be the tips of the LEDs. The preferable encapsulant is the potting compound frequently used in commercial electronic equipment. If you cannot find this, you can substitute the more readily available silicone sealant.

Four holes are required, in the corners of the circuit-board assembly, through which plastic cable ties must pass to secure the assembly to the jumper cables. If the potting compound or sealant gets into these holes, clear it away. Then secure the Booster Smarts module to the jumper cables about 18 inches from the clamps at one end of the cable, snugging down the cable ties to assure the module will remain in place, as illustrated in Fig. 4. (Take a turn or two of the test probe wire around one tie before snugging it to serve as a strain relief.)

There are two general types of booster cables on the market. The less expensive ones usually have the two cables separated, while the more expensive ones have the two cables attached to each other via the insulation (and sometimes with reinforcing plastic clips) throughout most of their length. For this project, you want the latter to simplify securing the cables to it. If you already have the less-expensive variety of cables, you can still use them, but solidly bind them to each other for a distance of 6 to 8 inches, starting 15 inches from the clamps. Waxed lacing cord or plastic cable ties work well as a binding agent here. Then mount the assembly on the cables.

Solder the free ends of the red- and black-insulated wires to the jumper-cable clamps with the same color coding. Then use cable ties or waxed lacing cord to secure the wires in place as illustrated. As an aid in using Booster Smarts at the project end of the booster cables use black paint or

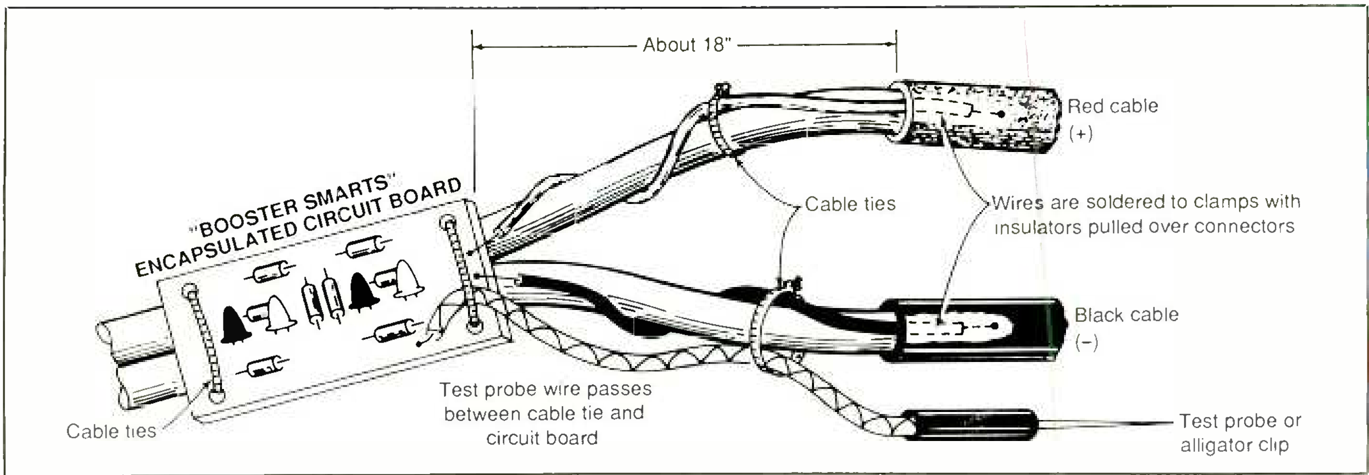


Fig. 4. Booster Smarts circuit-board assembly mounts directly to jumper cables with two plastic cable ties. Label cable clamps at end nearest project assembly "GOOD" and at other end "DEAD" for identification purposes.

permanent marker to put the legend DEAD on the handle of the red-coded cable clamp. Similarly, use white paint to put the same legend on the black-coded clamp. In like manner put the legend GOOD on both cable clamps on the other end of the cables.

Using the Project

There are two ways to use Booster Smarts. These are as follows:

• *Standard Method.* When a vehicle must be jump-started, attach the red-handled cable clamp with the GOOD legend on it to the positive (+) terminal or post of the good battery and the red-handled cable clamp with the legend DEAD on it to the + terminal or post of the dead battery. Then connect the black-handled cable clamp labeled GOOD to the negative (−) terminal or post of the good battery. If the connections are correct, only a green LED should be lit. A lit red LED indicates the wrong polarity and you must transpose the clamps on the battery terminals or posts. If no LED turns on, there is no electrical continuity, which means that you must thoroughly clean away from the battery terminals or cable clamps whatever is interfering with continuity.

Connect the red-handled clamp labeled DEAD to the dead battery's positive terminal. Before making the final connection with the black-handled clamp labeled DEAD, touch Booster Smarts' test-lead probe or clip to the negative terminal on the dead battery. If everything is okay so far, the other green LED should light. If the red LED lights instead, remove the red-handled clamp from the battery's positive terminal and replace it with the DEAD black-handled clamp. If no LED lights, either dirt, oxidation or other debris is interfering with electrical continuity (clean the battery's terminals and the cable's clamps to rectify this) or the battery is so far gone it does not have enough "juice" left to light a LED (which is unlikely).

Once you have only the second green LED lit when the probe or clip is touched to the dead battery's negative terminal, connect the last cable clamp to that terminal. With both green LEDs on, you can proceed to jump starting the vehicle.

• *Trial-and-Error Method.* Without taking any particular care to properly polarize them, connect the jumper cable clamps labeled GOOD to the good battery. If a green LED lights, fine, but if a red LED lights, transpose the clamps on the battery's terminals. Connect the red-handled clamp to either terminal on the dead battery and touch the probe to the other terminal and note which LED lights. If the red LED turns on, move the cable clamp to the other battery terminal.

Connect the final clamp to the one remaining terminal. Whichever method you use to connect the jumper cables to the two vehicles, it is recommended for reasons of safety that you connect the final black-handled DEAD cable clamp to a heavy metal bracket about 18 inches away from the dead battery itself and *not* directly to the battery's negative terminal. Also, make sure that the cables are not on or near pulleys, fans or other vehicle parts that are normally in motion when the vehicles' engines are turned on.

With the booster cables connected as described, start the engine of the vehicle that has the good battery. Run the engine at a moderate speed for several minutes. Then start the engine of the vehicle whose battery is dead.

Thus far, our discussion has assumed that your are dealing with vehicles that both have negative-ground electrical systems. Be aware, though, that there are still quite a few vehicles with positive-ground systems.

The type of grounding system a vehicle has can be checked as follows. Connect the black-handled cable

Jump-Starting Tips

Though "Booster Smarts" can make jump-starting a vehicle safer than without it, keep in mind that the procedure can still be dangerous to perform. Carefully follow the jump-starting instructions in your vehicle's owner's manual and add to them the following:

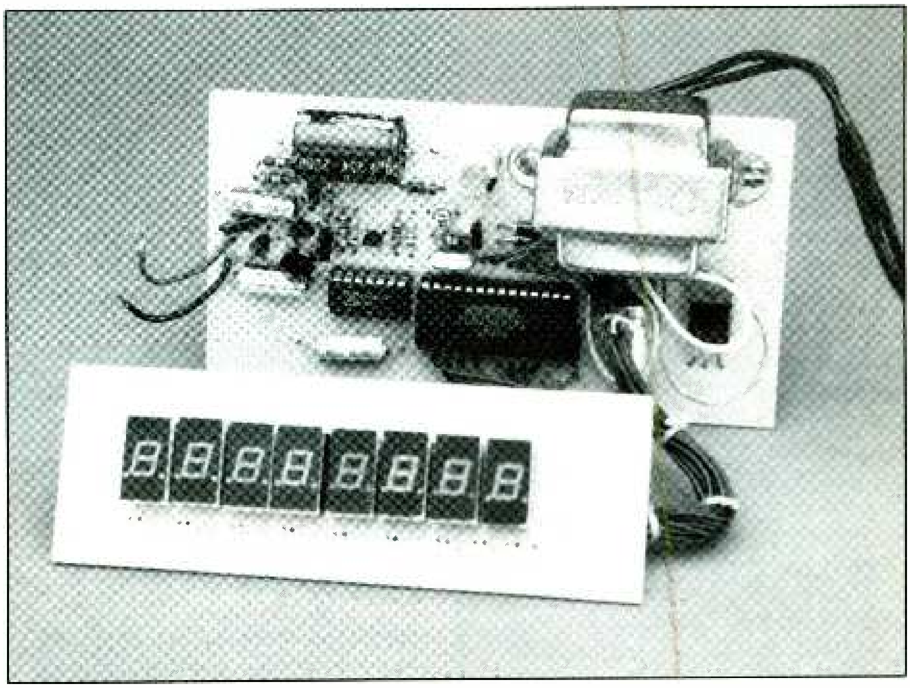
- Use only good-quality booster cables.
- Do *not* use a 12-volt battery to jump start a vehicle that uses a 6-volt battery. A dimly lit LED indicates a probable 6-volt battery.
- When using this project, make sure that both green LEDs are on before making the final connection.
- Do not let the vehicles touch each other—they may have different electrical grounds!
- Turn off the ignition and any lights and accessories that are not absolutely essential to the starting procedure to minimize the load on the good battery.
- Apply the parking brake and place automatic transmissions in park or neutral before starting the engines.
- Shield your eyes and avoid leaning over the battery at start-up.
- Do not expose the battery to an open flame or sparks. As the battery is charging, it gives off explosively combustible hydrogen!
- Make certain that batteries equipped with filler caps have enough fluid in them.
- Do not let battery acid get into your eyes or on your skin.

clamp labeled GOOD to an unpainted metal part of the vehicle and alternately touch the terminals of the vehicle's battery with the red-handled GOOD clamp while observing the Booster Smarts assembly for LED activity. If the green LED lights, the vehicle has a negative ground. However, it the red LED lights, the vehicle has the rare positive ground. To avoid confusion, if a vehicle has a positive-ground electrical system, connect *both* cable clamps directly to the battery's terminals to avoid having to deal with a "ground" altogether. ME

A 10-MHz Frequency Counter

Though low in cost to build, this instrument has excellent performance

By Anthony J. Caristi



If you work on digital circuits a frequency counter can be just as important a test instrument as a multimeter or an oscilloscope. Though most commercial frequency counters may be too expensive for your budget, you can build the 10-MHz instrument to be described for a cost low enough to justify even if you are operating on a tight budget and you need it only occasionally. Moreover, this counter sacrifices very little in terms of quality.

Originally designed to serve as an accessory to the Function Generator featured in the January 1988 issue of *Modern Electronics*, our 10-MHz frequency counter can be used with any other audio or r-f generator as well. It provides an eight-decade LED display and features automatic decimal-point switching, leading-zero blanking and a crystal-controlled timebase. It also has a RANGE switch for selecting 0.01-, 0.1-, 1- or 10-second gate time. Display resolution can be as high as 0.1 Hz, depending on range selected.

About the Circuit

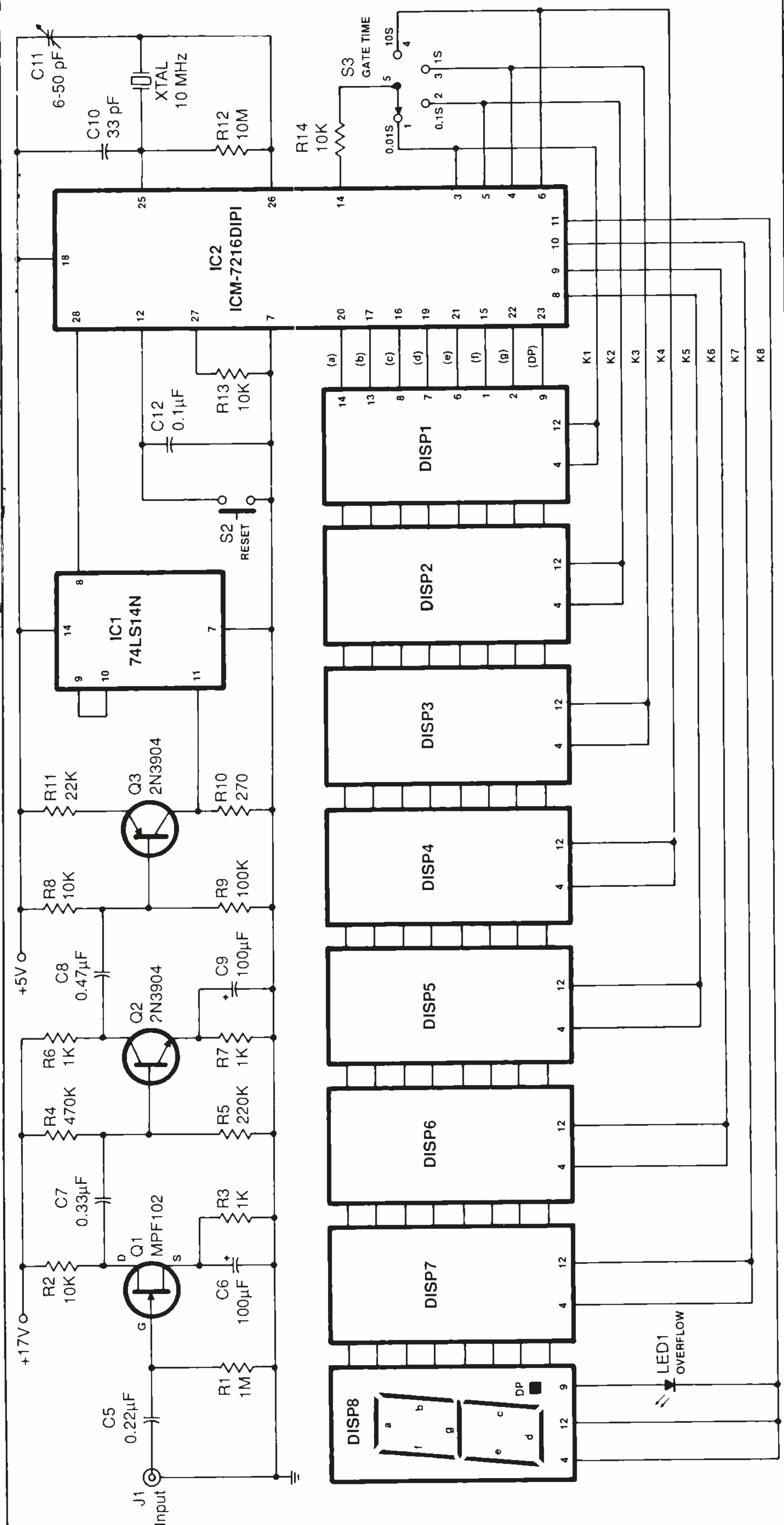
As shown in Fig. 1, the heart of the circuit is the Intersil ICM-7216DIPI frequency-counter chip used for *IC2*. This fully integrated frequency-counter chip has on-board LED display drivers, a high-frequency oscillator, a decade timebase oscillator, an eight-decade data counter and latches. Also on-chip is a seven-segment decoder and eight-digit multiplexer that is capable of directly driving a set of LED numeric displays.

The multiplexing circuitry greatly reduces the number of conductors that must bridge the chip's digit driver outputs with the segment inputs of the multiple-decade LED numeric display. Circuitry within *IC2* automatically drives each digit on a time-share basis so that each digit is driven in sequence with all other digits off. The multiplexing rate is at such a high frequency that all decades that must be active for any given count appear to be on simultaneously.

Designed to operate at TTL levels, *IC2* requires a potential of 0.8 volt or less for a logic low (0) and 2.4 volts or greater for a logic high (1). Since such a voltage excursion is not sensitive enough to assure positive triggering of the counter chip for reliable operation, the input signal must be amplified before being applied to *IC2*. This is accomplished with the three-stage amplifier composed of *Q1*, *Q2* and *Q3* and their associated components.

Field-effect transistor *Q1* provides a very-high input impedance at signal INPUT jack *J1* and some amplification for any ac signal that might appear at this jack. The output of *Q1* is approximately 10,000 ohms, which feeds an amplified version of the input signal into the base of *Q2*.

It is in the *Q2* stage that the bulk of the amplification for the entire preamplifier circuit takes place. With the arrangement shown, any ac signal, applied to the INPUT via *J1*, whose amplitude is 25 millivolts or



more over most of the instrument's frequency range will reliably switch *IC2*'s input to produce an accurate display of its frequency. Since both *Q1* and *Q2* are operated from a 17-volt dc power source, signal levels at the collector of *Q2* are not necessarily at the standard 0- to 5-volt dc levels required by *IC2*.

To provide the necessary transformation to the TTL levels, the output signal taken from the collector of *Q2* is coupled into the base of *Q3*, which is powered from a +5-volt dc power source. A bias network in the base circuit of *Q3* enables this transistor stage to be cut off in the absence of an input signal, with *Q3*'s collector voltage going to 0 volt with reference to circuit ground. The result is that the logic-0 level at *Q3*'s collector is also felt at the pin 11 input of *IC1*. When a signal is applied to *J1* and is sensed as a logic 1, it "toggles" the amplifying network so that a logic 1 also appears at the collector of *Q3*, after undergoing a voltage gain of about 10 to properly drive *IC1* with the required TTL voltage excursion.

Because the frequency counter may be called upon to measure ac signals other than square waves (sine, triangle and even asymmetrical waves, for example), the signal applied to the pin 28 input of *IC2* must be "conditioned" so that it has a sharp wavefront with no hint of oscillation. The transistor amplifying network may not produce a signal at the collector of *Q3* that is fast enough to properly trigger *IC2*'s counting stage.

To assure adequately fast pulses that will reliably trigger *IC2*, a special type of TTL chip is used as an interface. This is Schmitt trigger *IC1*, which also serves as a buffer, which provides a hysteresis effect on signals applied to its input. Hence, if the input signal at pin 11 of *IC1* is a very slowly rising waveform, as might be generated by, say, a low-frequency

Fig. 1. Schematic diagram of basic frequency counter.

PARTS LIST

Semiconductors
D1 thru D4—1N4004 or similar silicon diode
DISP1 thru DISP8—Common-cathode seven-segment LED numeric display (Radio Shack Cat. No. 276-075B or equivalent)
IC1—74LS14N Schmitt-trigger hex inverter
IC2—ICM7216DIPI frequency counter (Intersil)
IC3—LM7805CT +5-volt regulator
LED1—2-volt, 20-milliampere red light-emitting diode
Q1—MPF102 n-channel field-effect transistor
Q2—2N3904 or equivalent npn silicon transistor
Q3—2N3906 or equivalent pnp silicon transistor

Capacitors
C1—330-μF,, 16-volt electrolytic
C2—2,000-μF,, 25-volt electrolytic
C3—1,000-μF,, 16 volt electrolytic
C4,C6,C9—100-μF,, 16-volt electrolytic
C5—0.22-μF, ceramic
C7—0.33-μF, ceramic
C8—0.47-μF, ceramic
C10—33-pF ceramic
C11—6-to-50-pF trimmer (Radio Shack Cat. No. 272-1340 or similar)
C12—0.1-μF, ceramic

Resistors (¼-watt, 5% tolerance)
R1—1 megohm
R2,R8,R13,R14—10,000 ohms
R3,R6,R7—1,000 ohms
R4—470,000 ohms
R5—220,000 ohms
R9—100,000 ohms
R10—270 ohms
R11—22 ohms
R12—10 megohms

Miscellaneous
F1—1-ampere slow-blow fuse
I1—Panel-mount neon-lamp assembly (Radio Shack Cat. No. 272-712 or similar)
J1—Panel-mount BNC-type coaxial connector
S1—Dpdt slide or miniature toggle switch
S2—Spst momentary-action, normally-open pushbutton switch
S3—4-position, nonshorting rotary switch
T1—12.6-volt, center-tapped, 450-milliampere power transformer (Radio Shack Cat. No. 273-1365 or similar)
XTAL—10-MHz microprocessor crystal
Main and display printed-circuit boards; sockets for all DIP ICs and numeric displays; suitable enclosure; holder for F1; ac line cord with plug; terminal strip (optional—see text); small-diameter heat-shrinkable or plastic tubing; lettering kit; machine hardware; coaxial or shielded cable; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Main pc board, $9.95; display board, $9.95; 74LS14N, $2.25; ICM7216DIPI, $34.50; LM7805CT, $2.95; MPF102, $2.50; 2N3904 and 2N3906, $1.50 each; 10-MHz crystal, $7.95. Add $1.50 P&H per order (allow 4 weeks additional processing time for personal checks). New Jersey residents, please add state sales tax.

sine wave, at some point along the rising edge of the waveform the buffer stage will trigger on. It will remain on even though the signal's wavefront may not rise very fast. Also, for the logic level at output pin 10 of *IC1* to revert back to its original level, the input to the buffer must fall significantly below the level that was present at pin 11 when the rising wavefront caused triggering. Thus, the output of *IC1* at pin 8 is guaranteed to be an oscillation-free TTL waveform, which is exactly what *IC3* needs.

Also shown in Fig. 1 is the complete eight-decade numeric display consisting of seven-segment LED indicators *DISP1* through *DISP8* and optional OVERFLOW light-emitting diode *LED1*. When used, this LED turns on during a measurement when the frequency at the input is beyond the counter's ability to display (beyond 10 MHz) with *S3* set to either 1 or 10.

Three switches are the only controls supplied on this instrument. Dpdt POWER switch *S1* (see Fig. 2) turns on and off power to the instrument. Momentary-action RESET switch *S2* is briefly pressed and released to reset the counter to start a new count. Rotary GATE TIME switch *S3* provides a choice of 0.01-, 0.1-, 1- and 10-second gate times to accommodate different count-measuring requirements.

Since the preamplifier circuit and counter chip in this instrument require separate dc power sources of +17 and +5 volts, the power supply, shown schematically in Fig. 2, has been designed to provide both potentials from a single transformer. The +5-volt supply that powers *IC1* and *IC2* must be held within strict amplitude limits. To accomplish this, +5-volt regulator *IC3* follows rectifier *D3/D4* and filter capacitor *C3*. The output from *IC3* is held within the range of +4.75 and +5.25 volts, regardless of variations in ac power-line voltage or load on the circuit.

A half-wave voltage doubler circuit consisting of *D1* and *D2* is driven by half the secondary voltage from power transformer *T1* to generate the +17 volts required by the preamplifier circuit. Clamping action of *D1* prevents the ac waveform at its cathode from going below 0 volt. After this, *D2* rectifies the ac waveform to produce pulsating dc, which is then smoothed to pure dc by filter capacitor *C2* to produce a potential that is about twice the amplitude of that on the positive (+) side of *C3*. The preamplifier circuit draws very little current; hence, the relatively poor regulation of the doubler circuit is not a factor in the performance of the amplifier stages.

