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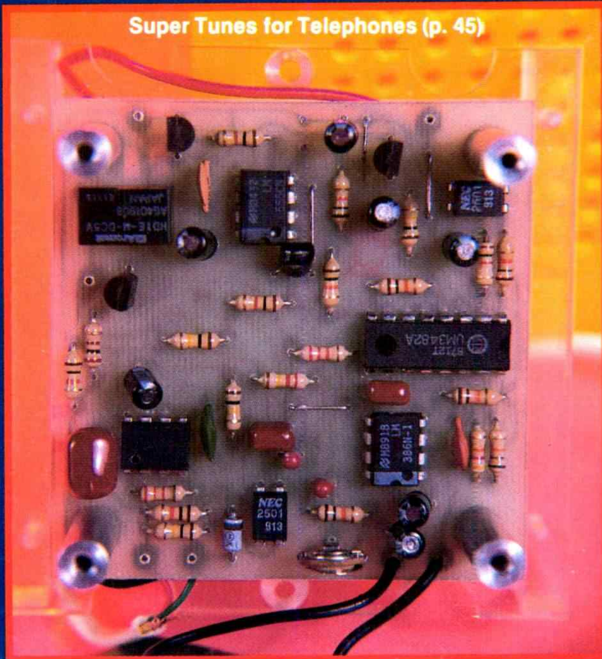
MODERN ELECTRONICS™

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

How Digital Voltmeters Can Display Light Levels

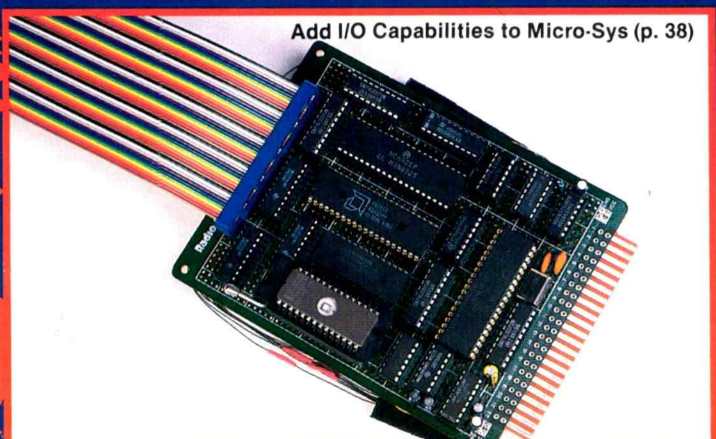
Phone Plug-In Plays Different Tunes Each Ring



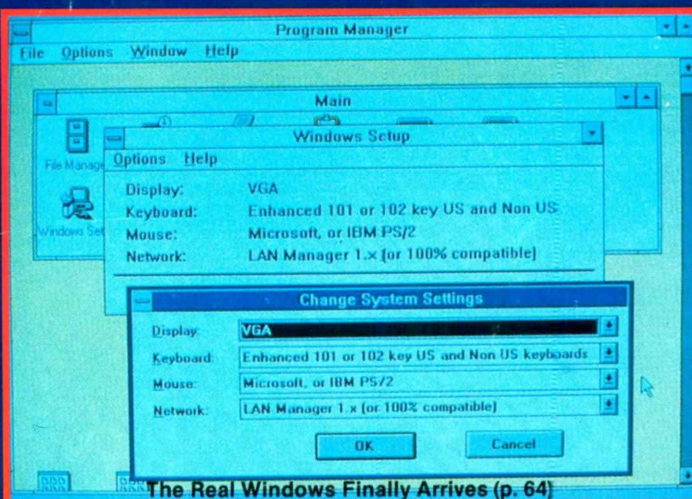
Super Tunes for Telephones (p. 45)

Also:

- I/O Add-On Enhances Micro-Sys SBC
- How To Make Older Video Monitors Work With Newer Personal Computers
- Send And Receive Morse Code And Voice Through The Earth



Add I/O Capabilities to Micro-Sys (p. 38)



The Real Windows Finally Arrives (p. 64)