Construction

Though you can build the frequency counter on perforated board with holes on 0.1-inch centers and using

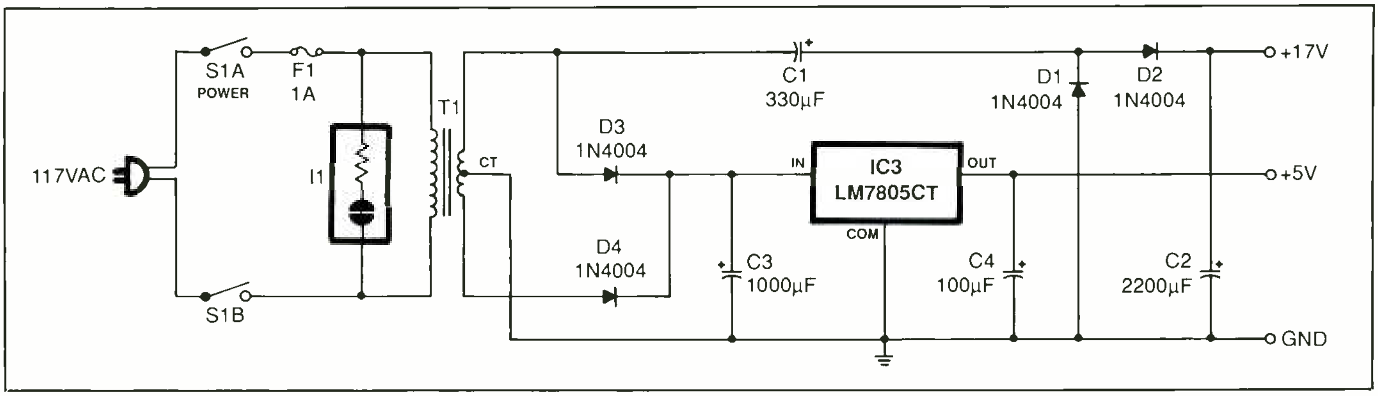


Fig. 2. Schematic diagram of line-operated power supply for frequency counter.

suitable soldering or Wire Wrap hardware, printed-circuit construction is recommended. Use of pc wiring reduces the possibility of wrong connections as well as speeds up the wiring process. In either case, you will need two boards, one for the main electronics and the other for the display system.

You can etch and drill your own single-sided boards for the main electronic and display subassemblies using the actual-size artwork shown in Figs. 3. Alternatively, you can purchase ready-to-wire boards from the source given in the Note at the end of the Parts List.

Bend the pins of regulator *IC3* at a 90-degree angle toward the rear of the device. Plug the pins into the IC3 holes in the main board in the orientation shown in Fig. 4(A). Press the regulator down on the board so that its metal surface lies flat against the top of the board and trace the outline of its mounting hole onto the board. Remove and set aside the regulator. Then use a 5/32-inch drill to bore a hole through the board in the center of the drawn outline.

Begin stuffing the main board with DIP sockets for *IC1* and *IC2* as shown. Though sockets for these ICs are optional and can be eliminated, their small extra cost is well worth the additional investment should you ever have to replace a chip in the future. Install only the sockets—*not* the ICs themselves. The ICs will be installed after you have performed initial checkout.

Next, install and solder into place the resistors, and then rectifier diodes *D1* through *D4*, followed by the capacitors. Make certain that the diodes and electrolytic capacitors are properly polarized before soldering their leads to the copper pads on the bottom of the board.

Now install the MPF102 FET in the Q1, 2N3904 npn transistor in the Q2 and 2N3906 pnp transistor in the Q3 locations. Make certain the leads of these transistors go into the appropriate holes in the board. Then, with the bottoms of the transistor cases about 3/8 inch above the top surface of the board, solder the leads to the copper pads.

Plug *IC3* back into the board and solder its pins to the copper pads. Trim excess lead lengths from all transistors and the regulator after soldering. Use a 4-40 × 1/4-inch machine screw, lockwasher and nut to secure *IC3* to the board via the previously drilled hole.

Trim the leads on power transformer *T1* to 2 inches in length and remove 1/4 inch of insulation from them. Plug the transformer's secondary and center-tap (C.T.) leads into the appropriate holes in the board and solder them into place. Mount the transformer on the board with two sets of 4-40 × 1/4-inch machine screws, lockwashers and nuts. Then plug its primary leads into the appropriate holes and solder into place.

Strip 1/4 inch of insulation from both ends of eight 8-inch and eight 6-inch lengths of stranded hookup wire. Plug one end of the 8-inch wires into cathode holes K1 through K8 and the 6-inch wires into segment holes a through g, and DP. Solder each wire into place as you install it.

As above, prepare eight 7-inch stranded hookup wires. Plug one end of each of these wires into the holes in the board labeled S1, S2, S3,1 through S3,5 and F1. Solder all wires into place as you install them. Keep in mind that the project contains a high-gain, high-frequency amplifier section. Therefore, if you decide to wire on perforated board, follow the component layout shown in Fig. 4(A) as closely as possible. Also, keep all component leads as short as possible. Temporarily set aside the main circuit-board assembly.

Place the display board in front of you in the orientation shown in Fig. 4(B). It is important that you use sockets for mounting the seven-segment displays on this board. Fortunately, all you need are the low-cost conventional sockets commonly used with DIP ICs. Though the displays themselves have pins missing on them, you can use IC sockets without having to modify them. (Note: If you use the display board from the source given in the Note at the end of the Parts List, you must first remove pins 3, 5, 10 and 11 from all eight sockets before installing them on the display board.)

Install and solder the sockets into place. Plug the left-most numeric display into its socket. Then, making certain that you plug the cathode (K) lead into the hole shown and the anode lead into the other hole for *LED1*. Push the LED down toward the surface of the board until the top of its domed case is at the same level as the front surface of the display, solder its leads into place and clip away any excess lead lengths. Unplug the LED display from the socket and set it aside.

You can house the project in any type of enclosure of your own choosing as long as it is large enough to accommodate both circuit boards without crowding and has panel space on which to mount INPUT jack *J1*, neon lamp assembly *I1*, POWER switch *S1*, RESET switch *S2* and GATE TIME switch *S3*.

If you use a molded plastic enclosure that has a removable metal panel, replace the panel with a 3⁄16- or 1⁄4-inch-thick transparent plastic panel so that you do not have to cut a window in it for the numeric displays and OVERFLOW LED. Transparent red is best, but clear plastic with a thin red filter behind and a sheet of matte-black paper with a window slot cut out to block out view of the interior is okay, too. If you go this route, substitute longer screws for the ones provided, if necessary. Of course, you can use an all-metal enclosure if you wish, machining it as needed.

Whichever enclosure type you choose, drill mounting holes in its front panel for the switches, jack and neon-lamp assembly. Plan your layout so that *I1* is near *S1*. Your choice of fuse holder, whether bayonet or block type, should mount on the enclosure's rear panel. Mount the holder anywhere near the line-cord entry hole, where it will not interfere with the main circuit-board assembly.

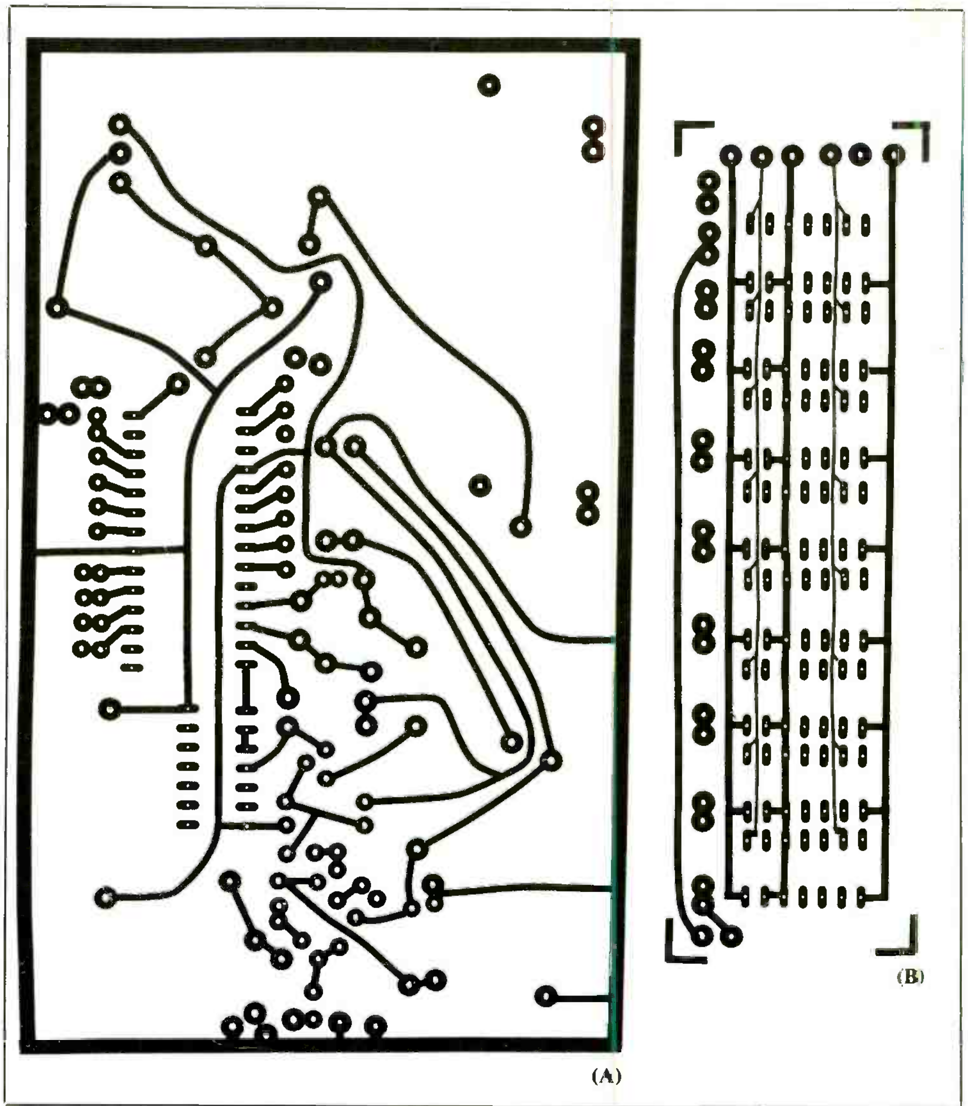


Fig. 3. Actual-size etching-and-drilling guides for main and display boards.

Plug the free ends of the a through g segment, D.P. and K1 through K8 cathode wires on the main board into the respective holes in the display board and solder into place. Gather these wires into a neat bundle and secure them together with three or four small plastic cable ties or with waxed lacing cord.

Mount the jack, switches, neon-lamp assembly, and fuse holder in their respective holes (make rotary switch *S3* only finger tight). If you are using a metal enclosure, line the ac cord's entry hole with a small rubber grommet. Tightly twist together the fine wires of both conductors of the ac line cord and lightly tin with solder. Pass the free end of the line cord through the hole and tie a strain-relieving knot in it about 6 to 8 inches from the free end inside the enclosure.

Crimp but do not solder the ac line cord to the toggle lugs of *S1*. Use a length of fairly heady-duty stranded hookup wire to bridge from the free lug on one side of *S1* to one lug on the fuse holder and solder both connections. (Note: Prepare the ends of all stranded hookup wires as detailed above.)

Crimp one neon-lamp assembly lead and the free end of the wire com-

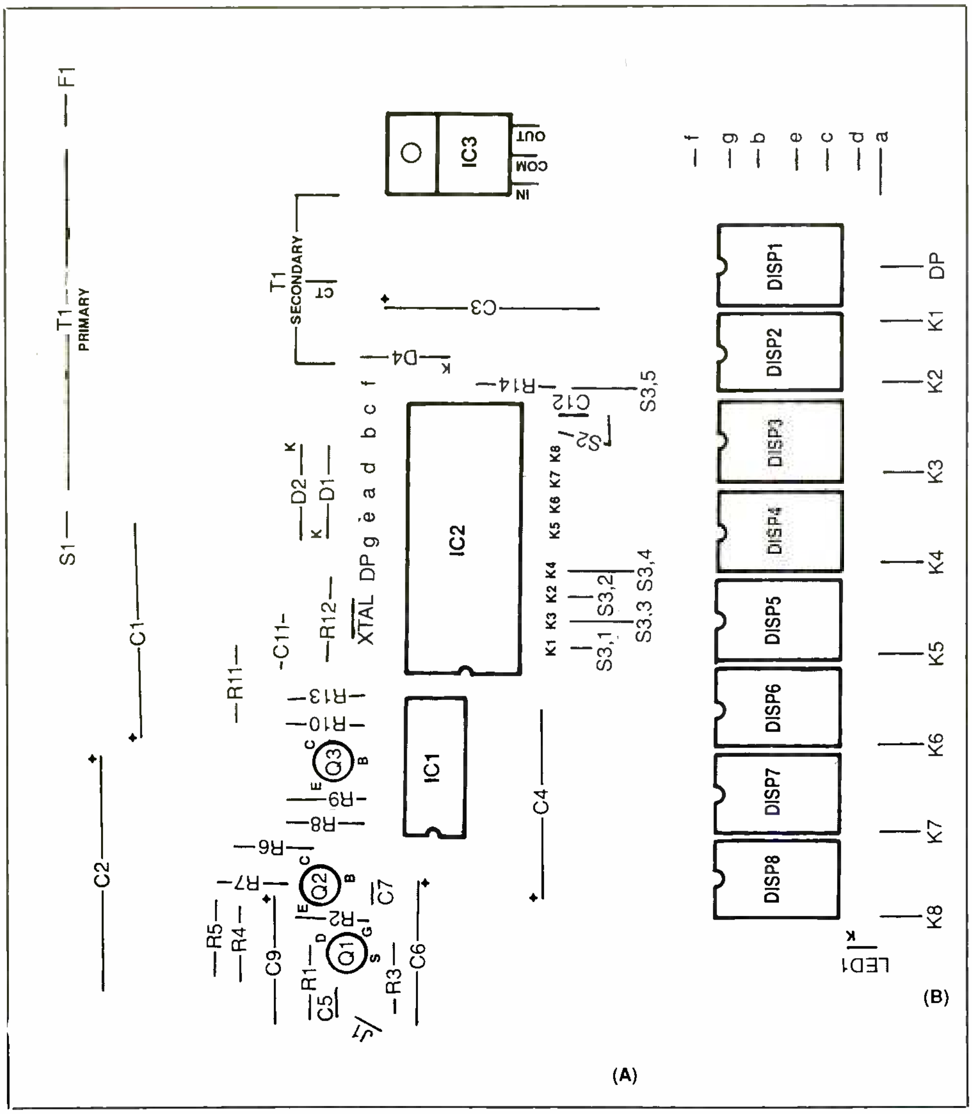


Fig. 4. Wiring guides for main and display boards.

ing from the S1 hole on the main circuit-board assembly to the remaining *S1* lug and solder the connection.

Prepare a long enough stranded hookup wire to reach from the free lug of the fuse holder to the free lead of *I1*. Slide a 1-inch length of small-diameter heat-shrinkable tubing over the free lead of *I1*. Crimp together the free *I1* lead and one end of the wire just prepared and solder the connection. Slide the tubing over the connection to insulate it and shrink into place.

Locate the free end of the wire coming from the F1 hole on the main board. Crimp it and the free end of the wire just connected to *I1*'s lead to the remaining lug on the fuse holder.

Locate the free ends of the wires coming from holes S2 and GND on the main circuit board and connect and solder them to the lugs of pushbutton switch *S1*. Likewise, locate the free ends of the wires coming from the holes labeled S3,1 through S3,5. Connect and solder the S3,5 wire to the rotor lug of rotary switch *S3*. Then, making sure that you wire them to the switch in the proper sequence, connect and solder the remaining wires to the stationary lugs of the switch (see Fig. 1 for lug numbering scheme).

Determine how long must be the coaxial cable that goes from *J1* on the front panel to the appropriate holes in the main circuit board and add about an inch to allow for slack. After cutting the cable to length, trim 1 inch of outer plastic jacket from both ends. Separate the shield wires at both ends back to the outer plastic jacket, tightly twist them together and sparingly tin with solder. Then strip ¼ inch of insulation from the inner conductor at both ends and, if necessary, twist together the fine wires at both ends and sparingly tin with solder.

Plug the inner conductor at one end of the coaxial cable into the main board hole labeled J1 and solder into place. Plug the shield at that end into the adjacent GND hole and solder it into place. Then connect and solder the inner conductor and shield at the other end of the cable to the inner lug and ground tab of *J1*. If *J1* is to mount on a plastic panel do the following to avoid heat damage to the panel. Dismount the connector and slide the anchoring nut and grounding tab ring over the free end of the cable. Pass the cable through the connector's mounting hole and then connect and solder the shield to the grounding tab in free air. After the connection has cooled, remount the connector on the panel.

Using suitable hardware and spacers, mount the main circuit-board assembly to the floor of the enclosure. Then, making certain that the numeric displays and OVERFLOW LED are centered in the display window, mount this assembly into place. Install the fuse in the holder.

Use a dry-transfer lettering kit or plastic label maker to label the various switches according to function and position. Also label *J1* INPUT and *LED1* OVERFLOW.

Initial Checkout

To perform preliminary checkout, you will need a voltmeter that has an input impedance of at least 20,000 ohms/volt. Any VTVM, TVM or DMM will do fine. Make sure that *IC1* and *IC2* are not installed in the sockets on the main circuit board and that none of the LED numeric displays are installed in the sockets on the display board.

Before proceeding, a note of caution is in order. Keep foremost in mind that potentially lethal 117-volt ac line power appears on the lugs of POWER switch *S1*, lugs of *F1*'s fuse holder, leads of *I1* and connections to *T1*'s primary. Therefore, exercise extreme caution when reaching into the project to make connections when power is applied.

Clip the voltmeter's common probe to the negative (−) lead of *C3* on the main board and plug the project's line cord into an ac outlet. Indicator lamp *I1* should now be on. Set *S1* to ON. Touch the meter's "hot" probe to the positive (+) lead of *C3* and note that the reading obtained is +8 to +9 volts. Touching the meter's "hot" probe to the positive (+) lead of *C4* should yield a reading of approximately +5 volts. You should obtain the same reading at pin 8 of the *IC1* socket and pin 18 of the *IC2* socket.

Without removing the meter's common probe from the negative lead of *C3*, touch the "hot" probe to the positive lead of *C2*. This time, you should obtain a reading of approximately +17 volts.

If you do not obtain the proper voltage readings at any of the points detailed, or *I1* does not light, power down the project and unplug its line cord from the ac receptacle. Carefully check the orientations of *D1* through *D4*, *C1* through *C4* and *IC3*.

If all power supply components are properly oriented, there may be a short circuit on one of the supply outputs. To check this out, use an ohmmeter to check the +5-volt, +8-volt and +17-volt rails to circuit ground for zero indicated resistance. Whatever may be the cause of the problem, rectify it before proceeding.

Once you know that the power-supply portion of the project is operating as it should, carefully install the ICs and numeric displays in their respective sockets. Make certain that each is properly oriented before plugging it in and that no pins overhang the socket or fold under between device and socket as you push each home. When installing the numeric displays in their sockets, note that the decimal points are diagonally opposite pin 1 in all cases and should be located at the lower-right when installed.

With the ICs and numeric displays installed, plug the project's line cord back into the ac receptacle and set the POWER switch to ON. One decimal point in the display should now be lit, and you may see a random count in the display if the INPUT jack has nothing connected to it.

Set GATE TIME switch *S3* to the 0.1 second position and apply an audio or r-f signal to the project from a signal generator through the INPUT BNC connector. This signal's frequency must be less than 10 MHz and at least 0.1 volt in amplitude. Always use sufficient signal level to obtain a steady, reliable reading, but avoid overdriving the circuit with signals that have too great an amplitude.

Note that the display indicates the frequency in kilohertz (kHz) and that it continuously updates every second or so as you vary the generator's frequency. Rotate the GATE TIME switch to each of its other positions and note that the decimal point automatically goes to the proper position in the display to provide the correct kHz reading. Also note that when you need full resolution, you can use as short a gate time as desired consistent with required resolution.

Now set the GATE TIME switch to 10 seconds and press and release RESET switch *S2*. The display will initially reset to zero and a new count will begin. The RESET switch allows you to start a count whenever you wish and is functional on all settings of the GATE TIME switch.

If the signal generator you are using is capable of producing frequencies beyond 10 MHz, set it to about 11 or 12 MHz. Set the GATE TIME switch to 1 second. Then press and release the RESET switch. When the display updates, the OVERFLOW LED should light to indicate that the total number of input pulses during the 1-second gate time has exceeded the counter's capacity. When this occurs during an actual measurement, you can still obtain a count by switching to a 0.1- or 0.01-second gate time.

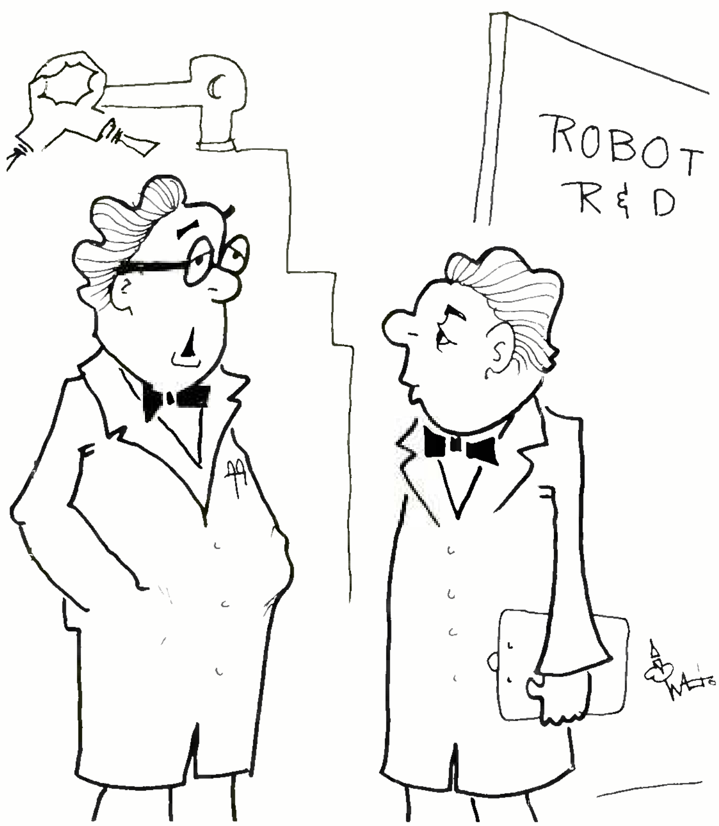
If your frequency counter does not operate as described, use an oscilloscope to troubleshoot it. Check pin 26 of *IC2* for presence of the 10-MHz clock waveform. This waveform should have an amplitude of 3 volts peak-to-peak and, if present, indicates that the oscillator is operating. Next, check the K1 through K8 outputs from *IC2* for the multiplex drive signals that should be occurring at a 500-Hz rate.

Check pin 28 of *IC2* to ascertain that there is a TTL-level signal (about 0 to 4 volts) present here when a signal is applied to the INPUT jack. Check the display board very carefully to be sure that none of the closely spaced IC pads and traces is shorted to another pad or trace.

One circuit adjustment that can be made to obtain the greatest possible accuracy from the project—adjustment of *C11* to put the crystal oscillator exactly on the proper frequency. One way to do this is to use a commercial frequency counter known to be accurate. Simply use the commercial instrument to measure the oscillator frequency as you adjust *C11* for an exact 10,000,000-Hz count. As you do this, you must not disturb the oscillator with a direct connection. Therefore, it is best to use inductive coupling with a pickup loop. Alternatively, you can apply the same signal to the inputs of both instruments and adjust *C11* until both give the same displayed count.

An alternative allows you to use a shortwave receiver to set oscillator frequency without requiring use of an oscilloscope. Set the receiver to pick up the WWV transmission on 10 MHz. With a pickup loop made up of one or two turns of wire at the end of a piece of coaxial cable, couple the counter's oscillator signal to the antenna of the receiver so that a beat frequency is heard in the speaker. Adjust *C11* for zero-beat, at which time the counter's oscillator will be as close to 10 MHz as possible.

A note about accuracy: Your counter will measure frequency with an accuracy that is equal to the accuracy of the crystal used for *XTAL*, +1 count. Since the typical microprocessor crystal, such as used in this project, has a rated accuracy of 0.005 percent, this instrument is capable of resolving a frequency with an error of less than 50 parts per million. **ME**



"Don't call small parts, little . . . say 'micro' . . . it sounds more technical."

A Nap Timer

A low-cost programmable short-time wake-up alarm for senior citizens and others who must take therapeutic naps

By Charles Shoemaker, Ph.D.

Senior citizens and older people who have health problems are often required to take a nap or rest as part of daily living. In this situation, a short nap is preferable over the single night-long sleep most of us are accustomed to taking. Timing the nap cycle with a conventional alarm clock leaves much to be desired. What these people need is a simple-to-use programmable timer that emits a pleasant audio wake-up tone at the end of the timed cycle. This article describes how to build such a Nap Timer.

With our Nap Timer, you have a choice of different timed nap cycles. The project is low in cost and is easy to build, thanks to its simplicity and to printed-circuit-board construction.

About the Circuit

The complete schematic diagram, minus its plug-in dc power supply, is shown in Fig. 1. In this circuit, quad 2-input AND-gate integrated circuit *IC1* is wired to operate as a sequential timer. Keep in mind that, under the rules of logic, the output of an AND gate can go high only when both inputs are also high.

Pinouts for the 4081 quad 2-input AND gate are as follows:

- Gate A (inputs on pins 1 and 2, output on pin 3)
- Gate B (inputs on pins 5 and 6, output on pin 4)
- Gate C (inputs on pins 8 and 9, output on pin 10)
- Gate D (inputs on pins 12 and 13, output on pin 11)
- V+ (pin 14)
- Ground (pin 7)

Therefore, with the circuit wired as shown, input pins 1, 6 and 9 of AND gates A, B and C are held high at all times. Under these conditions, for there to be a high on output pins 3, 4 and 20, there must also be a high on input pins 2, 5 and 8, respectively.

When power is first applied by closing *S5* and with *S1* open, input pin 2 of gate A is initially held low but slowly goes positive when *C1* begins to charge. Rate of charge is determined by the RC time constant of *R1*, *R2* and *C1*. A value of 3 megohms each for *R1* and *R2* (6 megohms total) and 500 microfarads for *C1* yields a time constant of 50 minutes, derived from the formula: t = RC/60, where *t* is in minutes, *R* is in megohms, *C* is in microfarads, and 60 is the number of seconds required to yield a result in minutes (instead of the usual seconds). Therefore, t = (6 megohms × 500 microfarads)/60 seconds = 3000/60 = 50 minutes, which is the amount of time needed for *C1* to charge to 63 percent of the +5-volt power-supply potential. Closing *S1* places only *R1* in the network and reduces the resistance in the network to only 3 megohms and the period to 25 minutes.

Since only 50 percent of the applied voltage, in this case 2.5 volts, is needed for gate A's output at pin 3 to go high, the time period for this to occur will be less than 50 seconds. The above formula must be modified as follows: t = 0.79 RC/60. Hence, the actual time it takes for a high to appear at pin 3 of *IC1* is: t = 0.79 × 6 × 500/60 = 39.5 minutes, which we round out to 40 minutes. (With *S1* closed, this becomes 20 minutes.)

When the pin 3 output of gate A goes high, the second stage of the sequential timer begins. Now the +5 volts at pin 3 charges *C2* through *R3*, until the charge reaches +2.5 volts on input pin 5 of gate B and causes output pin 4 to go to +5 volts. Once again, the time it takes for this to occur depends on an RC network (*R3* and *C2*). The same rules apply to this RC network as detailed above for the first network. Hence, t = 0.79(RC/60) = approximately 13 minutes.

With +5 volts on the pin 4 output of gate B at +5 volts, the final stage of sequential timing is initiated. That is, *C3* begins to charge through *R4*. Here, the time constant is: t = 0.79 (RC/60) = approximately 4 minutes. That is, it takes 4 minutes for the potential on input pin 8 to rise sufficiently for a high to appear on the pin 10 output of gate C.

The high on pin 10 of *IC1* is coupled directly to the enable input of *IC2* and triggers on this 555 timer. The timer is wired to output a steady tone at pin 3, which is coupled through *C5* to the speaker. The time it takes for the tone to be emitted is the sum of the RC time constants detailed above: 40 + 13 + 4 = 57 minutes. This is an approximate figure; it may be slightly greater or slightly less, due to tolerances of the components used in the RC networks. In any case,

PARTS LIST

Semiconductors

IC1—CD4081 CMOS quad 2-input AND gate
IC2—555 timer
IC3—7805 +5-volt regulator
Q1 thru Q3—2N2222 or similar switching transistor (optional—see text)

Capacitors (25 WV)

C1—500-μF electrolytic
C2—300-μF electrolytic
C3—100-μF electrolytic
C4—0.01-μF disc
C5—47-μF electrolytic
C6—0.047-μF disc

Resistors (¼-watt, 10% tolerance)

R1,R2,R4—3 megohms
R3—3.3 megohms
R5,R6—10,000 ohms
R7—22,000 ohms
R8—1 megohm (optional—see text)
R9—2.2 megohms (optional—see text)
R10—4.4 megohms (optional—see text)
R11—6 megohms (optional—see text)
R12—1,000 ohms (optional—see text)

Miscellaneous

B1—9-volt battery
J1—Chassis-mount power connector for external dc power supply
S1,S5 thru S10—Miniature spst slide or toggle switch (S7 thru S10 are optional and can be replaced with single 4-position nonshorting rotary switch—see text)
S2 thru S4—Normally open, momentary action spst pushbutton switch
SPKR—2" miniature 8-ohm speaker
Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure; +9- to +12-volt dc plug-in power supply; silicone adhesive; lettering kit and clear acrylic spray; 9-volt battery snap connector and holder; machine hardware; hookup wire; solder; etc.

the time is roughly 60 minutes, or one hour.

If you wish to have other nap time periods available, you can incorporate into the Timer the resistor and switch arrangement shown as *R8* through *R11* and *S7* through *S10* in

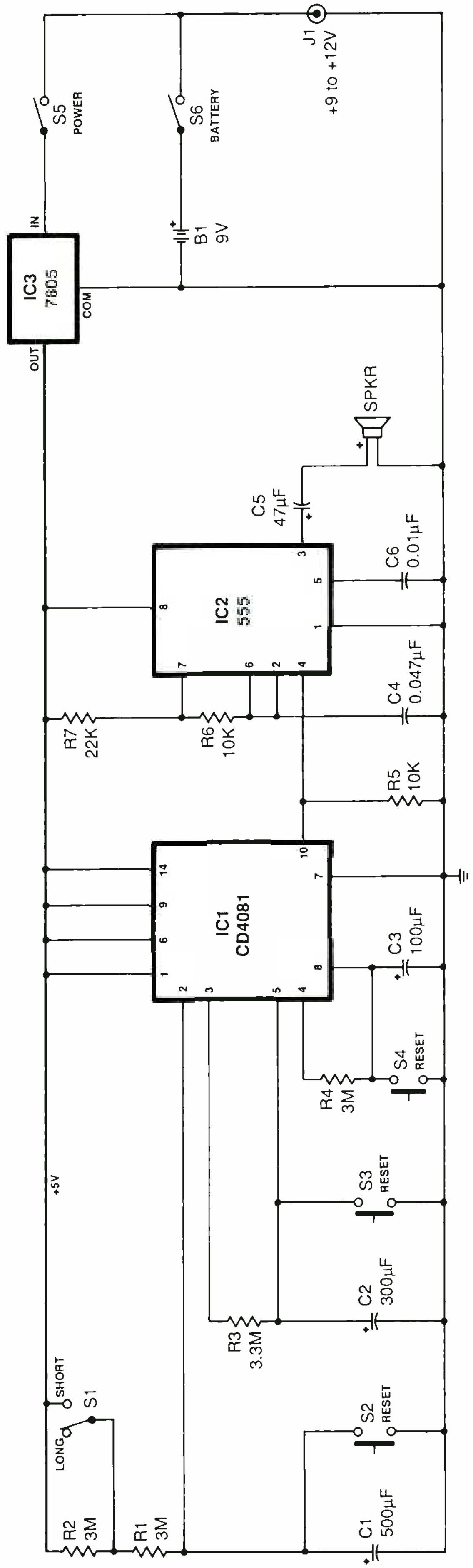


Fig. 1. Schematic diagram of the basic Nap Timer circuit.

Fig. 2 to give you a choice of 20, 30, 60, and 90 minutes. Although separate switches are shown for *S6* through *S9*, you can easily substitute a four-position, nonshorting rotary switch to provide the same selections. Simply wire the rotor contact to *IC1* pin 2 and the individual stationary contacts to the resistors.

Upon wake-up, you simply set POWER switch *S5* to "off" to shut off the project. doing this allows the charges on the electrolytic capacitors to slowly bleed off. Returning to Fig. 1, switches *S2*, *S3* and *S4* provide a low-cost means of quickly discharging *C1*, *C2* and *C3*. In use, you simply press all three switches for a couple of seconds after turning off the project.

A slightly more costly reset arrangement is shown in Fig. 2. Here, transistors *Q1*, *Q2* and *Q3*, resistor *R12*, and RESET pushbutton switch *S10* provide a means for resetting the Nap Timer at any time while it is operating. To reset the circuit, you simply press and release the RESET switch, which causes any charges on *C1*, *C2* and *C3* to discharge to ground through *Q1*, *Q2* and *Q3*, respectively.

Power for the Nap Timer is supplied by a commonly available 6- to 9-volt dc plug-in power supply, which connects to the circuit through POWER jack *J1*. Incoming +9 to +12 volts is regulated to +5 volts by *IC3* for distribution as needed to the various elements in the circuit. Battery *B1* and BATTERY switch S6 permit the Nap Timer to be used where no ac power is available. To use the battery supply, you must close both POWER switch *S5* and BATTERY switch *S6*.

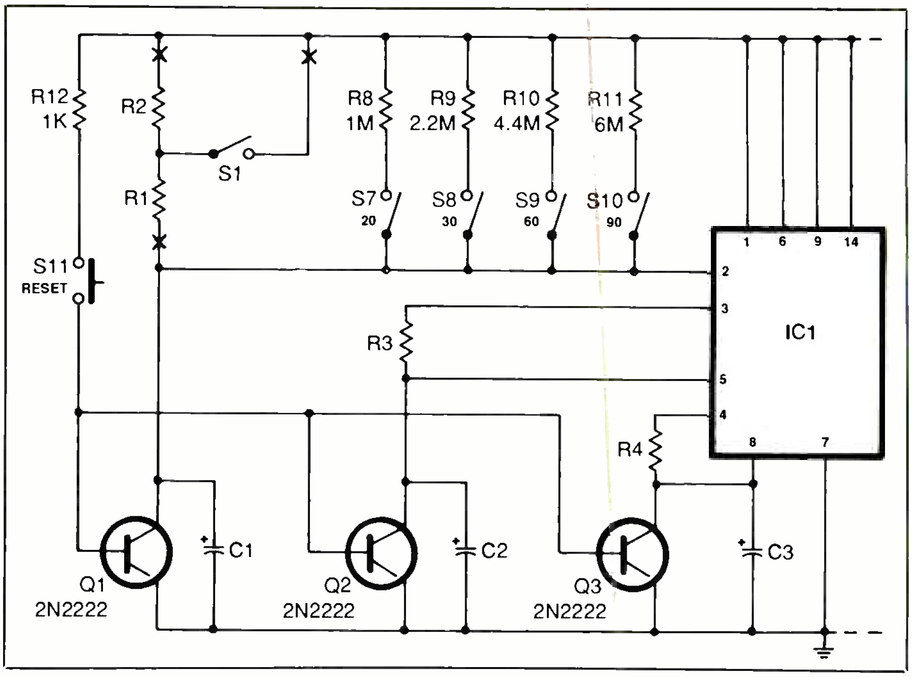


Fig. 2. To the basic circuit, you can add multiple time selection options via R8 through R11 and S7 through S10 and a reset function while the project is powered via R12, S11 and Q1/Q2/Q3.

Construction

There is nothing critical with regard to component layout in the Nap Timer. Therefore, you can use any wiring technique that suits you. If you wish printed-circuit construction, you can use the actual-size etching-and-drilling guide shown in Fig. 3 to fabricate your own pc board. Alternatively, you can use perforated board that has holes on 0.1-inch center and suitable Wire Wrap or soldering hardware to mount and wire the circuit.

Note in the Fig. 4 wiring guide that the pc board has complete facilities for both the selectable-time and transistor-operated reset functions. If you wish, you can incorporate either or both options into your project or leave them out as you see fit.

The following construction procedure is for pc wiring. If you use point-to-point wiring, the procedure is similar and component layout on the board is roughly the same as shown in Fig. 4. The only difference is that you must hard-wire the interconnecting "traces" that are on the pc board.

Begin populating the board by installing and soldering into place sockets for *IC1* and *IC2* in the indicated locations. Do *not* install the ICs in the sockets until after you perform voltage checks upon completion of wiring. Then do the same for the resistors and capacitors. Be sure to check the polarization of the electrolytic capacitors before soldering their leads to the pads on the bottom of the board.

If you have decided to incorporate the transistors, resistor and switch for the reset function, install *R12*, *Q1*, *Q2* and *Q3* in the indicated locations. Make certain that the transistors are properly based before soldering their leads to the copper pads. If you decide against using the transistors, leave the Q1 through Q3 holes vacant.

Assuming you want selectable times, install *R8* through *R11* in their respective locations. If you do this, eliminate *R1*, *R2* and *S1*. Then, taking care to properly base it, install and solder into place *IC3*.

Prepare 5-inch lengths of hookup wire as needed for the switches, speaker and power jack by stripping ¼ inch of insulation from both ends.

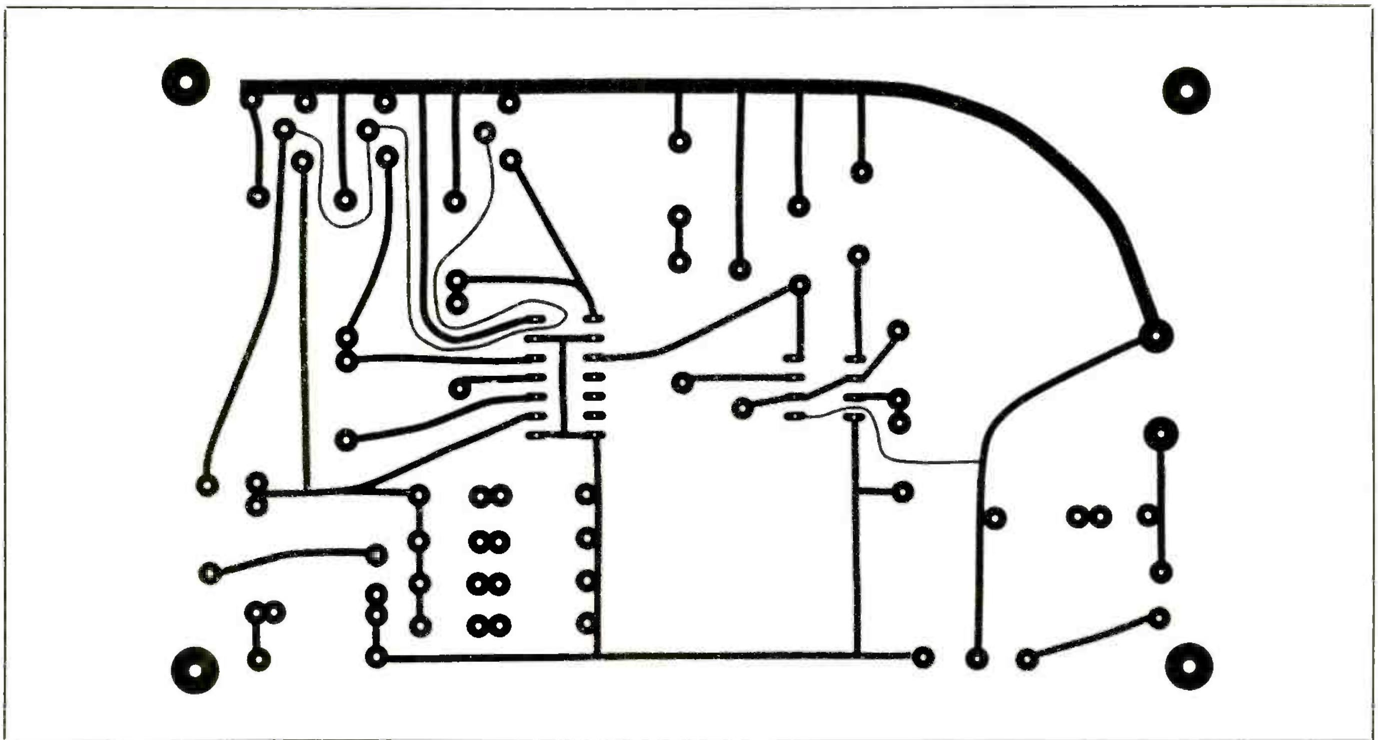


Fig. 3. The actual-size etching-and-drilling guide includes facilities for both options to be installed.

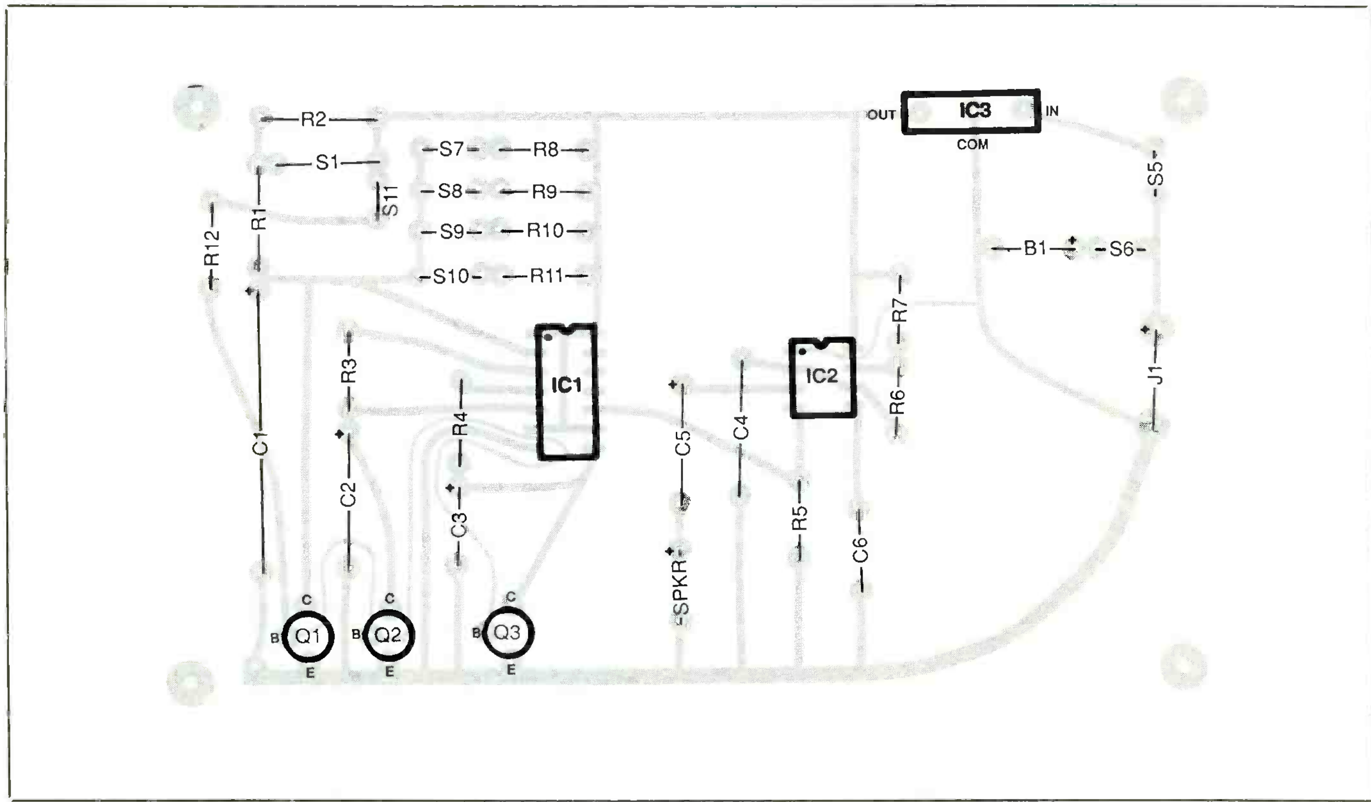


Fig. 4. Wiring diagram for pc board (use this as a rough guide to component layout if you use perforated-board construction). If you incorporate multiple nap-time selection eliminate R1, R2 and S1. If you do not include the transistors, wire S2, S3 and S4 in place of Q1, Q2 and Q3 using the collector and emitter pads for the connections.

For the "no-frills" version of the project, first plug one end of six of these wires into the holes labeled Q1 C, Q1 E, Q2 C, Q2 E, Q3 C and Q3 E (the other ends of these wires will connect to *S2*, *S3* and *S4*). Then do the same with the holes labeled SPKR + and SPKR –, J1 + and J1 –, S1, S5 and S6.

Use of the time-selection arrangement requires that one end of the hookup wires be plugged into the holes labeled S6 through S9 near R8 through R11. If you are using separate switches for *S7* through *S10*, you must also install and solder into place hookup wires for the other S7 through S10 pads. On the other hand, if you are using a rotary switch, a single wire to any of these last four pads is needed.

When the circuit-board assembly is fully wired (with *IC1* and *IC2* still not installed in the sockets), carefully inspect it for poor soldering and solder bridges between closely spaced pads and conductors. Reflow the solder on any connection that is suspicious and use solder wick or a vacuum-type desoldering tool to remove solder bridges. Also, double check the basing of the transistors and *IC3* and the polarities of the electrolytic capacitors.

Tightly twist together the fine wires of both conductors coming from the 9-volt battery snap's connector and tin with solder. Then plug the red- and black-insulated wires into the holes labeled B1+ and B1–, respectively and solder into place.