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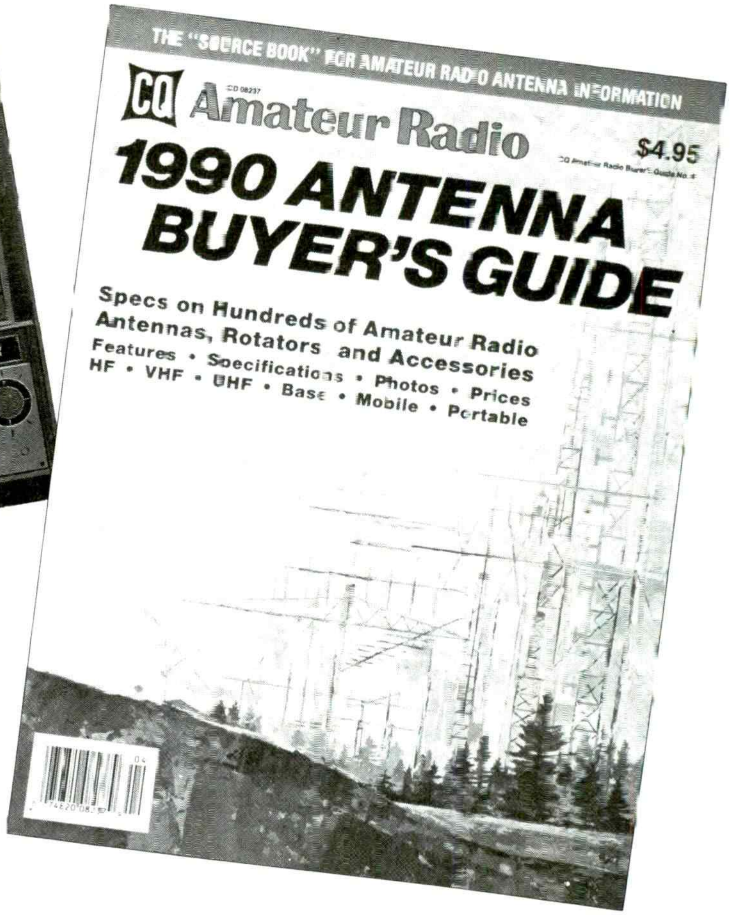

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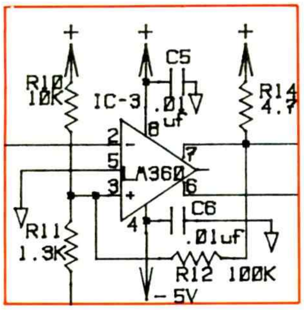
MODERN ELECTRONICS

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

SEPTEMBER 1990 **VOLUME 7, NUMBER 9**



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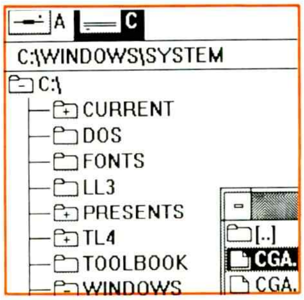

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Offices: 76 North Broadway, Hicksville, NY 11801. Telephone: (516) 681-2922. FAX (516) 681-2926. Modern Electronics (ISSN 0748-9889) is published monthly by CQ Communications, Inc. Subscription prices (payable in US Dollars only): Domestic—one year $18.97, two years $36.00, three years $53.00; Canada/Mexico—one year $21.00, two years $40.00, three years $59.00; Foreign—one year $23.00, two years $44.00, three years $65.00. Foreign Air Mail—one year $76.00, two years $150.00, three years $224.00.

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MODERN ELECTRONICS NEWS

HANDS FREE FUN 'N' GAMES. Broderbund Software has introduced hands-free-control cartridges for Nintendo Entertainment Systems. With its "U-Force Power Games," a 4-games-in-1 cartridge, all the player has to do is wave his hands or turn his body to control game play. No wires, joysticks, or whatever. It operates without any external power source and works with more than 40 percent of existing games, allowing game play in an entirely different way. The U-Force costs from $70 to $80. Included are accessories, such as a firing handle combination to intensify play for certain games, as well as other enhancers.

Selectech, Ltd., So. Burlington, VT, announces it has completed development of a novel remote control "mouse" for interactive video. The cordless device, called an "AirMouse," works in conjunction with an AirMouse base station mounted atop or at the side of the video monitor or TV set. Using digital infrared technology with a patented sensor, the single-button point-and-pick device is said to work like a conventional computer-type mouse, but with no set connection.