You can use any type of enclosure you wish, as long as it is large enough to accommodate the circuit-board assembly and battery in its holder and has panel room for mounting the various switches used, the speaker and the power jack. Machine the enclosure accordingly. Drill at least two dozen small holes in the speaker mounting area for the sound to escape.

Before mounting anything into place, label the switch and jack locations according to the legends in Figs. 1 and 2. For the power jack, use the legend +9V to +12V. If you use dry-transfer legends, spray at least two *thin* coats of clear acrylic over them to protect them from scratches. Allow each coat to completely dry before spraying on the next.

When the acrylic spray has completely dried, mount the components, battery holder and circuit-board assembly in their respective locations. Do *not* install *IC1* and/or *IC2* in their respective sockets.

Locate the free ends of the wires coming from the holes labeled S5 and connect and solder them to the lugs of the POWER switch. Do the same for the wires coming from the holes labeled S6 and the BATTERY switch. If this is a "bare-bones" version, connect and solder the free ends of the wires coming from the holes labeled S2, S3 and S4 to the individual RESET switches. Similarly, connect and solder the free ends of the wires coming from the S1 holes to the lugs of the time-selector switch *S1*. Finally, connect and solder the free end of the J1+ and J1– wires to *J1*, taking care to observe proper polarity.

If your project makes use of multiple time selection, connect and solder the free ends of the S7 through S10 on the *IC1* pin 2 side to the bottom lugs of the selector switches. Should you be using a rotary switch instead of individual switches, connect and solder the single wire from this common point to its rotor lug. Then connect and solder the free ends of the remaining S7 through S10 wires to the upper lugs on the selector switches or appropriate lugs on the rotary switch. (Bear in mind that with this option installed *R1*, *R2* and *S1* should *not* be installed on the board.)

Finally, connect and solder the free ends of the speaker wires to the lugs on the speaker. The SPKR+ wire goes to the "hot" speaker lug, the SPKR– wire to the unidentified speaker lug. To mount the speaker, run a bead of silicone adhesive around the perimeter of the speaker and press it into place on the enclosure's panel, directly behind the holes you drilled for the sound to escape. Allow the adhesive to fully set.

Checkout & Use

With *IC1* and *IC2* still not installed in their respective sockets, snap the battery connector onto a 9-volt battery and slip the battery into its holder. Set both POWER switch *S5* and BATTERY switch *S6* to "on" and use a dc voltmeter or a multimeter set to dc volts to check the voltages at pins 1, 6, 9 and 14 of the IC1 socket, pins 7 and 8 of the IC2 socket and pin 3 (OUT) of *IC4*. For these measurements, connect the meter's common probe to the negative (–) lead of *C1* and use the "hot" probe to touch the indicated points in the circuit.

Repeat the above measurements with the BATTERY switch set to "off," the POWER switch set to "on" and a 9- to 12-volt dc plug-in power supply plugged into *J1*. The power supply should be plugged into an ac outlet for this test.

If you do not obtain the proper readings at any or all specified points in the circuit, power down the project and check for wiring errors, components installed in the improper locations, poor soldering, etc. Rectify the problem before proceeding.

Once you know that the circuit has been wired correctly, power down and allow the charge to bleed off *C1*. Then carefully install the ICs in their respective sockets. Make sure the ICs are properly oriented and that no pins overhang the sockets or fold under between sockets and ICs.

Now that the project is ready to be used, you can check out its operation. You do not need test instruments to do this. Simply set the POWER switch to "on" and, if you are using the battery for the test, the BATTERY switch to "on" as well. Use the shortest time setting for this test.

Depending on the time selected, you will hear the audio tone at the end of the selected period.

When using the Nap Timer, all you need do is select the desired nap period. If you should start a nap-timing cycle before you are ready to take a nap, turn off the project and press the three RESET switches for a second or so to discharge the capacitors in the RC timing network and then turn on the power again when you are ready for your nap. If you have the reset transistors installed, all you need do to reset the Nap Timer to start a cycle is to momentarily press and release the single RESET switch. Do this just as you are ready to take your nap.

When the wake-up tone sounds, simply reach over and set the POWER switch to "off."

There are two *caveats* to keep in mind. One is that when powering the Nap Timer from its internal battery, always do so with the plug-in dc power supply unplugged from the project. If you leave the power supply plugged in, the battery's charge will be depleted much more rapidly because the supply will place a load on it. The other *caveat* is that you always keep the BATTERY switch set to "off" when using the external dc power supply.

When operated from its internal 9-volt battery, the Nap Timer draws only about 4 milliamperes on standby but considerably increases its current demand when the tone circuit is operating. If you immediately disable the tone circuit upon wake-up, the battery should last quite a long time. **ME**

LETTERS . . . *(from page 5)*

room temperature instead of LN2, and at various levels of coverage. See what happens.

Charles H. Chandler, P.E.
Malden, MA

• Your interpretation of the result of cooking the thorium sample to liquid nitrogen temperatures is in error. The thorium is an alpha (helium 4 nucleus) emitter. Alpha particles are easily stopped by any barrier and the liquid nitrogen in the cup around the sample simply attenuated the intensity by 50%. Only electron capture decay rate has shown any dependence on the physical surroundings of the radioactive nuclei involved. In this case, the decay rate is decreased in the presence of bonds to atoms of strongly electronegative elements.

David G. Hennings
Crete, NE

• As a chemist with some passing familiarity with radioactivity, I must take more than mild exception to Mr. Mims' recent (April '88) remarks in "Electronics Notebook." He would have us conclude that radioactivity declines to zero as temperature approaches absolute zero. It doesn't!

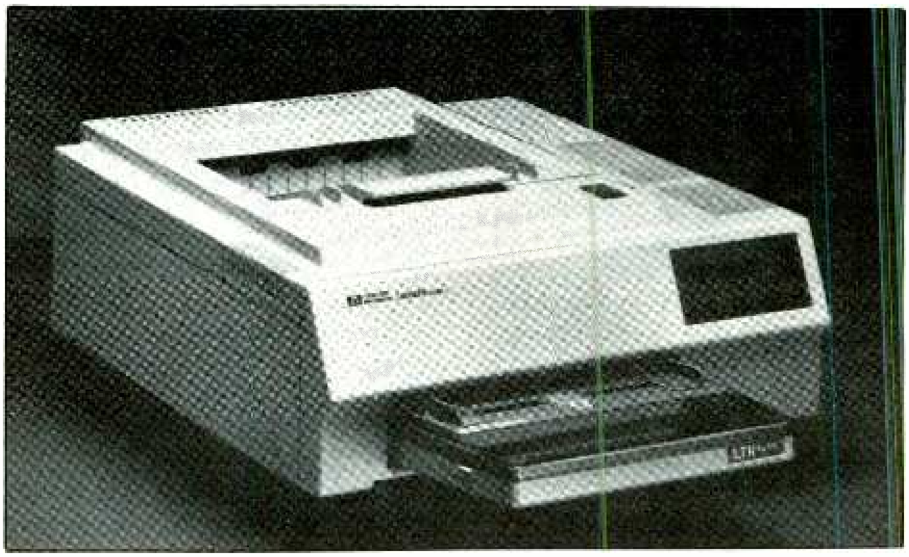
Mr. Mims made two errors. First, he overinterpreted his data without confirming it; second, he (at least subconsciously) assumed that radioactivity is a chemical phenomenon, which is not true. To behave as he concludes, radioactivity should also show a gain in disintegrations per minute if the mantle he tested is put into boiling water. This suggests, ultimately, that smelting radioactive ores would lead to a transient increase in their measured radioactivity. That just isn't observed. Radioactivity is a nuclear phenomenon, and simply doesn't follow the rules that chemical reactions do.

The most likely cause of the effect he observed (his data aren't wrong, just the interpretation) was ignored. Thorium is primarily an alpha emitter; a few isotopes of short (hours) half-life are beta emitters. Alpha particles are helium nuclei, and are notoriously easy to stop. A favorite demonstration from high-school physics is the use of a sheet of paper to affect measured alpha particles, when interposed between the source and detector. I think it's most likely that Mr. Mims was observing the shielding effect of the nitrogen. If so, an easy experiment can confirm that: doubling the thickness of the nitrogen layer should lower the count rate still further. I haven't tried the experiment, but feel moderately confident of the result. Another simple test would be to replicate it with another isotope, preferably one with predominantly gamma or at least beta emissions. A handy source might be mineral collectors' specimens.

There are some additional, practical, data available. Liquid scintillation counting is commonly used to measure radioactivity. Such counters are often refrigerated to minimize thermal noise in the detectors. If cooling affected the rate of disintegrations, it simply wouldn't be an acceptable option because of its effect on counting statistics and timing, given the low activity levels of most samples. Since cooling is used, and since no one

(Continued on page 68)

Desktop Publishing: Hewlett-Packard's LaserJet II laser printer



Only a few years ago, Apple Computer packaged its Macintosh computer, its LaserWriter printer, and Aldus Corp.'s PageMaker software program and promoted it as a moderately priced system for "desktop publishing." The catchy expression held fast, as people who were never wholly in the page-creation end of things were beguiled by the prospects of acting as their own print shop to produce newsletters, brochures, flyers, etc., at a somewhat affordable price.

Hewlett-Packard had already introduced a laser printer as a high-quality printer alternative for MS-DOS computers, pioneering this breed and entrenching itself as the market leader of this product type. A variety of print-shop software followed the Apple/PageMaker lead to also give IBM-type personal computers desktop publishing capability.

The laser printer is now often the quality computer printer of choice even when page composition isn't important at all. Lowered prices and the ability to print graphics and select many type faces and sizes, combined with excellent print quality, fairly good print speed and quiet operation, have cut into daisy-wheel printer sales though the latter is still the true letter-quality printer.

Accordingly, we'll look at the laser printer on its own merits as a computer printer—in this instance, Hewlett-Packard's newest LaserJet model, the Series II.

Laser-Printer Overview

Hewlett-Packard introduced its HP LaserJet laser printer in 1984, providing superb near-letter-quality printing *quietly* for $3,500 "list." It was an alternative to daisy-wheel impact printers that quickly spawned a host of competitors. H-P led the way with a Canon "engine" based on what Canon used in its low-cost Personal Copier photocopy machines. It employed a *disposable* photoconductor drum with self-contained toner designed to print 500 to 3,000 pages per month.

The operating principle remains the same for today's moderately priced laser printers. A modulated laser beam moves across a rotating photoconductive drum while essentially chiseling away images, at least in terms of electrostatic polarity. Typically, a fast-scanning beam discharges spots on the drum so that electrostatic toner (a black-powder substance) having an opposite charge sticks to the laser-touched areas, whereupon it's transferred to the paper. This is done with the assistance of a fine steel wire that delivers a negative charge to the paper that attracts the opposite-charged toner sticking to the drum. Some heat and pressure then fuses the image to the paper. Though not exhibiting quite the sharpness produced by a formed-type-face printer, such as a daisy wheel, it nevertheless serves well for most purposes as "letter quality."

The printing process takes place at a typical rate of 6 to 8 pages per minute, contrasting very well with a top daisy-wheel printer's production of about one-half page per minute. Moreover, there's a wider choice of type fonts and sizes that one can use. Resolution is 300 dpi (dots per inch), which compares satisfactorily with the daisy wheel. A Diablo 630 produces the equivalent of about twice this resolution at a half page per minute, while a top dot-matrix printer operating in quadruple-density mode produces about a full page a minute with a coarser 200 dpi at best, and true typesetting machines easily produce 1,200 dpi and more.

H-P LaserJet Series II

Hewlett-Packard upped the laser-printer ante last year with its sleek-looking Series II machine, leaving competitors who parroted the product in the same price category in the dust. (They're just now catching up anew.) It features a new, smaller Canon engine, the LPB-SX (the original Canon was a CX model) that provides a host of printer benefits compared to H-P's older model, the LaserJet+. Among them, the Series II is two-thirds the size and weight (50 lb. vs. 70 lb.) and produces darker, more even blacks. It apparently contributes to lower price than its predecessor model, too—$2,595 vs. $3,995, retail (mail-order price for the basic machine is around $1,700.) The basic Series II comes with 512K of memory that can be expanded another 4 MB, both parallel and serial ports, and six internal type fonts.

Though text print speed is the same,

nearly 8 ppm (graphics are slower, naturally), many improvements were made in the newest model that users will appreciate. The most important one for people who plan to use the printer for much graphics is its doubled memory-expansion capacity to 4.5 megabytes. The optional RAM boards that plug into the side of the Series II are available as 1 MB ($495), 2 MB ($995) or 4 MB ($1,995). You'll need an added 1 MB to maintain the printer's 300-dpi resolution with a lot of graphics on a single page; more if you work with a substantial amount of graphics on multiple pages. Otherwise, graphics resolution is halved!

Further, if you'd like to have a wide variety of downloadable "soft" fonts at your fingertips, you should get as much memory as you can afford since this eats up so much of it. Happily, the Series II accommodates the most memory of any lower-cost laser printers we know of. Memory boards that plug into the computer itself are also available from other sources, such as Tall Tree Systems. Also, The Laser Connection (a QMS company) offers an expansion board, the $2,495 Jet Script, that fits into your IBM or true-compatible computer and converts the Series II into a PostScript page-description-language (PDL) laser printer, much as Apple's LaserWriter. This 3-MB board connects to the Series II's 3″ × 5″ controller board video jack, adding 35 typefaces in any size. (H-P is expected to introduce its own page-description language soon, using a Series II expansion slot for an I/O adaptation board. Actually, it's said to be a document rather than a page description language, handling multiple pages in one fell swoop as a single document instead of on a page-by-page basis.)

The paper input tray now holds 200 sheets rather than 100, and the output tray (letter or optional legal size) holds 100 pages as compared to the earlier model's 20 pages. An added paper-handling improvement that the Series II has is outputting printed sheets face down, eliminating the need to manually reverse pages to get them in the right order because their order in the output tray was on a face-up basis. This can be reversed if one does want collated face-down output. Envelopes and other non-standard paper sizes are easily handled, too, as well as up to 35-lb. paper. You can also feed sheets or forms manually with a front feed. A second font plug-in cartridge slot was added to the Series II, providing more convenient font-choosing flexibility for, say, switching between a headline font and a body-text font.

Another improvement over the earlier pace-setting LaserJet+ is much faster warm-up time, which is now an impressive ½ minute instead of 2 minutes. A welcome change, too, is the Series II's new front-panel 16-character liquid-crystal display that calls out information such as "Paper Out" and an appropriate code number instead of just the latter, menus, etc. Front-panel controls make font selection and commands such as number of copies very convenient to use. Finally, the manuals have been nicely improved, with fine "Getting Started" and "Users Manual."

```
                    -------- PORTRAIT FONTS --------

FONT                                      POINT SYMBOL
 ID            NAME                 PITCH SIZE   SET        PRINT SAMPLE
---- -------------------------      ----- -----  ------ ------------------------
INTERNAL FONTS

I00  COURIER                         10    12      8U  ABCDEfghij#$@[\]^'{|}~123
                                                       ÀÂ°ÇÑ¡¿£§êéàèëöÅØåæÄÜßÁÐÒ
I01  COURIER                         10    12     10U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I02  COURIER                         10    12     11U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I03  COURIER                         10    12      0N  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       ¡¢³´¶¸¹»½ÁÅÈÉÍÎÐÒÔ×ØÛÞàãè
I04  COURIER BOLD                    10    12      8U  ABCDEfghij#$@[\]^'{|}~123
                                                       ÀÂ°ÇÑ¡¿£§êéàèëöÅØåæÄÜßÁÐÒ
I05  COURIER BOLD                    10    12     10U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I06  COURIER BOLD                    10    12     11U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I07  COURIER BOLD                    10    12      0N  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       ¡¢³´¶¸¹»½ÁÅÈÉÍÎÐÒÔ×ØÛÞàãè
I08  LINE_PRINTER                    16.6   8.5    8U  ABCDEfghij#$@[\]^'{|}~123
                                                       ÀÂ°ÇÑ¡¿£§êéàèëöÅØåæÄÜßÁÐÒ
I09  LINE_PRINTER                    16.6   8.5   10U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I10  LINE_PRINTER                    16.6   8.5   11U  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       íó│┤╢╕╣╗╜┴┼╚╔╩╠╨╥╘╪╫█▌απΦ
I11  LINE_PRINTER                    16.6   8.5    0N  ABCDEfghij#$@[\]ˆ`{|}¯123
                                                       ¡¢³´¶¸¹»½ÁÅÈÉÍÎÐÒÔ×ØÛÞàãè
```

This printout of the LaserJet II's resident print fonts shows font names, gives pitches and sizes for each and is accompanied by print samples.

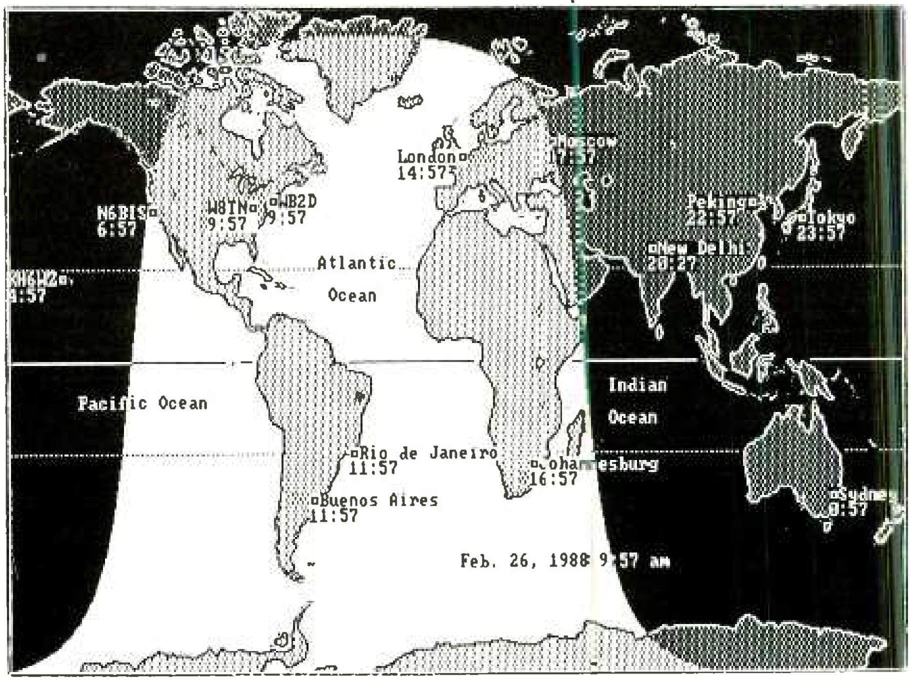
User Comments

Setting up the H-P LaserJet Series II was straightforward, simply following the unpacking and installation instructions provided by Hewlett-Packard. The printer's all-in-one drum/toner/developer disposable cartridge simplified things. It might cost a bit more than changing toner separately when its useful life is over (about 4,000 pages, its rated monthly duty cycle), but I think the "no muss/no fuss" convenience of opening the printer's cover and sliding in the cartridge is worth it. Be forewarned, however, that it'll set users back about $100 a toner/drum change.

H-P wisely maintained full compatibility with its earlier models, so there was no concern about waiting for application

PRODUCT EVALUATIONS . . .

Hewlett-Packard's Laser Jet II Continued . . .



This printout of the "Terminator" world map, done under "Pizzaz," illustrates some of the LaserJet II laser printer's graphics capabilities.

software to come up with a new driver patch. The company didn't maintain the fuller explanation of commands that it had in the original LaserJet manual, though. They pulled an IBM here by referring the reader to its tech manual. But this is minor when weighed against the overall excellence of the printer.

The Series II is a solid-feeling piece of equipment that measures 18"W × 19"D × 8.5"H and weighs 50 lb. Though it may weigh about 15 lb. more than a similarly priced laser printer equipped with a Ricoh engine and it doesn't come with as many built-in type styles (six) as some other competitors have (Okidata's Laserline has 15), its capabilities and features are exceptionally well balanced.

We printed text on it from both WordStar and WordPerfect files directly, and drawings from a variety of inexpensive graphics programs. Creating pages with page-composition software (Ventura Publisher) and printing them on the Series II expanded our experience with the printer even further. Our printer sample had an optional 2-megabyte board installed, for 2.5 MB total. Most of our work was done with an XT-compatible with 640K memory and a 20-MB hard disk; an AT-compatible with a 40-MB drive was also used. The latter is the minimal computer type that should be used for heavy desktop publishing work, though the slower XT can be satisfactorily employed It should be obvious that the faster the machine, the better for this purpose.

The Series II produced nice consistent dark-black text and charts (using Stella Business Graphics). It was far superior to what various dot-matrix printers were able to generate more slowly and more noisily. Though it did not equal the finer type quality produced by a good daisy-wheel printer or a Selectric typewriter, it was close enough to pass muster for all but the most demanding alphanumeric work, such as important letters. And it can produce excellent line graphics. For more serious illustrative work, an image scanner peripheral (which we did not have) is imperative so that photographs and line art can be digitized and integrated into the work. Do not expect high-quality half-tone reproduction, however.

Although its rated print speed is 8 ppm, a user should not expect actual printing to match this speed except under the best of circumstances. For example, if you're making multiple copies of one short page of text, you might average 7 ppm. A single copy of, say, four different pages, might earn you an average of 5 ppm. But 12 seconds per page printing is still going at a nice clip.

Conclusions

It's easy to understand why Hewlett-Packard's LaserJet II is outselling other laser printers. It builds on a product that spearheaded the low-cost-end of laser printers and established some standards that others are compelled to follow. There are a score of plug-in font cartridges available as well as many more downloadable (soft) fonts to choose from and more than 200 programs designed to work with the LaserJet family.

The foregoing aside, LaserJet II operates flawlessly and is easy to set up and get going fast. Its overall speed and print quality is very good for most purposes, though it isn't designed for producing more than a few hundred pages every day. A heavy-duty (and costlier) laser printer should be purchased if this is your objective.

It's an ideal component for desktop publishing purposes, though, unlike the graphics-oriented Apple MacIntosh desktop publishing system, one has to mix and match the various other components needed to make up a system, including adding a mouse. (Ashton-Tate's "Byline" page-composition software, however, is designed for keyboard control rather than mouse pointing and clicking.) Moreover, H-P's printer control language (PCL) isn't as versatile as Adobe PostScript, which can generate type in any size or orientation. But you can add a board, as previously cited, to run PostScript, if you wish.

For ordinary printing purposes, the laser printer in general has much to offer the quality-conscious user. In the moderate-price category, the LaserJet II should be a leading candidate for purchase much as IBM computers were before the clones took over. Hewlett-Packard has a true product star here. ME

—By Art Salsberg

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The PC Configuration Handbook by John Woram. (Bantam Books. Soft cover. 451 pages. $19.95.)

This book's aims are clearly stated in its subtitle, "A Complete Guide to Assembling, Enhancing, and Maintaining Your PC." If you have an IBM PC, XT, AT or compatible computer, this is one you should keep handy. Written to help the novice become acquainted with his computer, it will also appeal to users who are more familiar with their machines, if only because of the wealth of useful information represented by the numerous tables, photos and line drawings liberally peppered throughout the text.