PERSONAL COMMUNICATIONS. An Arthur D. Little survey predicts skyrocketing personal mobile communications services. Half of all U.S. households want to become part of such a revolution, according to the independent study. In the next three to five years, 12-million households will actually buy such services, the firm's telecommunications industy experts estimate. This goes beyond existing cellular offerings, with services linked into the public telephone network. It's expected that subscribers will carry and speak over pocket-size mobile phone sets rather than over telephones attached to walls. Accordingly, such personal communications services will provide people-to-people communications when they are not even near an office, home or pay telephone.

There's a proposal out to the FCC to create a new "CD-quality" broadcast radio service for the automobile radio market. Satellite CD Radio (202-408-0080) made the application. Program material would be delivered over satellite facilities to existing broadcast stations that choose to operate as radio "superstations." This would require new CD car radio receivers and antennas. According to a spokesman, this car equipment would cost the owner less than $200.

The Ford Motor Company annouces a national carrier airtime network as part of its launch of the Ford Cellular System. The airtime network will allow Ford dealers, who already offer factory-installed cellular phones for Lincoln cars, to activate the phones before delivering new vehicles. The Network consists of major carriers throughout the country. Subscribers will also receive a free 60-day custom calling packing.

CHALLENGING THE SPINNING-DISK METER. The 100-year-old spinning disk electric utility meter long used by the industry is being challenged by electronics technology. A new technology, NetComm (Network Coimmunications), is Southern California Edison's experimental system to develop all-electronic meters to the utilities' computers via a network of packet-switching radios located atop street lights. The low-power transceivers use the 900-MHz band. Currently linking 1,000 Valencia-area customers, field tests include metering, monitoring and diagnostics.

EDITORIAL

Never Buy a Zero

Macintosh computer users are generally deeply attached to computing with the machine, it always seems to me. Is it because of its graphical user interface (GUI), with easy-to-identify icons? Maybe it's due to the interactive movement of the mouse, clicking on objects, dragging graphic symbols from one location to another, and not having to remember a host of disk operating system code letters and words to make things happen.

Most Mac users are still working in monochrome, although I must admit that it's paper-white video is super. They paid a bundle for the machine and its peripherals, too, while IBM-type computer prices are relatively low. But maybe this lends a sense of elitism to its proponents, endearing the computer and its innovative creators to them. Mac applications software is easier to learn and use, it's been said. And until the recent advent of Hewlett-Packard's LaserJet II, Postscript typography really only made sense with a Mac and a Postscript-type laser printer, both quite costly. But cost aside, one didn't have to wait forever for print output, and cursive type faces came out looking the way they are supposed to instead of the disfigurement caused by the dropping of dots.

Recently, this all changed. With the H-P Model III, printer type fonts with serifs are automatically scaled so that all the dots are reproduced instead of being tossed out because some don't fit into a set frame. It's almost like having a 600-dpi printer instead of having a 300-dpi printer. The final touch, though is the introduction of Microsoft's "Windows 3.0."

I never liked Windows in all its earlier incarnations: Too slow, klutzy-looking graphics, etc. But 3.0 transformed an ugly duckling into a princess. Working with it has brought me computing pleasure that I never had before with an IBM-type computer. Yes, the Mac owners certainly had reason to crow.

In a way, they still do. After all, the cheapest Mac is built with a classy GUI. To approach it, an MS-DOS computer had better be equipped with plenty of memory and a mouse or trackball. And it can't be anything less powerful than a speedy 286 computer, although I would prefer at least a 386SX with a minimum of 2MB of memory.

Add color (VGA as a minimum) to the above and wait a bit for some new applications software designed to take advantage of Windows 3.0, and Macintosh better watch out. Graphics are splendid now. And the 640K DOS barrier is broken without muss or fuss. Moreover, it's got multitasking, virtual memory, a bevy of beautiful desktop accessories and a Paintbrush program that works in full color, not to mention a terrific Solitaire electronic card game that even impressed my non-computing wife.

Admittedly, operating speed isn't breathtaking, although it's now sufficiently fast to not be bothersome. And it's certainly a memory hog (6MB worth on your hard disk). Also, it works terribly on laptop computer LCD screens that are anything less than VGA paper white. But its pluses clearly overshadow these shortcomings, which will have to wait for the OS/2 operating system to eliminate. It even has such niceties as COM3 and COM4 communication ports, network support and a very easy Setup program that does all sorts of things for you automatically.

Windows 3.0's abbreviated terminal communications program is fine for anyone except true modem power users. It now supports binary file transfer with XMODEM and Kermit (University students and staff will appreciate the latter). The latest Windows version now has a dual-mode calculator, adding a scientific calculator that tech people will surely appreciate. A new recorder simplifies making macro programs by capturing keystrokes instead of forcing you to fight your way through various codes. In this vein, too, a text editor allows you to edit ASCII files without resorting to DOS's cryptic EDLIN.

Windows 3.0 has worked flawlessly for me for the past month. The "fun" hasn't worn off yet, either. I still need another month or two to give Windows 3.0 a more thorough workout, of course, since there is so much to investigate. I haven't even loaded the runtime version of Toolbox by Asymetrix that's included with the new Windows, for example. With it, it's claimed that you can write your own applications without being a programmer. We'll see about this and other things in a while.

Thus far, for the first time, I believe I have a version of software with a zero extension (3.*0*) that I can recommend. Prior to this, I witnessed DOS 1.0, 2.0, 3.0 and 4.0 bomb out with major bugs or obsolescence, as did all other software I know of whose version number ended in ".0." Never buy a zero? Well, there are always exceptions to the rule, I guess.

Art Salsberg

Product Update

• We would like to correct some information that got by us with regard to the B&B Electronics Model 232MSD modem security device featured in the July 1990 New Products section of *Modern Electronics*. One is that the actual retail price of the unit is \$149.95. The other is that automatic rate selection is from among 300, 600, 1,200, 2,400, 4,800, 9,600 and 19,200 baud.

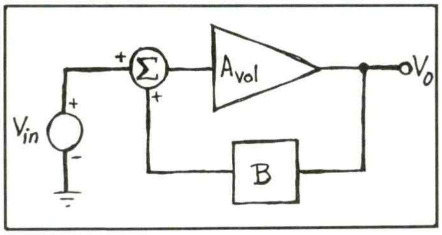
B&B Electronics Mfg. Co.
Ottawa, IL

Reader Feedback

• "Designing Oscillators" in the June 1990 issue contained errors. In Equation [1], for example, the first "L" should be deleted. Equation [4] should read $V_o = V_iA_{vol}$, Equation [5] should read $A_v = V_o/V_{in}$ and Equation [8] should read $A_v = A_{vol}/(V_iA_{vol})$. In the paragraph just before the section on Wein-Bridge Oscillators, R4 should be equal to or greater than 29R1. Finally, the waveforms shown in Fig. 4(B) are 90 degrees out-of-phase, regardless of what the text states.

Robert Smits, EE
Lafayette, CA

• In the Basic Theory section of "Designing Oscillators" (June 1990), I had a hard time following the derivation of the transfer function of the feedback network. A much simpler way is as follows:



In the above diagram, A_{vol} and B are the gains of the amplifier and feedback network, respectively. Notice that $V_1 = BV_o$; $V_2 = V_{in} + V_1 = V_{in} + BV_o$; and $V_o = V_3 = A_{vol}V_2$. Substituting the expression for V_2 in the last equation, we get $V_o = A_{vol}(V_{in} + BV_o)$. Rearranging this last equation, we obtain $V_o = (A_{vol}V_{in})/(1 - A_{vol}B)$ and $(V_o/V_{in}) = A_{vol}/(1 - A_{vol}B)$, which is the same as Mr. Carr's Equation [9].

Jerry VanWinkle
University of Texas at Austin

Math Feedback

• We were glad to see the flattering review of out Derive® symbolic math program for IBM PC and compatible computers in the May 1990 issue. Here are a few clarifications:

Shift-PrtSc dumps a graphics screen to a graphics printer or to a file, provided a screen dumper or screen grabber is loaded prior to loading Derive. Respective commercial examples of such programs are Raindrop™ from Electric Systems (703-440-0064) and Pizazz Plus™ from Applications Techniques (508-433-5201). WordPerfect™ includes a grabber named GRAB, and Word™ 5.0 includes one called CAPTURE.