The handbook will help you get your computer up and running, keep it running and track down causes of troubles should it fail to run properly. To this end, the author begins with the techniques needed to help the computer user diagnose and fix problems and to decipher error messages and error codes and makes more clear the IBM diagnostics diskette. For the newcomer, a whole chapter is devoted to creating configuration and batch files to simplify his operating task.

You will find in this book important drawings of system-board configurations, connectors, switch settings and mechanical mounting details. Much more information is contained in the tables, which give current/voltage requirements; comparisons for typical PC systems; a cross-reference of all PCs, XTs and ATs by model number, including system RAM, style of keyboard, disk drives, microprocessors, clock speed, etc.; connector contact identifications; currently available hard-disk drive types; all possible combinations of EGA switch settings; and a cross-reference to conductors used in various RS-232 cable applications.

Helpful BASIC program listings are also provided. One is for storing and replacing configuration data so that an AT computer does not have to be reconfigured every time the battery is replaced. Other programs let you display scan codes, test color displays, test the Hercules Graphics Card, swap printers, and more. In essence, author Woram has extracted a great amount of information buried in a host of IBM manuals, much of which was written in a confusing manner, codified it, and presented the information in plain English from the perspective of an owner who is a doer. To this, he added considerable data to round out the reference book that will assist most anyone in the throes of diagnosing a PC problem or enhancing a computer with memory expansion and other upgrades. Highly recommended!

Satellite Technology and Its Applications by P.R.K. Chetty. (TAB Professional and Reference Books. Hard cover. 432 pages. $39.95.)

Written by an expert who has extensive professional experience in the technology, this book was authored to serve the reader as a single source of information when solving problems of design, analysis and other aspects of satellite systems and their applications. Though written to provide the professional designer and engineer with up-to-date information in the field, the text also offers the nonprofessional a fascinating tour of the technology, from its earliest days to the present.

Following introductory material that

LETTERS . . . *(from page 63)*

corrects the measured radioactivity to a standard temperature, I think this common procedure reinforces my conclusions about Mr. Mims' experiment.

When the interpretations of an experiment conflict with pretty well-established theory, most scientists will bet on the theory being right and look for an error in interpretation first. The prudent experimenter will do well to give his conclusions a "sanity check."

Gerald L. Carlson, Ph.D.
Racine, WI

• I found your column in the April 1988 issue interesting in its investigation of the properties of LEDs at low temperatures. I am skeptical about your statements regarding the decrease of radioactivity of thorium, however. From what I know about physics, it seems unlikely the cooling could be responsible for the effect you observed. Temperature can usually be viewed as the speed of a substance's molecules as they randomly move or jiggle. Typically, a gas at room temperature has molecules with an average velocity of about 500 meters/second (about the speed of sound.) This velocity corresponds to an energy of about $\frac{1}{40}$ ev or electron volt. As the gas is cooled to absolute zero, this average velocity tends to a very small value.

To apply this kinetic view to the thorium, imagine its molecules to be jostling each other as they jiggle at 500 m/s. There are a lot of jostlings per second, maybe 10^{13} a second for a single molecule. Very rarely, the energy of motion of the molecule may be transmitted through the electron cloud around the thorium nucleus to the nucleus itself. At the nucleus, the kinetic energy may be absorbed in such a way as to introduce a radioactive decay or reaction. However, the energy scale to appreciably affect a nucleus is about a million electron volts, or a speed of about ten million meters/second (on the order of 1% the speed of light.) This energy and velocity is much greater than what is available at room temperature. So for the nucleus, the difference between 300-degrees K and 77-degrees K is negligible.

An interesting related topic is the continuing effort to develop controlled thermonuclear fusion. Light nuclei, usually various types of hydrogen, are heated to extremely high temperatures (about 100 million degrees K, forming a plasma) in the hope that the high velocities will allow the nuclei, which are all positively charged and so repel each other, to approach each other close enough for a fusion reaction to occur, forming a single heavier nucleus from the two light ones that collided. A lot of extra energy is also released, which many hope can be used to generate electricity.

If the temperature is assumed to be a negligible factor for radioactive decay, then why did you observe a decrease in the count rate for the thorium? I would guess that the radiation of the thorium was being absorbed by the liquid nitrogen. In effect, you have developed a radioactive thickness gauge, akin to those used to control the thickness of plastic sheeting as it is rolled out. To test this guess, you can try two things. You could

(Continued on page 96)

explores the evolution of communications satellites, the author reviews the benefits derived from communications satellites and discusses satellite applications in a wide variety of fields, including (but not limited to) communications, navigation, weather forecasting, meteorology, mineral location and crop-yield forecasting. Satellite-specific material covered is broken up into satellite "building blocks," each given its own chapter: power systems; the attitude control system; the telemetry, tracking, command and communications system; propulsion system; thermal control system; and such mechanisms as antenna pointers, solar array drive and power transfer assembly and gimbals.

The topics of spacecraft testing and reliability are discussed in detail, as are satellites and rockets and spacecraft structure. Each chapter is a mini-course on a given subject. Hundreds of illustrations and photos, pertinent formulas, calculations and practical design applications, as well as an extensive bibliography, should be welcomed by engineers working in the satellite field. It will also serve well as an introductory college textbook.

Electronic Systems & Techniques by K.F. Ibrahim. (Longman Scientific & Technical, John Wiley & Sons, Inc. Soft cover. 267 pages. $19.95.

Written to serve as a tutorial for electronic technician certification in Great Britain, this book consists of 37 chapters, each of which successively builds upon material covered in previous chapters. The subject matter of the first four chapters, an introduction to the basic principles of electricity, lays the foundation for later ones. The next 14 chapters use block diagrams to cover a wide variety of electronic systems. This section begins with single-stage amplifiers and oscillators and works on up to digital and microcomputer systems, along the way stopping at power supplies, modulators and other basic circuits. A third block of chapters analyzes components commonly used on electronic circuits, while the final two chapters deal with instruments, testing and troubleshooting.

In keeping with the intent of this book, coverage is essentially in the form of circuit analysis to give the reader a logical approach to maintenance, troubleshooting and repair of modern circuits. With the single exception of the video cathode-ray tube (CRT), the material throughout the book maintains a constant focus on solid-state components, both discrete and integrated.

Text material is well written and easy to follow. Extensive use of block diagrams, schematics (many with typical component values), waveform and load-line diagrams, tables and simple algebra back up the text. As a result, this book does well in providing a reader who does not have a mathematical background with the overall electronics basics and servicing techniques to understand modern electronic systems.

A 256-Step Programmable Controller

By Forrest M. Mims III

Last month, I described a 16-step programmable digital controller or sequencer. Now I will describe the design and operation of a 256-step controller that features two microinstructions, as well as several external circuits that can be connected to the outputs of both controllers.

Microinstructions

Before describing the hardware, which is the principle subject of what follows, it's important that you know the definition and purpose of a microinstruction. All digital computers are programmed by sequences of instructions. At their most basic level, these instructions are patterns of binary bits known as machine language or machine code.

Machine language is difficult to remember and tedious to use. Therefore, higher-level languages, such as BASIC, C, Pascal and Fortran, have been developed. In a higher-level language, a single, easily remembered instruction activates a string of machine-language instructions.

In a microprocessor, a machine-language instruction may itself activate a brief string of built-in instructions called "microinstructions." These even simpler instructions, which are also patterns of binary bits, are usually fixed and cannot be changed. In some microprocessors, the built-in microinstructions can be rearranged or microprogrammed to provide entirely new instructions.

The controller to be described incorporates two very basic microinstructions—JUMP and HALT. When the controller advances to a memory location containing the JUMP microinstruction, on the next clock pulse, the address counter moves to the memory location specified by a manually loaded address switch.

The second instruction implements a HALT. When this instruction is absent, the controller continues to cycle through its memory. If the controller advances to a memory location containing a HALT microinstruction, clock pulses are prevented from reaching the address counter and the controller ceases to cycle through its memory.

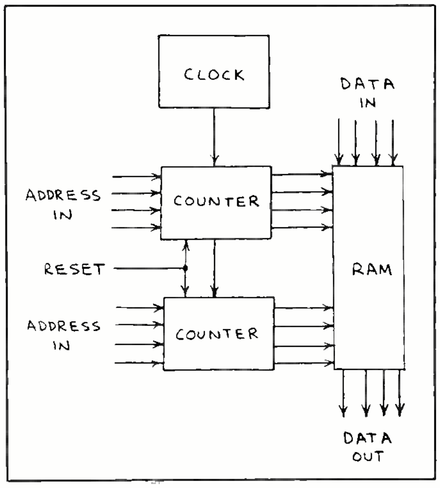


Fig. 1. Block diagram of a 256-step, 4-bit controller.

Though these two functions may seem to be very simple, they have many practical applications. Furthermore, they provide an excellent lesson in the operation of microinstructions in microprocessors and microcomputers.

A 256-Step, 4-Bit Programmable Controller

Figure 1 is the block diagram of a 256-step, 4-bit programmable controller that can be assembled from low-cost components. In operation, the clock sends a series of pulses to a 4-bit counter. The counter advances one count for each pulse. When it arrives at a count of 1111, it emits a carry pulse upon arrival of the next pulse. The carry pulse goes to a second counter, which then advances one count. This cascade arrangement permits the two 4-bit counters to function as a single 8-bit counter.

The output lines of the two counters are connected to the address lines of a 2101 (256 × 4-bit) RAM. The data word loaded into a particular memory location within the RAM appears on the memory device's output lines when that location or address is selected by the counter.

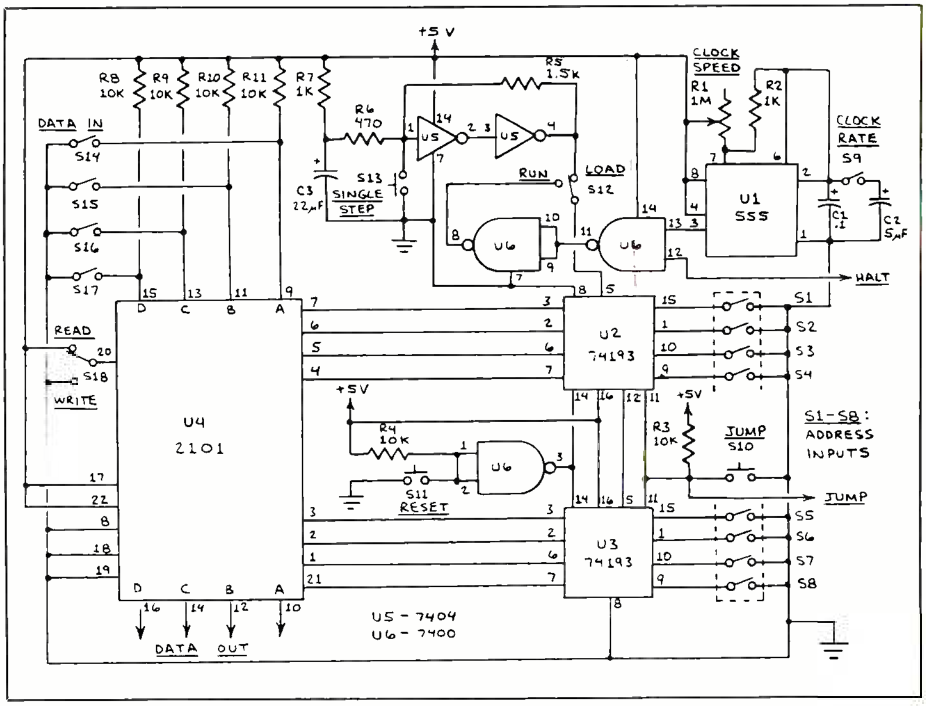


Fig. 2. Schematic diagram of a 256-step programmable digital sequencer.

In Fig. 2 is shown how the Fig. 1 block diagram is expanded into a functioning circuit. Here's a step-by-step description of the controller's design and operation:

• *Data Input Switches.* Data was entered into the 16-step controller described last month by means of a simple optoelectronic card reader. The reader can easily be adapted for use with the Fig. 2 arrangement. Otherwise, data can be entered into the Fig. 2 circuit by means of data input switches *S14* through *S17*.

Loading data by flipping switches is tedious and time-consuming. But it's easier than making a 256-step data card or tape and then hand-punching the program data into it.

• *Random-Access Memory.* The 2101 RAM is a 22-pin, 1,024-bit n-channel MOS random-access memory chip that is organized into 256 4-bit words. The device is fully static and requires no refresh operations. All the inputs and outputs of the 2101 are TTL-compatible, and the chip operates from a 5-volt dc supply.

An important feature of the 2101 RAM chip is that it is a three-state device. In other words, its output lines can be placed in a high-impedance mode to effectively be disconnected from any external circuit. This feature is particularly useful when the output lines from two or more 2101s are connected to a common data bus. Only one set of output lines connected to a bus can be active at any one time. All other output lines connected to the bus must be placed in the high-impedance mode.

Because the 2101 is a MOS device, appropriate handling precautions for such devices must be exercised. Otherwise, the chip can be permanently damaged by static electricity.

The 2101 has two MEMORY ENABLE (ME) or CHIP ENABLE (CE) inputs: ME1 at pin 19 and ME2 at pin 17. The chip is enabled when ME1 is placed in the low (logical 0) state and ME2 is placed in the high (logical 1) state.

Each of the 2101's 256 memory locations is accessed by applying an 8-bit binary pattern to eight address lines. After a specific location has been addressed, a data word applied to the chip's inputs can be written into the location by placing the pin 20 WRITE ENABLE (WE) input (also known as the READ/WRITE, or R/W input) in the logical 0 state.

Data stored in an address location will appear on the chip's output lines when the WE input is high and the OUTPUT ENABLE (OE) input at pin 18 is low. When the OE input is high, the chip's output lines assume a high-impedance state.

Referring to Fig. 2, spdt switch *S18* controls whether the 2101 is in the read or the write state. Control inputs ME1 and ME2 are hard-wired low and high, respectively, to enable the 2101. Finally, the OE input is hard-wired low to enable the output lines.

The output lines of the 2101 can directly drive low-current LEDs. Connect the anodes of the LEDs to the positive supply rail through individual 1,000-ohm current-limiting resistors, and connect the LED cathode leads to the appropriate output pins of the 2101.

• *Dual Address Counter.* The two 74193 4-bit counters identified as *U2* and *U3* in Fig. 2 are cascaded to provide an 8-bit address counter. When a clock pulse arrives from the 555 timer, *U2* is incremented one count. After reaching a count of 1111, *U2* generates at its pin 12 CARRY output a count pulse that is sent to UP input pin 5 of *U2*. The current count status is applied directly to the address inputs of the RAM.

The CLEAR inputs at pin 14 of both counters are tied together and connected to *S11*. When *S11* is closed, both counters are reset to 0000.

The 74193 is a programmable counter. Note in Fig. 2 that the current count of both *U2* and *U3* can be changed by changing the settings of *S1* through *S8*. Closing *S10* causes the counters to assume the count status loaded into *S1* through *S8*. Stated differently, closing *S10* implements a manual address jump. With this arrangement, programmed address jump is also possible.

• *Clock.* A 555 timer serves as the circuit's clock oscillator, whose speed can be adjusted by means of *R1* and *S9*. Normally, the clock is in its high-speed mode. Closing *S9* places the clock in its low-speed mode. In both cases, *R1* provides a means for making fine speed-control adjustments.

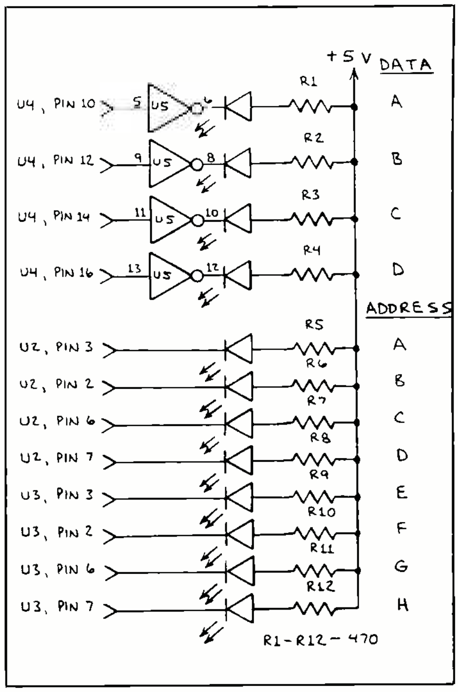


Fig. 3. Details of how to add data and address LEDs to the 256-step sequencer.

When spdt switch *S12* is set to RUN, pulses from the clock are coupled into the UP input of *U2*. When *S12* is set to LOAD, clock pulses no longer reach *U2*. Instead, the output from the Schmitt trigger formed from *U5* is coupled into *U2*'s UP input. Closing SINGLE STEP switch *S13* develops a sharp output pulse that advances *U2* one count state. (It is *S13* that is used when loading data into the RAM.)

Figure 2 also shows that one of *U6*'s inputs at pin 12 is labeled HALT. When the HALT line is high, clock pulses reach *S12*. When this line is low, clock pulses do not reach *S12*, causing the circuit to stop sequencing through its RAM.

You can hard-wire the HALT line into one of the RAM output lines or one of the outputs from a 4-line-to-16-line decoder connected to the outputs of the

RAM. This provides an opportunity for a programmed HALT.

Using the Controller

To load data into the controller, first place *S12* in the LOAD position and *S18* in the WRITE position. Then press *S11* to reset the address counter to 00000000. Next, load the first data word into switches *S14* through *S17*. The word will be loaded into RAM.

After the data word is loaded, press *S13* to advance the counter to address 00000001. Then enter the second data word into switches *S14* through *S17* and press *S13*. Continue performing these steps until all the data words are loaded into RAM.

After the controller has been programmed, press *S11* to reset the counter to 00000000. Then set *S18* to READ and *S12* to RUN. The address counter will then begin sequencing through the addresses in RAM. The previously programmed data words will appear on the RAM's data output lines.

Adding Indicator LEDs to the Controller

Figure 3 shows how to add both data output and address LEDs to the Fig. 2 controller. These LEDs are almost essential if you plan to load more than one program into the controller's RAM. The only reason why they are not shown in Fig. 2 was to keep the size of the schematic diagram within reasonable size limits. They were certainly included in the prototype controller I built.

You should note that the data output lines are buffered by the remaining four inverters in *U5* in the Fig. 2 circuit. This means that a glowing LED indicates a logical 1 and an extinguished LED indicates a logical 0.

Adding a 4-Line-to-16-Line Decoder

The four data output lines from the RAM can control up to four separate devices simultaneously or individually. If

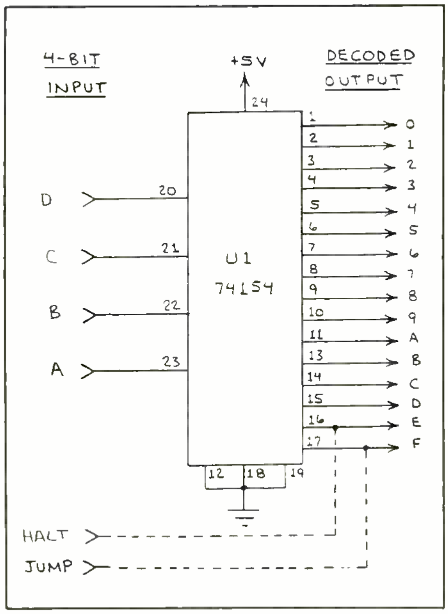


Fig. 4. A 4-bit decoder for the digital sequencer.

you need more outputs, you can connect a 74154 4-line-to-16-line decoder to the RAM's output lines. This arrangement will allow the circuit to control up to 16 devices. However, since only one output from the 74154 can be active at any give instant, the decoder can control only one device at a time.

Figure 4 shows the pin connections to the 74154. CHIP ENABLE inputs at pins 18 and 19 connect to ground to keep the chip active. The most interesting feature of this circuit is its provision for dedicating two of the outputs as control lines. These two lines connect to the HALT and JUMP inputs of the Fig. 2 controller circuit. With the connections shown, the HALT output will be activated when the input word from the RAM is 1110. The JUMP output will be activated when the input word is 1111.

The data words for HALT and JUMP function as microinstructions for the controller. Therefore, when the control lines for these functions are in place, the appropriate action will be taken when the address location containing either microinstruction is accessed by the address counter. If the 1110 microcode for the HALT microinstruction is present, pulses from the clock will no longer reach the address counter and the circuit will cease cycling through the RAM addresses.

If the 1111 microcode for the JUMP microinstruction is present, the address counter will jump to the address previously loaded into switches *S1* through *S8*. The circuit will then begin cycling through the RAM addresses from its new location.

Keep in mind that when these two functions are enabled, the 1110 and 1111 data words can be used only if a HALT or JUMP is desired. The remaining 14 data words (0000 to 1101) can be used for any other purposes.

Analog Output System

Figure 5 shows a simple analog output system that can be added to the Fig. 2 controller. Both this system and the decoder in Fig. 4 can be used simultaneously, thereby greatly increasing the range of possible applications. This capability also permits the HALT and JUMP instructions to be included in the programs designed to drive the analog output system.

The analog output system includes a digital-to-analog converter (DAC), a power output and a voltage-controlled oscillator (VCO). Both the VCO and power output are driven by the DAC.

The DAC is formed by the resistor ladder comprised of *R1* through *R8* and dual operational amplifier *U1*. The input to the DAC is connected to the output of the RAM in Fig. 2. The DAC regards the data words stored in RAM as binary numbers. The output from the DAC is a stepped voltage that reflects the amplitude of the binary numbers appearing on its input lines.

Use of an oscilloscope is the easiest way to monitor operation of the DAC. Connect the scope to output B in Fig. 6 and then load a series of sequential data words (0000, 0001, 0010...) into the controller's RAM. If you don't want to load all 256 memory locations, include a JUMP instruction after data word 1101 and set

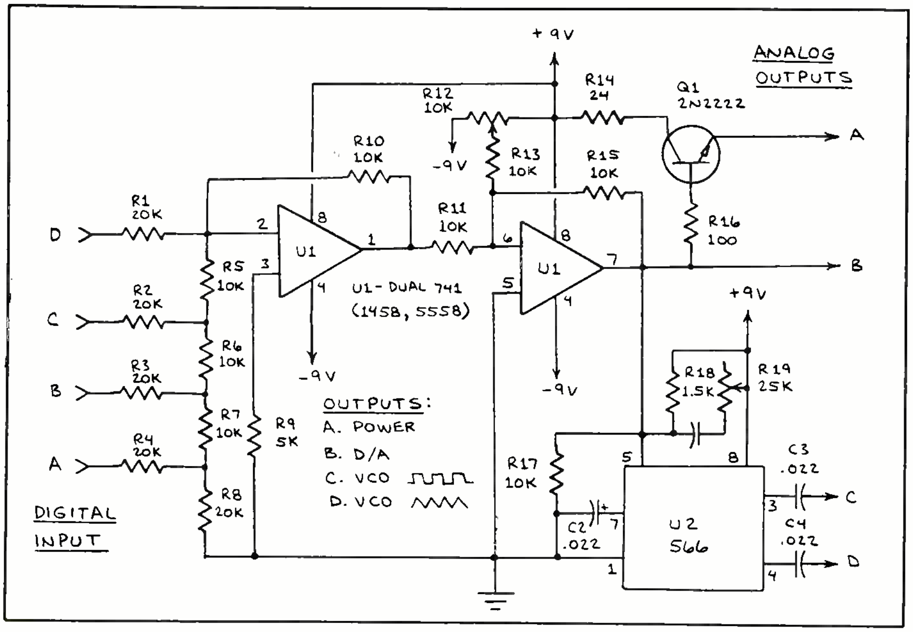


Fig. 5. An analog output system for the digital sequencer.

counter address switches *S1* through *S8* to 00000000. This will set up a loop that will cause the controller's output to count from 0000 to 1101 and automatically recycle. If you don't want to use a JUMP, you can manually reset the address counter to 00000000 at any time simply by pressing *S11*.