The vector function produces a range

(Continued on page 68)

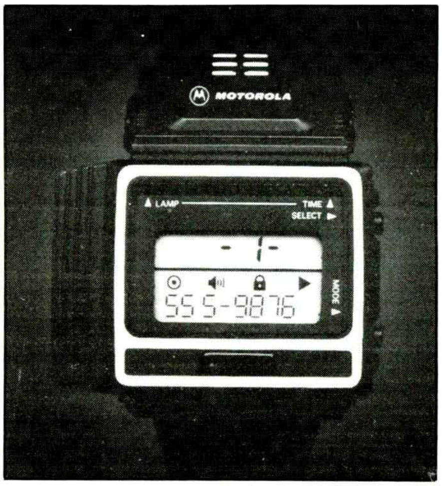
For more information on products described, please circle the appropriate number on the Free Information Card bound into this issue or write to the manufacturer.

Wrist-Watch Pagers

Telephone paging has caught up to Dick Tracy with two recently announced products from different companies. Motorola and Timex led the way with its land-mobile Wrist Watch Pager, with AT&E Corp. (Ogden, UT) and Seiko in the van.

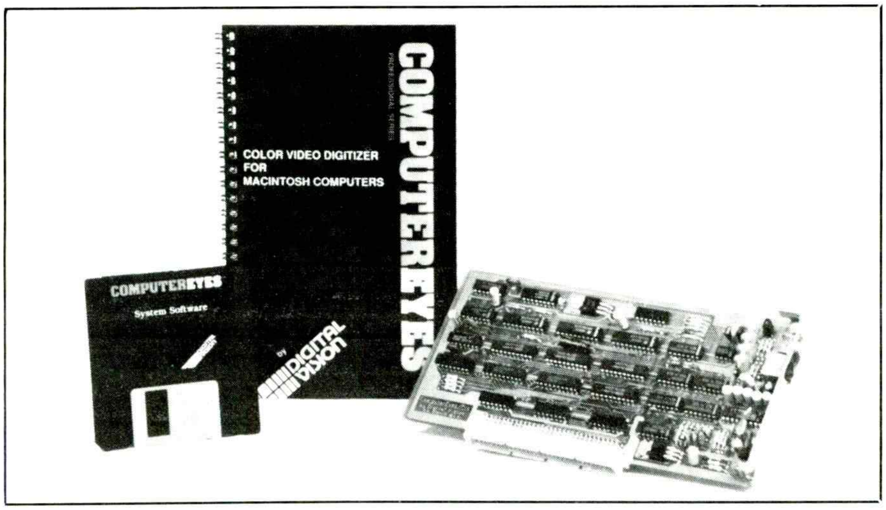
Motorola/Timex's user-friendly Wrist Watch Pager features separate controls for timekeeping and pager functions and weighs less than 2 ozs. Its nonvolatile memory stores messages even when the pager is turned off, and a message-erase feature allows the user to delete all read messages without affecting unread and protected messages. Message time-stamping displays the time a message was received on the LCD screen following the actual message.

The Wrist Watch Pager integrates the standard features of Motorola's



Color Video Digitizer

ComputerEyes Color Professional Series is a video digitizing system for the Macintosh II family of computers from Digital Vision, Inc. (Dedham, MA). It consists of a NuBus board and software on 3.5-inch diskette. The system captures high-resolution images by acquiring 640 × 480-pixel samples for display on either 8- or high-resolution 24-bit display systems. Images can be captured from any standard video source, including any NTSC composite or S-video source. It captures monochrome or color images with 8 or 24 bits of color information per sample for near-photographic quality imaging.



ComputerEyes Color captures and displays 256 colors in 8-bit mode and 16.7-million colors in 24-bit mode. It provides a complete color image scan in 6 seconds. It also offers a preview window for permitting color capture adjustments, including brightness, contrast and colors (which can be adjusted before or after capture).

This system is 32-bit QuickDraw compatible and supports standard Macintosh color file formats, including 1-, 8- and 24-bit PICT and TIFF formats for use in popular color graphics programs. It also optionally captures and displays monochrome images and supports the standard black-and-white formats (TIFF, PICT and MacPaint) for use in desktop publishing and other applications in which monochrome images are required.

System requirements include: any NuBus computer, 2 MB of RAM, a 3.5-inch floppy-disk drive and 8- or 24-bit color graphics display capability. $449.95.

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Digital Vision also has a version of ComputerEyes Professional Series video digitizer for capturing real-world, high-resolution (640 × 480-pixel) color images from any standard, Super-VHS or 8-mm camcorder on IBM PC and compatible computers. It does this at up to 24-bit (16-million-color) palette depth. Captured images are displayed in standard EGA, VGA or Super-VGA with no additional hardware.

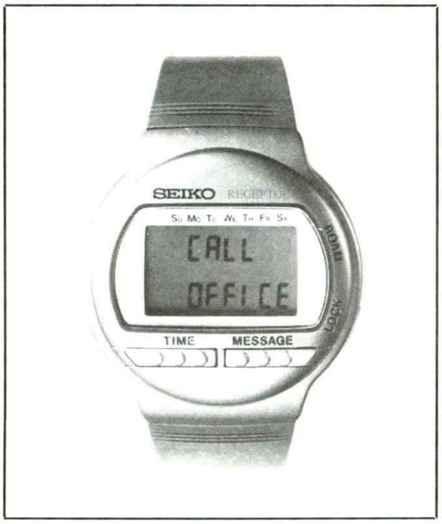
This version of ComputerEyes/Pro supports PCX, IFF, Targa TGA, TIFF, ColorRix, Windows and other formats, with full 24-bit color images possible in TIFF and Targa formats. A developer's software kit with object module and DOS call-able routines available. The kit offers developers the ability to easily incorporate image scanning capabilities directly into their applications. $449.95.

CIRCLE NO. 34 ON FREE INFORMATION CARD

pagers with those of a digital wrist watch. Its two-line LCD window displays time in 12- or 24-hour format, day of week and date. While reading a message, the time display is replaced with the message received.

CIRCLE NO. 35 ON FREE INFORMATION CARD

The AT&E Seiko Receptor MessageWatch allows messages to be initiated by telephone, called in to a local Receptor Message center, which then broadcasts the message over an FM subcarrier for readout by the wearer of the MessageWatch. Service for this Receptor Message center system is initially targeted for 52 cities nationwide and, ultimately, can become worldwide.



A unique miniaturized receiver is built into the case, an antenna into the wristband of the watch. The MessageWatch displays and stores a variety of messages (messages are numbered, and the eight most-recent ones are stored in memory, along with message number and time received), including alphabetic ones and telephone numbers designated by the caller. Messages can also be coded as urgent. In addition to displaying day, date and time, the MessageWatch keeps track of two different times. It automatically corrects the time 48 times per day, based on the National Bureau of Standards' atomic clock, in areas where AT&E's Receptor™ Personal Communication System (PCS) network is operational.

When a message is received, a beep sounds and the message appears in the display. The beep can be turned on and off. Subscribers can contact the Receptor Message Center to retrieve their messages for up to 48 hours after transmission and to enter, change or delete their passwords and privacy numbers. Messages can also be forwarded to other cities where Receptor PCS is available.

MessageWatch has four control buttons. TIME is for setting time in the secondary time zone. LOCK locks and unlocks the time mode. ROAM activates the frequency scanner to locate the FM signal in a new Receptor Service area. MESSAGE permits review of the up to eight messages stored in memory, message number and date and time received. $225, MessageWatch; $12.50 per month, messaging service charge.

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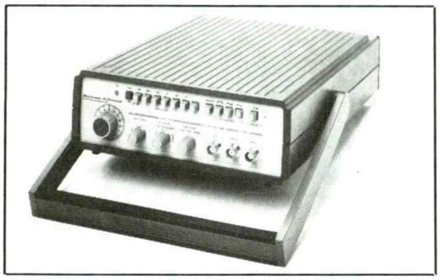
Function Generator

Beckman Industrial's new Model FG2A portable function generator generates sine, square and triangle waves over seven frequency ranges that cover from 0.2 Hz to 2 MHz. It features both TTL-pulse and adjustable low-distortion outputs in all



three waveforms. Pushbutton switches are provided for enabling and disabling power and selecting frequency range and waveform.