When this program is run, the scope will display a stepped voltage ramp that recycles itself. You can then adjust the amplitude of the ramp by means of *R13* in Fig. 5. You can also adjust the slope of the ramp by altering the controller's clock speed with *R1* and *S9* in Fig. 2.

The VCO outputs provide a method of hearing the changing output from the DAC. All that's required to do this is to connect a small speaker amplifier to either output C or D in the Fig. 5 circuit. DAC and VCO control potentiometers *R13* and *R18*, respectively, must first be properly adjusted as follows. With the controller running, adjust *R13* until a sequence of tones of increasing frequency is heard from the speaker. Then adjust *R18* for the desired frequency range. As the count sequence progresses, the speaker will emit a stepped series of rising-frequency tones. You can continue to adjust the potentiometers to modify the frequency range of the tones.

Once the VCO is properly adjusted, you can program the controller to play tunes. Incorporating a HALT instruction will cause the system to play the tune only once. It can be played again by pressing *S11* in the Fig. 2 circuit to reset the address counter to 00000000. A JUMP instruction can be used to recycle all or part of the tune until the system is switched off manually.

The output labeled A in Fig. 5 is the open emitter of a 2N2222 transistor whose base is connected to the output of the DAC. This provides a low-power driver output that permits the DAC to power small lamps and motors. If you connect a small motor between output A and ground, for example, the motor's speed will vary according to the DAC's output. Likewise, the brightness of a small incandescent lamp will vary in much the same manner.

An interesting experiment you can perform is to connect a cadmium-sulfide photoresistor across *R1* in the Fig. 2 circuit. This will cause varying light intensity to to alter the controller's clock speed. Place the CdS cell near a small lamp connected to output A in the Fig. 5 circuit. With this optical feedback arrangement, the clock's speed can be varied under program control.

With this arrangement, when the data words have a high value, the lamp will glow brighter and the resistance of the CdS cell will be lower than normal. This will speed up the clock. Conversely, when the data words have a low value, the lamp will dim and the resistance of the CdS cell will increase, slowing down the clock. The net effect can be quite striking, particularly when a 16-line decoder is added and the system is programmed to produce an alternating back-and-forth flasher.

In Fig. 5, the 556 vco chip provides both square and triangular wave outputs. While this chip works well, you might want to use the vco shown schematically in Fig. 6. Here, the 4046 produces only a square output wave, but I have found this circuit easier to use and adjust. A 4046 can be substituted for the 566 chip.

Controller Applications

I have already mentioned several applications for the controller. Some other possibilities include:

• *Data Logger.* Use the controller as a data logger by connecting an analog-to-digital (A/D) converter to its output.

• *Graphics Display.* The 16 LEDs connected to the output of the 74154 decoder can be arranged in any desired configuration. One possibility is a 4 × 4 square; another is a circle.

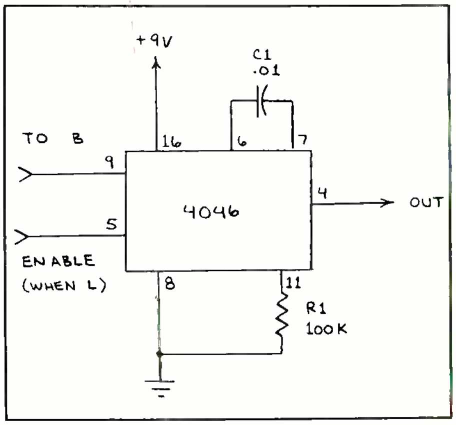


Fig. 6. An improved vco circuit.

• *Crystal-Controlled Clock.* For applications that require precision timing, the existing 555 clock can be replaced or be supplemented by a crystal-controlled clock. Ideally, the clock would have a range of outputs (0.1 Hz, 1 Hz, 10 Hz, etc.) separated by a decade each.

• *BCD or Hex Keypad Input.* Data input can be speeded up considerably by adding a hex keyboard input. If you want to build a BCD input from ordinary logic IC chips, refer to *The Forrest Mims Circuit Scrapbook* (McGraw-Hill, 1983, page 113).

• *Output Interfaces and Buffers.* The outputs from both the controller and decoder can be used to drive lamps, relays, SCRs, triacs and so forth. An add-on board containing one or more of these output devices would make a particularly practical addition to the basic circuit.

Going Further

Bear in mind that while the principles presented here are very basic, they are fundamental to the operation of microprocessors. For a detailed description of the operation of a hypothetical microprocessor, see *Understanding Digital Computers* (Radio Shack and Howard W. Sams, 1987). In this book, I review digital logic fundamentals and present complete details of a microprogrammable microprocessor. **ME**

A New High-Integration Analog Chip; Designer Integrated Circuits; New Literature

By Harry L. Helms

A contemporary microprocessor such as the 80386 or 68030 packs the computing power that once filled entire rooms into an area smaller than an average drink coaster. Such amazing feats are typical of contemporary electronics—but mostly when one talks about *digital* circuits. The results haven't been quite so spectacular in the analog area, particularly where radio-frequency (r-f) circuits are concerned. For example, there's no such thing as an "FM-stereo receiver on a chip" or a "single-chip vhf transceiver." Despite the many gains in integrated devices, radio communications circuits have remained (for a variety of reasons) stubbornly resistant to the sort of almost miraculous circuit integration we've come to expect in the digital area.

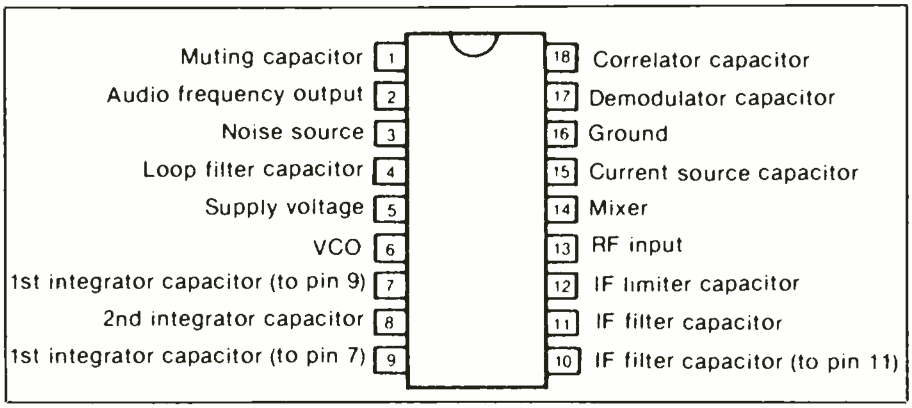


Fig. 1. Pin numbers and connections for the TDA7000 FM receiver on a chip.

Fortunately, we are starting to see more integrated devices intended for r-f applications. One currently available is the TDA7000, described as a "complete FM receiver on a chip." Developed by Signetics, this device contains an r-f input stage, mixer, local oscillator intermediate-frequency (i-f) amplifier/limiter, phase demodulator, and mute detector/switch in an 18-pin DIP package. In essence, this is the "heart" of a mono FM receiver. Only a tunable LC circuit for the local oscillator, a few ceramic capacitors, and one resistor are needed to implement a complete mono FM receiver that provides all the functions from antenna input to audio output. Figure 1 shows the pin numbers and connections for the TDA7000.

The TDA7000 uses a *frequency-locked loop* (FLL) stage that has an intermediate frequency of 70 kHz, with i-f frequency selectivity provided by active RC filters. In the FLL stage, output from the FM demodulator section of the IC shifts the local oscillator frequency in *inverse* proportion to the i-f deviation produced by modulation. The maximum i-f frequency deviation is ±15 kHz.

Use of an FLL section has several advantages, primary among them ease of tuning and high image-response suppression. Perhaps most important, it eliminates the need for variable tuned circuits in the r-f signal path and for tunable coils in the i-f stage. Proper tuning and adjustment of such circuits have long been a major source of problems in conventional FM receiver circuits. The input signal frequency range of the TDA7000 is from 1.5 to 110 MHz.

The choice of 70 kHz as an intermediate frequency makes the elimination of tunable coils and tuned circuits achievable. At this frequency, it's possible to provide the necessary degree of selectivity using RC filters. Resistors and capacitors used in these filters can be successfully integrated into the IC chip. Two stages of i-f filtering are used.

Figure 2 shows the TDA7000 used in a typical FM broadcast band (88-to-108-MHz) receiver with variable-capacitor tuning. Inductor *L1* (56 nH) is a Toko MC108 No. 154 HNE 150013S13 or equivalent; variable capacitor *C* (used for tuning) is a Toko No. 2A-15BT-R01. Output from this circuit will require an external audio amplifier for a usable signal. In urban areas near FM broadcast stations, no r-f amplification preceding the circuit will normally be required; however, it may be needed in weak-signal areas.

The circuit is designed to receive FM signals that have a deviation of ±15 kHz. Many FM signals in non-broadcast service use a ±5-kHz deviation. Figure 3 shows a typical "narrow-band" FM receiving circuit, originally intended for use in cordless telephones, built around the TDA7000. The local oscillator of the TDA7000 is crystal controlled in this circuit, which greatly reduces the i-f "swing" of the FLL. If the received signal has a deviation greater than ±5 kHz, the result will be badly distorted audio.

Using the component values shown in Fig. 3, the circuit will have an i-f frequency of 4.5 kHz and an i-f bandwidth of 5 kHz. Determination of component values for the crystal-controlled local oscillator is involved. For complete details, see "TDA7000 for Narrow-Band FM Reception," Application Note AN193, which is available from Signetics.

Further applications information on the TDA7000 is available in Signetics Application Note AN192, "A Complete FM Radio on a Chip," which is available from Signetics distributors, sales offices, or direct from the company at the address noted at the end of this column.

Custom ICs for Everyone?

The technology for application-specific integrated circuits (ASICs) continues to advance at a startling rate. How would you like to be able to go through a semiconductor manufacturer's data books, select various analog and digital devices (including memories), draw a block diagram of a circuit employing those devices, and be able to have a prototype ASIC based on the block diagram available in three months? This sort of technology was recently announced by Plessey Semiconductor's Ferranti Interdesign division with its *Compiled ASIC* program!

The secret to the Compiled ASIC system lies in the fact that virtually all of the standard Ferranti ICs are based upon the same basic five-mask fabrication process. The circuit functions represented by the standard ICs are known as "macros." Among the available analog macros are analog-to-digital (A/D) and digital-to-analog (D/A) converters, comparators, oscillators, mixers, full-wave rectifiers, phase detectors, and zero-crossing detectors.

Digital macros include logic gates, flip-flops, registers, counters, buffers, decoders, multiplexers/demultiplexers, and arithmetic/logic units (ALUs). Interconnection between the various macros on the chip-wafer level is handled by computer software, sparing the designer the effort necessary to do so.

The significance of the Compiled ASIC approach is that custom IC design with it doesn't require an expensive computer-aided design (CAD) workstation or even an engineering degree. Odds are that the typical reader of this column could design his own custom IC using nothing more complex than a pencil, paper, schematic symbol template, and a stack of data books! However, before you run out to become the first person on your block to have your very own custom IC, you might want to consider the costs involved. Plessey estimates that the cost to take a raw design through to a working prototype would be between $20,000 and $30,000, and the unit price in production would run between $3 and $6.

TDA7000 Specifications
Supply voltage: 4.5 volts
Supply current: 8 mA
Input frequency range: 1.5 to 110 MHz
Sensitivity for −3-dB limiting: 1.5 μV
Audio output into 22K load: 75 mV

While high by hobbyist/experimenter standards, such costs are very inexpensive to commercial customers. In fact, it means that one can start a semiconductor company offering a unique product for less money than the cost of many luxury automobiles. As a consequence, I feel you're going to see a flood of semiconductor "boutiques" springing up in the next few years offering specialty devices made possible by Compiled ASICs and similar techniques.

It doesn't take too much imagination to see some potential devices that could have wide appeal. How about a power supply chip that contains a full-wave rectifier and voltage regulators to supply different regulated outputs? Or clocked logic devices (such as flip-flops or counters) with an on-chip clock? (Why not make the clock frequency voltage-variable while we're at it?) In fact, one hot rumor I heard on the grapevine is that a famous electronics writer and circuit wizard has already completed some chip designs and made inquiries about manufacturing his own line of "designer ICs"!

It wouldn't be surprising if other companies with large catalogs of standard devices, such as National Semiconductor and GE/RCA Solid State, soon start offering their own equivalent of Plessey's Compiled ASIC program. Stay tuned for future developments!

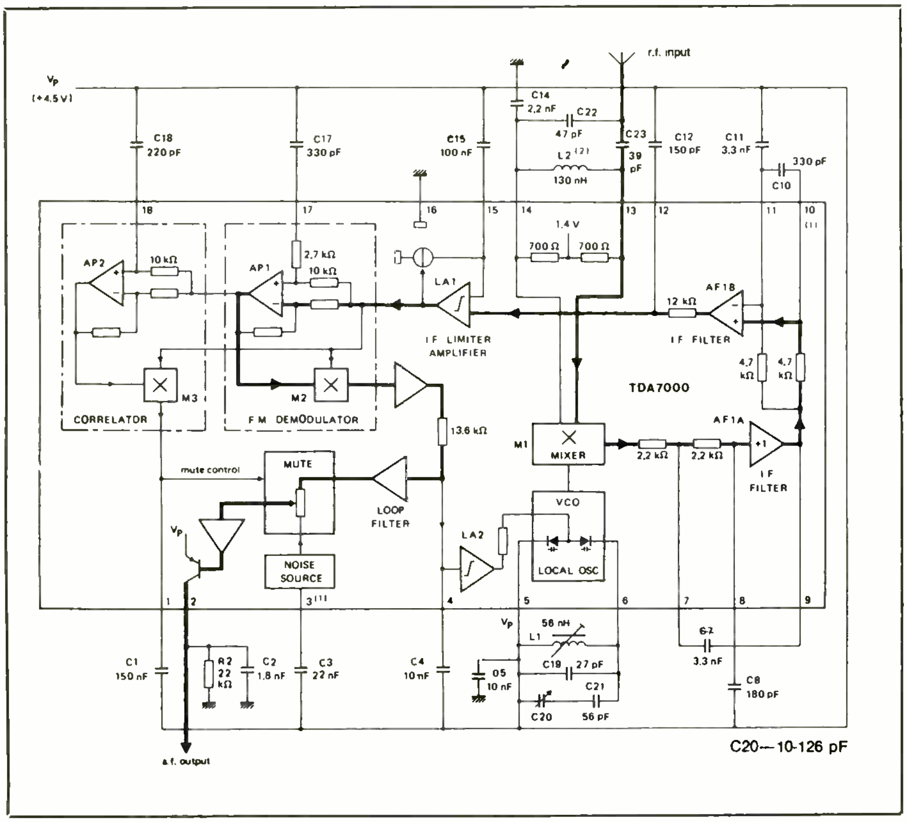


Fig. 2. The TDA7000 used in a typical 88-to-108-MHz FM receiver with variable-capacitor tuning.

New Literature

One of the items in this month's literature isn't "literature" in the conventional sense—it's an MS-DOS (that is, IBM-

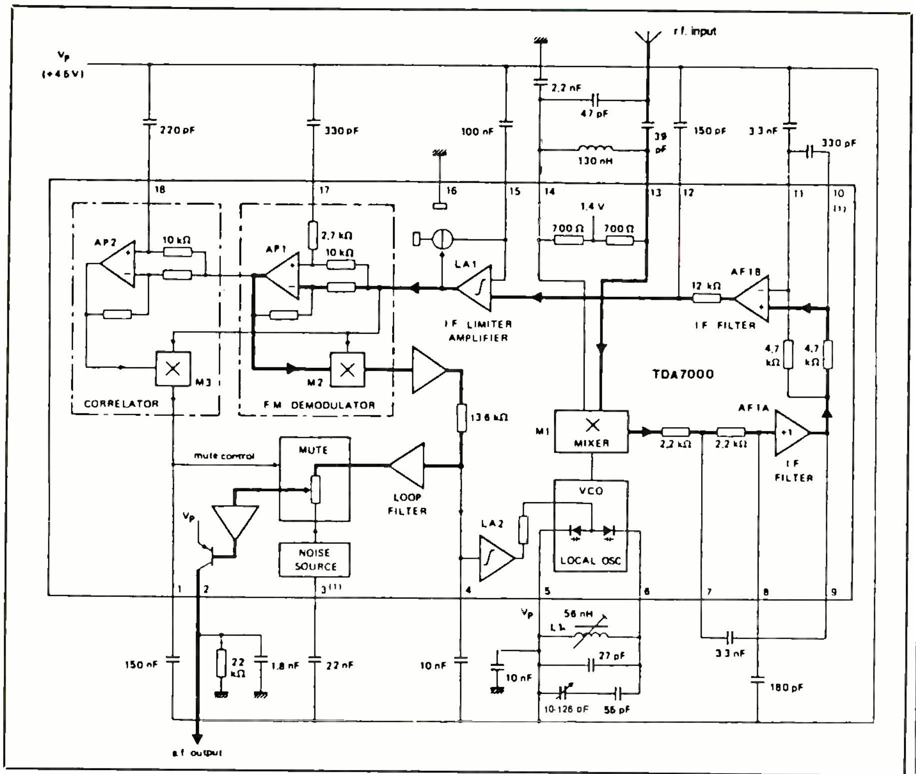


Fig. 3. A typical narrow-band FM receiver circuit built around the TDA7000 chip.

PC) format diskette from Motorola called *Specs in Secs*. The first edition covers Motorola's power-transistor offerings and lets you access its data in two ways, by part number or by parameters. For example, suppose you wish a list of all Motorola transistors that meet certain criteria, such as voltages, power, output current, and even price. These parameters can be input into your MS-DOS computer and you'll get a list of all Motorola devices that meet these criteria.

The diskette offers cross-reference capabilities, and users can access it in English, French, German, Italian and Spanish! While not intended to replace data books, this diskette does permit rapid selection of devices that meet minimum (or maximum, as the case may be) specifications, with a data book used to make final selections.

At this writing, Motorola plans to bring out additional diskettes that cover other areas of its product line if this initial offering is well-received. This diskette is currently available from your local Motorola distributor or sales representative. How much longer will it take for other semiconductor companies to jump on the bandwagon?

Since this month's featured device, the TDA7000, is from Signetics, it's only fitting to mention that Signetics has released its latest set of linear device data books. Volume 1 covers communications devices; Volume 2, industrial ICs; and Volume 3 details video chips. Each data book includes data sheets for all currently available Signetics devices and any available applications notes. You can request these data books from a Signetics sales office or representative, or you can request them on your company or professional letterhead from Signetics (811 E. Arques Ave., P.O. Box 3409, Sunnyvale, CA 94088-3409). ME

Satellite-TV Update; CD Audio & CD ROM; Low-Cost Modems

By Curt Phillips

Back in the early seventies, I don't remember any of the "futurists" predicting home satellite dishes sprouting up all over the rural countryside. But in the mid-1980s that's exactly what happened, as country folks sought access to the diverse programming available to their cable-connected friends in urban areas.

The TVRO (television receive-only) dishes and reception equipment were pretty expensive when they first came on the market, but with all the free programming available there was still enough incentive for sales to reach the million-unit level before several of the major programmers (beginning with HBO) started scrambling their signals in 1986. The advent of scrambling scared most people into thinking that the area of free satellite TV broadcasts was over, and sales of TVRO units plummeted.

But the death of satellite TV was greatly exaggerated. There are still more than 80 channels of unscrambled programming and the premium services offer subscriptions at fees comparable to those charged by cable systems.

The entry price for a satellite receiving system has dropped below $1,000, and an excellent-quality system can be had for less than $2,000. Descrambling devices that work legally with signals from services you have purchased are widely available.

Because descramblers can be accessed by the same radio signal that carries the video, you can subscribe to a new service and be connected almost instantly. "Showtime," for example, has a toll-free number and, after taking down your billing information and the unique code number of your descrambling unit, will speedily send a signal to enable your descrambler to decode the purchased channels. The whole process usually takes less than ten minutes.

Now many satellite TV receivers have built-in descramblers. They are known as integrated receiver/descramblers (IRDs). These receivers are usually the top-of-the-line models that also include such features as remote control and channel memory to automatically tune in your favorite satellites and transponders. The picture and stereo-sound quality available from these receivers exceeds that of almost any other source (including cable).

Receivers are available that will handle both C-band (3.7 to 4.2 GHz) and Ku-band (11.7 to 12.7 GHz); dual-band dishes also available give easy access to the maximum number of "birds."

The coming of high-resolution TV and higher-power satellites make for a bright future of TVRO, but the technology available today should not be ignored by anyone interested in state-of-the-art audio and stereo sources.

CD Audio & CD ROM

When I first saw an auxiliary output on the back of a Technics audio compact-disc player a couple of years ago, it seemed logical to anticipate a computer interface for it in the near future. Even back then, the promise of gigabytes of compact-disc read-only memory (CD ROM) was being touted as the next revolutionary development in the microcomputer field. Since all "high-tech" homes would have a CD player, as well as the requisite computer, a marriage of the two seemed inevitable.

Now that sales of computer CD ROM units are accelerating, I decided to check with several industry sources to see if an audio compact-disc player/computer interface is forthcoming. For those of us who already own audio compact-disc players, the answer is probably not. The specifications for CD ROM players are more stringent than those for CD audio players, and that would seem to preclude the possibility of adapting existing CD audio players for CD ROM use. At least one source said that they had heard of some experiments in that area, but nobody knew anything specific and all seemed doubtful of the possibility.

Most of the CD ROM drives sold now do have audio outputs, but the quality of the sound from them is not equivalent to that from the better audio-only CD players. Despite the tighter tolerances to which CD ROM drives must conform, their signal-to-noise ratio typically runs in the 75-dB range, compared to approximately 90 dB for audio-only CD players. CD ROM drives also do not have as broad a frequency range as audio-only compact-disc players, particularly at the low end. Note that all the audio performance characteristics of CD ROM drives are superior to most non-digital sources; it is only when they are being compared to the better audio-only players that CD ROM units fall short.

The audio playback features of CD ROM players are generally controlled through computer software. With the popular Amdek Laserdrive 1, pop-up software that stays memory-resident (like Sidekick) is provided so that the audio functions can be accessed no matter what other software is being run on the computer.

This method of control does not allow for the CD drive to be separated from the computer and carried to another room to be used for audio. Many serious computer users, the people who would be most likely to be interested in CD ROMs, keep their computers in "office" areas of their homes and their audio systems in their family rooms. Presently available systems do not lend themselves to being shuttled between rooms and uses.

It is still early in the development of CD ROM drives, and even CD audio drives for that matter. But at this point, it is difficult to justify part of the purchase price of a CD ROM drive as a CD audio player. With all the advances being planned for interactive computer, audio and video uses for CD ROM drives, perhaps this will soon change.

Inexpensive Modems

A wide variety of modems being promoted as being "Hayes compatible" are available from mail-order sources. The problem is that they often have generic names and it is difficult to determine their quality.

Two low-cost external modems that I have had the chance to evaluate recently are the SmarTEAM 2400 and the Packard Bell PB2400PLUS. These two modems are widely available from mail-order sources for under $200.

As their model numbers would indicate, both of these modems can operate at 2,400 bits per second. They can also operate at 1,200 bps and 0 to 300 bps, making them compatible with almost all computer bulletin boards and on-line services. Being external modems, they can connect to any computer that has an RS-232C serial port.

Both of these modems offer such features as: automatic dialing using either Touch Tone or pulse, auto answer, selectable full- or half-duplex operation, internal speaker, the ability to monitor call progress (differentiation between the dial tone, ringing and busy signals), and eight front-panel LEDs to indicate modem ready (MR), auto answer (AA), carrier detect (CD), off hook (OH), receive data (RD), send data (SD), terminal ready (TR), and high speed (HS). One difference between the two modems is that on the SmarTEAM the high-speed LED lights for both 1,200 bps and 2,400 bps, while on the Packard Bell the HS LED lights only when it is set for 2,400 bps.

When originating a call, both modems automatically detect and adjust to the transmission speed of the computer. When answering a call, they automatically determine and match the speed from the carrier signal of the originating equipment. Both have standard modular jacks for connection to the phone line and for an extension telephone. Both modems also include a modular cable for connection to the telephone line.

The Packard Bell modem uses a typical two-wire plug-mount power supply that provides 12 volts at 830 mA. This type of power supply is readily available should the original ever fail. The SmarTEAM modem uses an unusual five-wire power supply, similar to those used with Commodore C-64 and VIC-20 computers and providing +5, +12 and −12 volts. I suspect that this power supply would have to be special-ordered if the original fails.

One other operational difference is that the volume on the Packard Bell's internal speaker is controlled by software, with only four different levels possible. The SmarTEAM modem allows for continuously adjustable volume control from a back-panel potentiometer.

Both modems appear to be perfectly Hayes-command compatible. I replaced my own Hayes-brand Smartmodem with the SmarTEAM modem straight out of the box and without changing any of the default settings on the SmarTEAM or any settings on my communications program and began using it immediately. Later, I removed the SmarTEAM and installed the Packard Bell exactly the same way. Here, too, no changes were made to the settings of either the modem or the terminal program (though I did fiddle with the software volume control).

Throughout two months of heavy use, both modems performed flawlessly. I used them without a hitch at 300, 1,200 and 2,400 bps on private computer bulletin boards, both local and long-distance, as well as commercial on-line services via packet-switching networks. I also tried both of them with several terminal programs, and neither had any problems.

Comparing the two modems further, both are about the same size: the Packard Bell appears smaller, however, due to its design. The LEDs in the SmarTEAM model I have were not straight, which makes it look cheaper. On the other hand, I do not like the Packard Bell's software volume control, but since it is usually a "set-it-and-forget-it" feature, it is not a serious drawback. The Packard Bell comes with a slightly better instruction manual, though the manuals from both makers are quite adequate.

Which one would I choose? Since the Packard Bell is about $21 less at $169, I would buy this one. Both modems are excellent values, though, and either should do a fine job of providing you with a low-cost, multi-speed, multi-purpose modem.

Your comments and ideas are welcome. You can contact me by mail at P.O. Box 678, Garner, NC 27529, or by computer on Delphi (CURTPHIL) or The Source (BDK887).

ME

PC CAPERS

A New PC FAX Board; Help for Hurt Floppy Disks

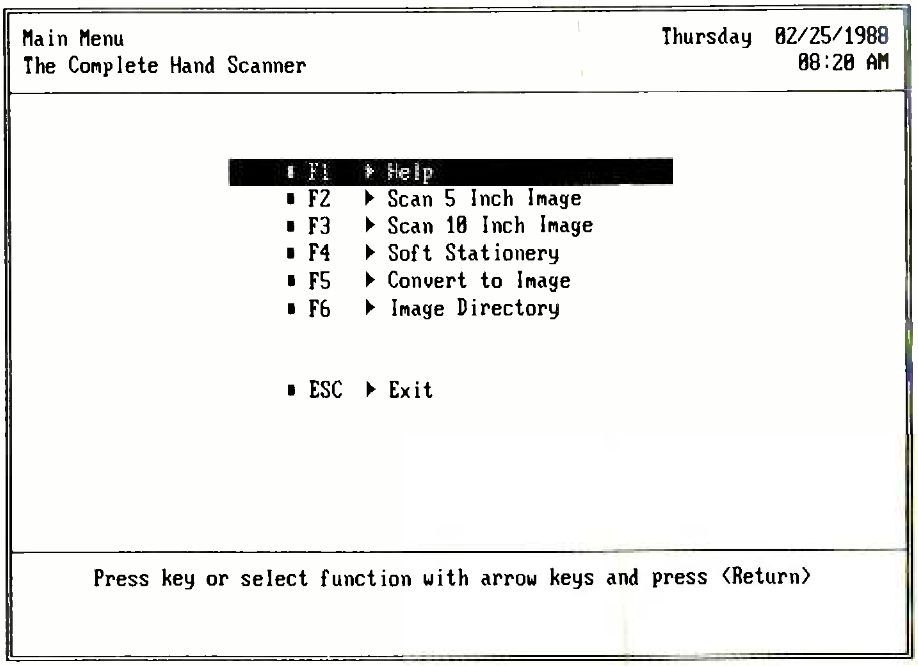
By Ted Needleman

There's this small company in Milpitas, CA that makes a variety of wonderful products that you really can use. The problem is that you don't know how much you really need them until you have them. The three products it offers at the present time are The Complete FAX (lets you use your PC to send and receive Facsimiles), the Complete Hand Scanner (a 200-dot-per-inch hand-held graphics scanner), and the Complete Answering Machine (which turns your PC into the equivalent of an expensive Voice-Mail system). The answering machine is a fairly complex product to review and I'll cover it in a future column. I'd like to tell you about the fax board and scanner this month, holding off on the third product, the answering machine, since it is fairly complex to examine and review at the same time.

Those of you who have been following this column know that I've been experimenting with fax boards for a while. These boards allow your PC to be used as a facsimile machine, enabling you to transmit letters and other documents over the phone lines to another fax machine or similarly equipped PC. January's column detailed my travails with the E.I.T. board and scanner, which I was never able to get going.

The Complete FAX differs substantially from the E.I.T. board and scanner. The first area is price. The E.I.T. and many other major manufacturers charge about a thousand dollars for their boards and software. The Complete PC goes for $499. The second difference is in speed. The E.I.T. is rated at 9,600 baud, while the Complete FAX operates at half that speed—4,800 baud. The third place where E.I.T. and Complete PC differ is that the Complete FAX board worked the first time out!

Since it is all too common in this industry to buy a product and have to struggle to get it working, I tend to be impressed by one that performs properly without a hitch. The Complete FAX, one such product, consists of a three-quarter size board (which should fit in most clones,



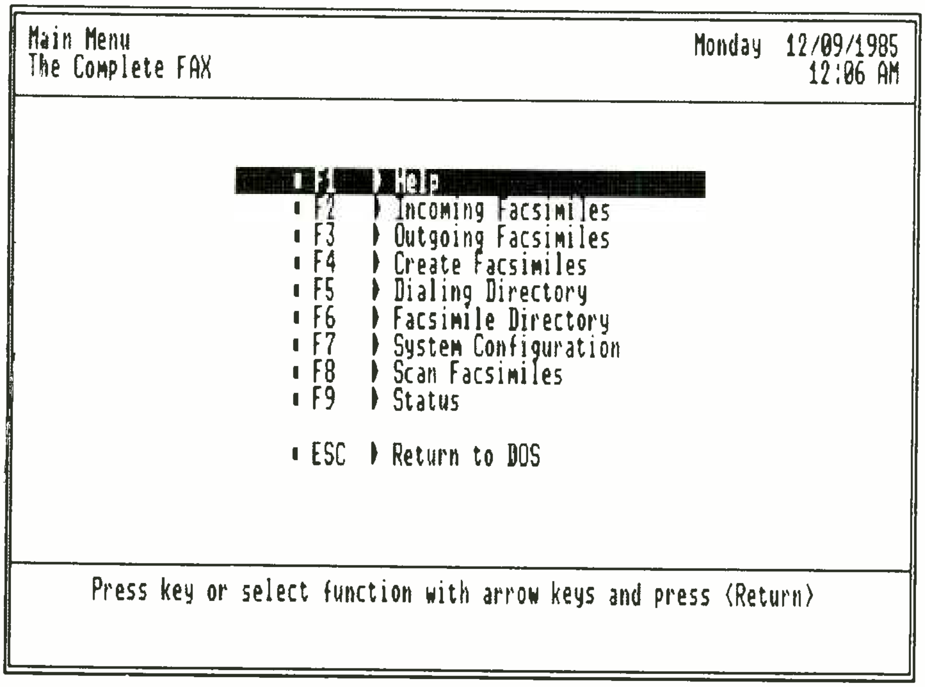
The Complete Hand Scanner's Main Menu.

including the Tandy) and software. Installation consists of inserting the board into your PC, plugging the included modular phone cord into a phone jack, and running the INSTALL program. This procedure asks you about your phone system and computer hardware. The Complete FAX requires that you have either a CGA-, EGA- or Hercules-compatible graphics adapter installed. You will also need a hard disk with between 3 and 4 megabytes of free space to store the software and your incoming and outgoing faxes.

The installation procedure also asks if you have the Complete Hand Scanner. If you do, you are prompted for the disks that accompany this product. The scanner can be used in conjunction with the FAX to scan in graphic images to be included in your fax transmissions. The INSTALL program also asks you to choose your printer from a long menu of those the software supports. The resolution of your printer will determine how close to a facsimile machine your output will appear. In FINE mode, resolution of a facsimile machine is 200 dots per inch. Unless you have a printer that can print at this density or better (usually a laser printer, though there are a few 24-pin dot-matrix printers that also give this resolution), your output will not match.

The Complete FAX supports the Group 3 standard, which is far and away the most-used one. Among other things, this standard defines resolution (up to 200 dots per inch), transmission speed (up to 9,600 baud), and transmission mode (digital rather than analog). This last feature, using a digital transmission mode, is one of the two factors that differentiates FAX modems from the ones you use to communicate with bulletin-board systems. The second difference is in the frequency pairs each use to communicate over the phone lines.

Once installed (and the whole process, including putting the board in your PC, takes under a half-hour), you can proceed to create, transmit and receive facsimiles. The software included with the Complete FAX allows the system to work in the background. This means you can receive and transmit facsimiles while you are working on another application, such as word processing. Facsimiles are created with a word processor or other



The Complete FAX's Main Menu offers a wide variety of choices.

text editor. Before they can be transmitted, though, they must be converted to FAX format. This is done from one of the selections on the CFAX menu. The process takes a while, as the text file is actually being converted into a digital image of each page in the file.

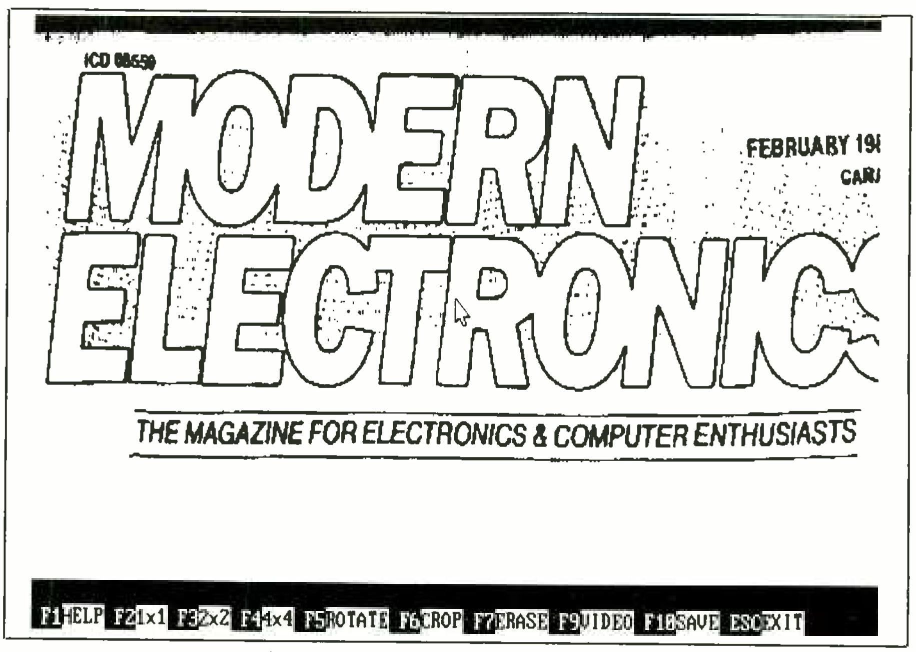
To convert a three-page text file on an 8088-based system takes almost 10 minutes. After the file is converted, you can transmit it to another FAX. This can be done immediately in either the foreground or background, or you can specify a time, such as the middle of the night when rates are low, for the system to make the transmission. I transmitted a three-page file immediately in the foreground. Transmission time for this file was about 2.5 minutes. This is about a minute longer than a 9,600-baud FAX would have taken—a reasonable trade-off, considering the price.

Complete FAX has some of the same features a high-end dedicated FAX machine offers. These include the aforementioned delayed transmission, automatic dialing from a built-in phone directory, the ability to automatically send the same fax to a list of recipients, and maintaining a complete log of all incoming and outgoing faxes. For $499, it's a great buy if you need (or want) the ability to use facsimile.

Adding greatly to the utility of the FAX board, and just plain fun on its own, is the Complete Hand Scanner, also from The Complete PC. It lists for only $249. Resembling a mouse on steroids, this hand-held unit has a 200-dot-per-inch charge-coupled device (CCD) pickup. Rolling it over the object to be scanned, you wind up with a scanned strip that is 2.25 inches wide by either 5 or 10 inches in length. The resulting scan can be cropped, rotated and saved in a variety of formats. Three of the popular PC graphics formats are supported (Dr. Halo II, PC Paintbrush, and Windows Paint). You can also save it in image format for use with the Complete FAX board.

Included with the scanner is a software package called "Soft Stationery." This lets you scan and save letterheads and signatures and combine them into complete electronic letters and documents that can then be either printed out or transmitted over the Complete FAX.

There are several caveats. Firstly, don't expect the same scan quality as a $1,000 page scanner produces. Those function at 300 dots per inch, and many are capable of using gray scaling to



A typical facsimile reproduction using the Complete FAX.

achieve better quality. The 200-dpi resolution of the Complete Hand Scanner is good for many uses, however. Secondly, I found the Hand Scanner has a tendency to skew slightly when being drawn down a page. I solved this by taping the paper I was scanning to the desk, then using duct tape to secure a straightedge to the side. This gave me fairly straight scans, but multiple passes required a fair amount of repositioning.

For its price, which is one-quarter or less than standard page scanners cost, it's an inexpensive, yet fun way to get started with scanned images. And when coupled with the Complete Fax board, it considerably extends the usefulness of the fax product.

My major complaint is that my PC clones have only five expansion slots, and all products from The Complete PC take up three of them. But I'm enjoying the trio so much that I'm considering buying or assembling another clone just to give them their own home.

Help for Hurt Disks

I almost didn't review the following product. It was developed by a friend of mine, and I worried whether there might be a conflict of interest involved. Then I put it to the following test—would I feel as good about it if it were developed by a stranger? Sometimes "nepotism" of a sort has its uses. In this case it got me an early look at a product I think you'll find helpful.

Back when I was in grade school, a common excuse used when someone didn't do his homework was, "The dog (or my little brother) ate it." The same one is still being used today, only now it's diskettes that seem to suffer a carnivorous fate. There isn't a whole lot you can do for a diskette full of tooth marks, but there is help for a more common diskette malady: Spilling a liquid on your disk. If you've ever accidentally put a fingerprint on a disk, then gotten a READ ERROR trying to use it, imagine what kind of problems you're in for when you spill something really gooey on your diskette, such as sweet coffee, soda, or juice.

Of course, one should not have liquids around a computer. But I can't be the only one who violates this "rule." A few years ago, Polaroid introduced its data recovery service, promising to recover data from a variety of substance-mutilated disks (as long as the disks were Polaroid brand). More recently, Verbatim introduced Teflon-coated disks that are said to protect the medium from such accidents. But most of us don't use these disks.

The First-Aid Kit for Disks, from Redlig Systems, Inc., was developed to let the average klutz (such as yours truly) recover data from diskettes subjected to the ravages of numerous spilled substances. Inside the box are two metal trays, two bottles of solution, five red empty diskette jackets, some small yellow dots, and two pages of instructions. The simple directions detail how to remove the soiled disk from its jacket, which solution to use for specific classes of soil, and how to use the empty replacement jackets.

The yellow dots are there so that you can mark the top surface on diskettes without a hub ring (there's nothing more frustrating than cleaning up a disk, putting it into a new jacket upside-down without realizing it, and having your system tell you the disk is bad). The instructions are simple enough so that none of you should have any difficulty recovering from your own particular meltdown.

Is the First-Aid kit worth the $29.95 Redlig asks? It depends. I've recovered from some disk mishaps by just removing the disk and washing it in clean tap water before placing it back into a clean jacket. But before Redlig's kit, I've never had any success with grease-based accidents such as fingerprints. If you're the type who *always* backs-up at very short intervals, you may not need the First-Aid Kit. If you're like the rest of us, though, send my friend the thirty bucks.

Considering the hours of wasted time I've accumulated over the years due to clumsy accidents (and having three toddlers roaming my house), it seems like cheap insurance. My friend also has a toddler roaming around his house—that's how and why the First-Aid Kit got developed. Redlig even offers a 15-day, no questions asked, money-back guarantee. And the first time you save a disk containing a precious file, you'll be glad you had the First-Aid Kit around. **ME**

Names and Addresses

The Complete PC
521 Cottonwood Dr.
Milpitas, CA 95035
(800) 634-5558
The Complete FAX Board

The Complete Hand Scanner
Redlig Systems, Inc.
2068 79 St.
Brooklyn, NY 11214
First-Aid Kit for Disks

Duet for Printer Control

By Art Salsberg

It's difficult and tedious to *fully* control a computer printer. Consumers Software's "Duet" is designed to provide you with this power. It's a memory-resident program that comes on three disks, accompanied by a 205-page user's manual. It requires an IBM PC/XT/AT or true compatible, MS-DOS 2.0 or later, and at least 256K of user memory. The full program takes up 128K, though there are installation options to lower this to 60K if you give up some features. The package is priced at $89.95.

Like all resident programs, it uses a "hot key" to activate it once it's been loaded into memory. It's set up to use "Alt F1," though it can be changed if it conflicts with another memory-resident program. Although a hard disk drive is most convenient to use, it can be employed with single or dual floppy drives, too. Installation is semi-automated, with files loaded properly just by answering a few questions, such as which drive you want the program loaded to, which printer port, etc. Since a sub-directory and sub-sub directories are required, having this done automatically takes the hassle out of installing the program or reconfiguring it.

Duet offers the user a host of welcome features controlled from a pop-up menu. It can print Lotus or Symphony spreadsheets without even booting up the application programs, for example. It can also print matter sideways, which is so desirable to do with most spreadsheet work. Furthermore, the user can choose from among 12 fonts.

Among its many other features, it has an unusual "spooler." This is a software print file buffer that enables you to print while continuing to use your computer. Duet's spooler, however, allows you to choose the order in which you want files printed, and the time, as well as changing print parameters. In effect, it's a queue management system.

Using the activated menu, you get complete control over suspending or resuming printing, printing from a disk file, whether it's ASCII text or Lotus 1-2-3's .WKS files, compressed or normal type, etc. Moreover, it copies a print file onto disk so that if there's a power outage you can pick up where you left off. Headers, footers, setup strings, borders, downloading fonts, page width, and margins are just some of the many other menu-select options that Duet places at your fingertips.

```
                                                              08:22 AM DUET V1.00
 Print  Off/on  Manage queue  Configure  Set printer  Uninstall  Quit
 Select a file to print

 JOBS IN QUEUE:  3                                   TIME  COPIES  DIRECTION
 C:\DUET\WS.@00 .......................................       1     normal
 C:\DUET\DBASE.@01 ....................................       1     normal
 C:\DUET\123.@02 ......................................       1     normal

 9   Total              1,000      1,425      1,400      3,825
 10
 11
 12  Sales Forecast            (Dollars)
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Duet's main menu.

In-Use Comments

Duet's main menu resembles Lotus 1-2-3's across-the-top-screen command options. Pop-up windows expand this usage ease. A list of files is maintained and displayed below the command options so that it's easy to keep track of what you've set up.

The program is a fast-operating one. Even sideways printing is accomplished reasonably fast. Data retrieval speed is achieved by the program saving information on disk that describes file or file portions so that it can call it up, rather than saving the whole file or part of it. This also saves disk space.

Its support for a very wide range of printers, including laser printers such as Hewlett-Packard's LaserJet Series II, is very welcome, too.

Having a host of print-control programs all on one disk, including some unique ones, can turn anyone into a power user of sorts. There are so many options, however, that I found that the fine accompanying manual had to be at my side just to remember all that Duet allows me to do. This includes printerless printing for setting up work right up to the point of choosing "on" from a menu called up at some later time. This is handy when you don't have a printer available, just don't want a printout immediately or transfer the information to another person. Other such not-so-customary features are using a font generator to create your own type faces and controlling print darkness by choosing the number of printing passes.

I only ran into one difficulty. Using a 576K-memory machine, an insufficient memory alert prevented me from loading the full 128K Duet when I already had a word processor, spelling checker, thesaurus, and a bevy of memory-resident programs already loaded. I could have done it by choosing a Duet option that used only 90K or 60K, but this would not have allowed me to print sideways or decode Lotus 1-2-3.

For most people, just being able to work on material while printing, printing sideways and decoding Lotus 1-2-3 and Symphony will be enough to attract them to the modestly priced Duet. The many other features this program offers are very appealing bonuses. **ME**

CIRCLE 83 ON FREE INFORMATION CARD

Another Kind of TV interference

By C. Hall

Some time ago, I noticed interference with my TV reception; the picture was covered by diagonal or herringbone lines. It was worse on the lowest numbered vhf channels, but still evident on the higher-frequency channels. The interference would occur at random times and last anywhere from a few minutes up to an hour or more. It occurred about the time neighbors returned home from work in the late afternoon. A quick check of literature on TVI indicated the source of trouble might be a nearby radio transmitter of some sort.

The Search

Assuming that the problem was caused by a ham or CB transmitter, I tried high-pass filters between the set's antenna terminals and the 300-ohm twin-lead ribbon cable from the antenna. The small, two-dollar variety of filter had no effect; the larger, six-dollar type helped a little, but not enough to allow a satisfactory picture on the TV screen.

Next, I tried winding the TV set's power cord onto a large ferrite toroid; about 15 turns was all I could manage. The idea here, of course, was to prevent TVI from getting into the set via the power cord. Unfortunately, the effort produced no improvement.

About this time, it occurred to me that more and more of our neighbors were acquiring cordless telephones and that these phones might be the source of the interference. Cordless telephones transmit FM signals on frequencies in the ranges of 46.61 to 46.97 MHz (base) and 49.67 to 49.99 MHz (handset). The TV receiver's picture carrier frequency, 45.75 MHz, seemed uncomfortably close to the 46-MHz band used by cordless phone transmissions. From this, I concluded that cordless phone transmissions might be getting into my set's i-f amplifier, producing undesirable visual effects.

If this were the case, the high-pass filters must have failed to work because they were designed to pass all frequencies above 54 MHz, and 46 MHz was just too close to the filter's passband for the filter to have much attenuation there. With these assumptions, I decided to make an inexpensive 46-MHz trap that could be connected directly to the set's antenna terminals.

The Trap

Very effective traps can be made from quarter-wavelength pieces of 300-ohm TV twin-lead transmission line. Figure 1 shows the equivalent circuits of quarter-wavelength short-circuited and open-circuited transmission lines. The short-circuited line behaves like a parallel-tuned resonant circuit that has a very high impedance, and the open-circuited line behaves like a series-tuned resonant circuit that has a very low impedance.

In both cases, the resonant frequency is that frequency at which the transmission line length is one-quarter of a wavelength, *electrically*. In most instances, transmission lines exhibit a difference between electrical length and actual physical length, but more about this soon.

To make a 46-MHz trap, I used the open-circuited line so that it would tend to short-circuit any frequencies in the vicinity of 46 MHz. The following procedure was used to determine the length of twin-lead required for the trap.

Electromagnetic waves travel in free space at the velocity of light, which is 300,000,000 meters/second. To convert frequency to wavelength, you simply divide frequency in Hertz into the speed of light, as follows:

$$\text{wavelength} = \frac{\text{speed of light}}{\text{frequency}}$$

$$= \frac{300{,}000{,}000 \text{ m/s}}{46{,}000{,}000 \text{ Hz}}$$

$$= 6.52 \text{ meters}$$

At 46 MHz, therefore, the length of one full wavelength is 6.52 meters. Since we want the distance required for only one-quarter of a wavelength, or ¼ of 6.52 meters, a 1.63-meter length is needed.

Meters can be converted to inches by multiplying by 39.37 inches/meter. Thus, 1.63 meters × 39.37 inches/meter = 64.19 inches. Consequently, a quarter-wavelength at 46 MHz is 64.19 inches in free space. But signals do not travel down a TV twin-lead transmission line at the speed of light; they are slowed down a bit.

Manufacturers of transmission lines specify a "velocity factor" for each type of transmission line to take this into account. This is the ratio of the velocity of the signal in the line to the speed of light. Most TV ribbon twin-lead cable has a velocity factor of 0.8, meaning that signals travel on twin-lead line at only 80 percent of the speed of light. Therefore, a quarter-wavelength of TV twin-lead at 46 MHz will be only 80 percent of 64.19 inches in length: 0.8 × 64.19 inches = 51.35 inches.

Thus, I cut my twin-lead line for a

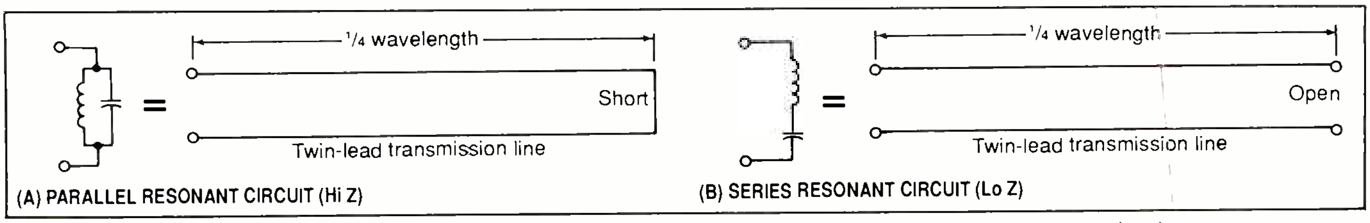


Fig. 1. Relationships between quarter- wavelength transmission lines and resonant circuits.

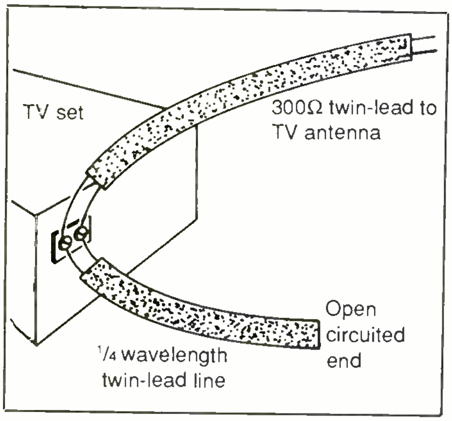


Fig. 2. Quarter-wavelength trap connects to TV set's antenna terminals in parallel with antenna line.

length of 51⅜ inches and connected it to the TV set's antenna terminals, as shown in Fig. 2. From that moment on, the video interference was gone. (In a coaxial-cable system, you could build a trap using coax, but you must know the velocity factor of the cable and cut the length of the coax accordingly.)

Conclusion

I was in a hurry when I made this trap, not knowing if it would do any good, so I did not bother trying to set the frequency right smack in the middle of the 46.61-to-46.97-MHz cordless-phone band. Actually, my trap is centered 0.61 MHz off to one side of the band, and it still does the job. This seems to indicate that it is a very good trap and is non-critical in its application. The center of this cordless-phone band is 46.79 MHz. If you cut your trap for this exact frequency, the length should be 50½ inches.

I did not prove beyond any doubt that my interference was caused by cordless telephones; it may have been caused by some other service operating in or near that frequency band. Nonetheless, this type of interference never appeared again since installing the trap described here, so the offending frequency must have been correct. ME

NEW LITERATURE

Testing & Prototyping Equipment Catalog. A 28-page catalog that lists and describes testing and prototyping equipment is available from Global Specialties. Included in the Spring 1988 catalog are listings for Global's full line of breadboarding and educational produces, logic test equipment, power supplies, test instruments and accessories. Also listed are several Datatran Corp. products, including the Pulse-Tracker pulse detector and Datatracker break-out box and cable tester. For a free copy, write to: Global Specialties, P.O. Box 1405ME, New Haven, CT 06505.

Tools/Test-Equipment Catalog. The new catalog from Jensen lists and fully describes a wide-ranging assortment of tools and equipment, including new service and maintenance tool kits and test equipment for electrical and electronics technicians. Included in the listings are hand and power tools in inch and metric sizes; work holding devices; light and optical aids; wire and cables; electrical safety products; equipment cases and shipping containers; soldering supplies; and more. Each product listing contains price. For a free copy, write to: Jensen Tools Inc., 7815 S. 46 St., Phoenix, AZ 85044.

Test & Measurement Catalog. A new 512-page catalog lists the John Fluke Mfg. and N.V Philips full test and measurement equipment lines, providing photos and ordering information for more than 600 products. It has product sections for oscilloscopes, logic analyzers, GPIB instrument systems, signal generators and counter/timers, to name a few. Products are grouped into category sections, of which there are 16, each numbered and with a visible tab to simplify look-up. Each section contains a description of the product category and a quick-reference selection guide. Thirteen newly introduced products are highlighted in a full-color section up front. The index is located at the front of the catalog and is arranged both alphabetically and by Fluke/Philips product number. Also contained in the catalog are a list of all Fluke and Philips technical literature, warranty information, worldwide sales and technical contacts and ordering instructions. For a free copy, write to: John Fluke Mfg. Co., Inc., P.O. Box C9090, Dept. ME, Everett, WA 98206.

PC-Based Equipment Catalog. Rapid Systems' new full-line catalog lists and fully describes PC-based instruments for the IBM PC/XT/AT and compatible computers for control, display and data storage and conversion. Among items listed are: digital storage oscilloscopes with bandwidths ranging from 500 kHz to 20 MHz; FFT spectrum analyzers with 0.1-Hz to 10-MHz bandwidths; data loggers; and a full line of data-acquisition cards with software. All product descriptions are accompanied by complete specifications, including prices. Included are a product selection table and a list of local suppliers. For a free copy, write to: Rapid Systems, 433 N. 34 St., Seattle, WA 98103.

Semiconductor Catalog. WorldWide Component Distributors has a catalog that details prices and listings of more than 26 series of original Japanese transistors, diodes, triacs, bridge rectifiers and SCRs. For a free copy, write to: WorldWide Component Distributors, 18 Stern Ave., Springfield, NJ 08081.

U.L. Standards Booklet. A new booklet that describes changes in the U.L. Standards and the 1987 National Electrical Code and how they relate to cables is available from Atronix, Inc. It explains changes in the NEC and pertinent U.L. subjects, such as 13 (NEC 625), 444, 478, 758, the the proper uses and typical abuses of appliance wiring materials. The 10-page booklet includes a summary of changes relating to signaling and power-limited circuits, fire-resistant cables, optical-fiber cables, CATV coaxial cables, etc. For a free copy of "A Guide to Changes in U.L. Standards and the National Electrical Code" write to: Atronix, Inc., Marketing Dept., 780 Boston Rd., Billerica, MA 01821.

Optical Isolators (from page 23)

The Schottky diode also prevents the transistor from going into a hard-saturation state. If the transistor turns on hard enough that the phototransistor's collector voltage falls more than 0.2 volt below the base potential of the phototransistor (about 0.7 volt), the Schottky diode turns on. At this point, all excess base electrons will be shunted away by the diode, leaving only enough electrons to keep the phototransistor slightly turned on. This prevents long delays before transistor turn-off initiates because of large amounts of electrons to be used up.

The bottom line with regard to the above is that the switching speed from the starting circuit to the final circuit is greatly reduced. Turn-on time started at 10.5 microseconds and has been reduced to 1.1 microseconds, for an almost 10-fold improvement. Turn-off time has been reduced from 44 microseconds to 3.2 microseconds, for a 14-fold improvement.

Although the fixes described here require some additional circuitry, total cost of the extra components needed is quite small when weighed against the improvements they bring. You should be able to incorporate these improvements at a cost of about $1.50 in addition to whatever you might have to pay for the low-cost optoisolator. A premium high-speed optoisolator, if available, may cost you $4.00 or more per device. The only real penalty you must pay to use a low-cost, commonly available optoisolator like the 4N35 in relatively high-speed (approximately 3.1-MHz, based on a 3.2-microsecond turn-on time) applications is an increase in circuit real estate. The Fig. 9 circuit shown here will provide adequate performance for all but the most demanding of high-switching-speed applications. Where very-high-speed switching is a critical requirement, you can always opt for a premium high-speed optoisolator. ME

Multiplexer (from page 39)

puter is connected to which input cable, but the printer *must* be connected into the system via the project's output cable. The proper hookup arrangement is shown in Fig. 3.

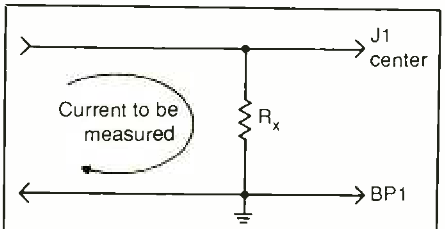
If you have an external printer buffer, you can also use it with the Printer Multiplexer. Simply install it between the Printer Multiplexer and printer, as illustrated in Fig. 4.

You may be wondering about the 36-inch length limitation for the cable between the Printer Multiplexer and printer. The reason for this limitation has to do with voltage loss on the cable. A 36-inch length was chosen to be sufficient to allow the project to be placed out of the way near the printer without introducing excessive voltage drop on the +5-volt line from the printer. A 30-gauge ribbon cable used for the prototype of this project dropped the printer's +5 volts to +4.8 volts at the Multiplexer, which is within the range to assure positive, reliable operation.

Once the Printer Multiplexer is connected into your computer system, it can be mounted wherever it will not physically interfere with any other element in the system. Owing to the fact that it automatically switches on when the printer is powered up, assuming your printer has +5 volts on line 18, you can simply forget about the project after installing it. Of course, if your printer does not have a +5-volt line, you must use the on-board dc power supply built into the project. This can be automatically switched on and off whenever you power up and shut down your computer with a master power controller. Alternatively, you can incorporate into the project a slide or toggle switch to turn on and off the power supply separately.

Though the Printer Multiplexer was designed to work with two computers, you can also operate it with a single computer should the need arise. So if you have to disconnect one computer for any reason, there will be no problem with operation. ME

100,000-Megohm-Input Meter *(from page 31)*



Current Range Desired Full Scale	Value of R_x in ohms	Setting of S1 in Volts
3 pA (3×10^{-12} A)	10,000M	0.03
10 pA (10^{-11} A)	10,000M	0.1
100 pA (10^{-10} A)	1,000M	0.1
1 nA (10^{-9} A)	100M	0.1
100 nA (10^{-7} A)	1M	0.1
1 uA (10^{-6} A)	100K	0.1
1 mA (10^{-3} A)	100	0.1
1 A	0.1	0.1
30 A	0.001	0.03

Fig. 8. The setup for making current measurements with the project.

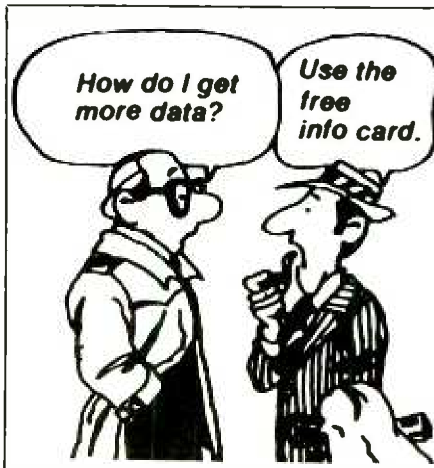
used with this project are shown in Fig. 7. The capacitive divider illustrated in (A) has the advantage of drawing no steady dc current from the circuit under test. However, with the input resistance to the project at *J1* being finite, the dc voltage across *C2* in Fig. 7(A) will gradually drop even if input voltage to *C1* is kept constant. Therefore, you must make sure that *C1* and *C2* are discharged before reading the voltage and immediately take the reading after connecting *C1* to the unknown voltage source.

The project has about 12 picofarads of input capacitance. This should be taken into account when making ac measurements. The electrometer's frequency response is about 10 Hz to 10 kHz, allowing it to be used for making low-level audio measurements. However, keep in mind that the project's capacitive input impedance is a limiting factor at very-high impedances. Bear in mind that 1 picofarad of capacitance is a 159-megohm reactance at 1,000 Hz. Therefore, at very-high impedance, this is not a negligible consideration.

Figure 8 illustrates the setup for making current measurements with the electrometer. It also details what settings to use for various current/resistance values. When measuring currents, be sure to connect the instrument exactly as shown.

When measuring static-clectricity charges, it is perhaps best to do so by proximity, using an "antenna" made from a straightened paper clip plugged into the center contact of the INPUT connector. Do *not* make a direct electrical connection to the antenna or a cable plugged into the INPUT jack when making static-charge tests. If the charge is too high, it will overload the electrometer and possibly even damage the MOSFET input to the op amp.

If you wish, you can perform a number of interesting experiments in electrostatics and high-impedance phenomena with this instrument that are impossible to do with general-purpose instruments. Its positive- and negative-scape provisions can identify the polarity of a static charge, for example. **ME**



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LETTERS . . . *(from page 68)*

cool the thorium in LN and then pour the LN out and quickly take a measurement. Also, you could not cool the thorium but pour some other liquid into the cup to see if you get a decrease in count rate. I see the possibility for much more investigation here to see how different liquids and solids, and different thickness affect the count rate.

Liquid nitrogen is great stuff. I have instructed several sections of undergraduate physics lab, and always found attendance and interest high when our low-temperature lab came around. It isn't the purpose of that lab to have fun with LN, but I think it is what the students remember the best out of the entire quarter of physics.

I really enjoy your column. You have inspired me to do a lot of hands-on work in electronics and have a lot of fun with it.

Everett Rubel
Davis, CA

• Forrest Mims had a major blunder in his column in your April issue. Radioactivity is NOT affected by temperature. The liquid nitrogen surrounding the lantern mantle "moderated" or absorbed most of the radioactivity. Had Mr. Mims also put the mantle in boiling water to get a third point on his curve of Fig. 7, he would have found that raising the temperature above ambient also appears to decrease radiation. This is because water is also a moderator.

Robert Kinnison
Las Vegas, NV

• Although I am no expert in radioactivity, I think you made a mistake in attributing the reduction in radioactivity to liquid nitrogen cooling (April 1988, *Modern Electronics*).

I am not sure of the decay products of thorium but if a percentage of it is alpha particles, then a reduction in radioactivity could be explained by the stopping power of the liquid itself! Putting your samples in room-temperature water should probably have the same effect.

Beta and gamma would also be reduced, but not to the same extent as alpha. I just don't think temperature has much effect on radioactivity.

John Logatin
Arden Hills, MN

• I always enjoy the column written by Forrest Mims III. I was surprised when reading the April issue where he claims that emission from a radioactive source is decreased at low temperatures. Radioactivity results from transitions that take place in the nuclei of unstable elements. These transitions are not affected by bulk kinetic effects as a consequence of conventional temperatures down to absolute zero.

The effects that Forrest observed were more likely due to the absorptive quality of the liquid nitrogen rather than the low temperatures. That is, the liquid was simply absorbing a portion of the radioactive emissions. A similar effect would probably be observed if he had used a liquid as water or gasoline at room temperature (21 °C). Each liquid would, of course, have its own absorptive properties.

Enjoy your magazine, having recently subscribed. Keep up the good column, Forrest.

Walter Pergans, WA2ZBE
Staten Island, NY

Forrest Mims Responds: I wish to thank those readers who commented on my observations about the apparent decrease in radioactive emissions from a thorium-impregnated lamp mantle immersed in liquid nitrogen. When the experiment was repeated with tap water instead of liquid nitrogen, I also observed a decrease in emissions. Therefore, readers who suggested that the nitrogen was absorbing alpha particles emitted by the thorium are correct.

Incidentally, some readers apparently believe thorium emits only alpha particles. While thorium is an alpha-emitting radioisotope, the first of its ten radiodaughters is radium 228, a beta emitter. Alpha particles can be stopped by a centimeter or so of air or a piece of paper. Beta particles are much smaller and faster than alpha particles and have considerably more penetrating power.

*Readers who wish to know more about thorium-impregnated lamp mantles should see "The Hidden Danger of Mantle Lamps" (*The Mother Earth News*, Nov.-Dec. 1982).*

I & R Migration

• There's an error in the February 1988 issue's "Mathematical Variations of Ohm's Law." It is in the first example cited, where the words "ampere" and "ohms" were mistakenly transposed in solving I = E/R.

Victor Rodriguez
New York, NY

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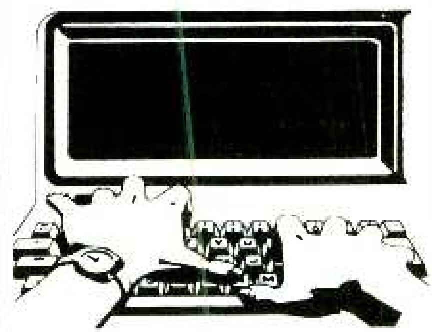

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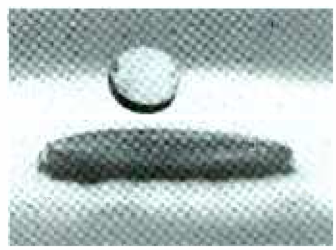

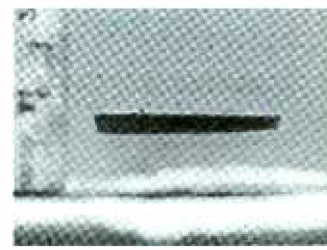

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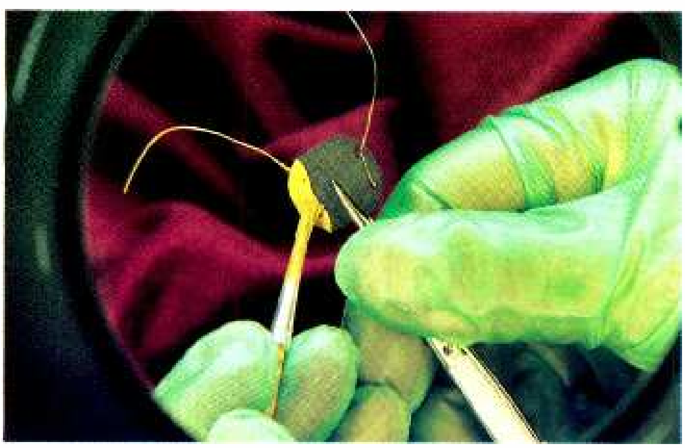

Each Fluoramics' superconductor is carefully drilled with 4 holes. Copper wire is threaded in place. Conductive silver paste is hand-painted to assure uniform area contact. Meissner levitation and transition curves are run on representative samples from each lot.

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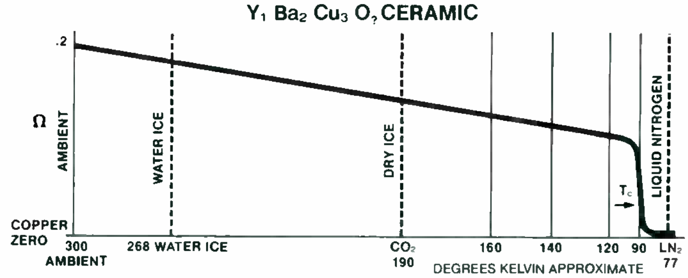
$Y_1 Ba_2 Cu_3 O_?$ CERAMIC



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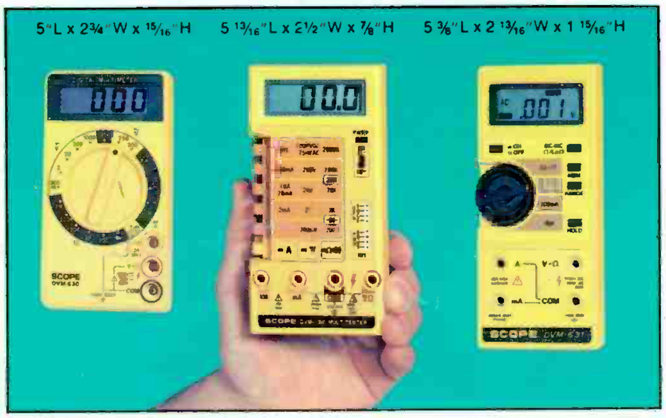

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