A Duty Cycle control allows the user to change the nominal 50% duty cycle of the signal to any desired value. A DC Offset control adds a variable dc offset voltage to the output sig-

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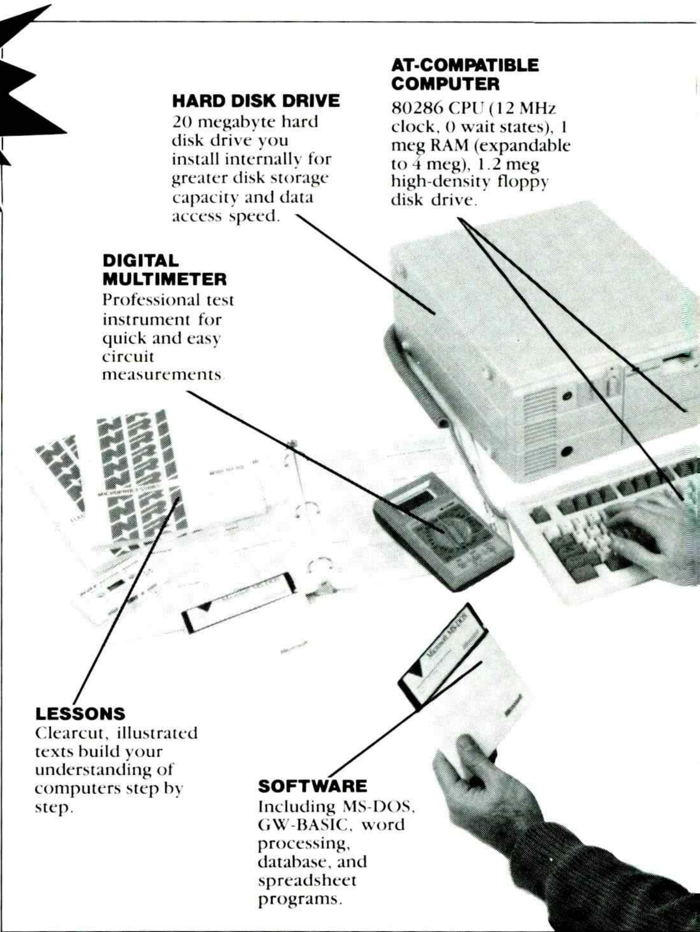

No doubt about it. The best way to learn to service computers is to actually *build* a state-of-the-art computer from the keyboard on up. As you put the machine together, performing key tests and demonstrations at each stage of assembly, you see for yourself how each part of it works, what can go wrong, and how you can fix it.

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NEW PRODUCTS . . .

nal. A VCF input permits the output frequency to be controlled with an external dc control voltage, a feature useful for generating 1000:1 or 1:1000 sweep signals.

Housed in a durable case, the Model FG2A also features a cushion-grip carrying handle that doubles as a tilt stand on the benchtop, rear cord wrap posts and a recessed area in the cover for easy stacking of multiple units. $215.

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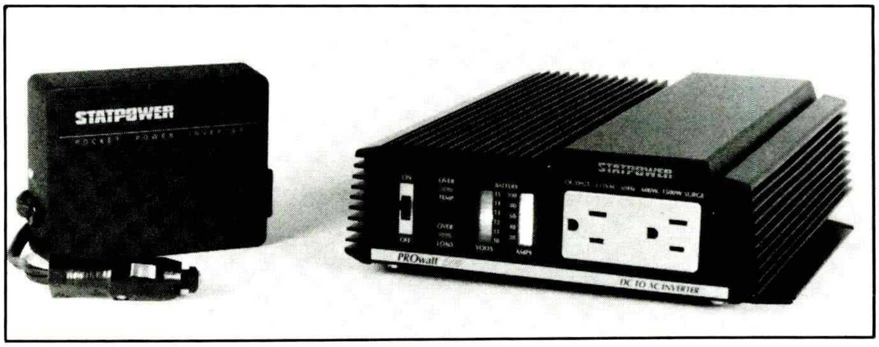
Solder Removal Braid

Solder Removal Co. (Covina, CA) now has Soder-Wick Brand Fine-Braid with water-soluble flux that eliminates the need for CFC solvents. With appropriate pH and holding medium, the flux coating acts as a mildly-activated flux. Residue is removed by applying de-ionized water and brushing. Fine-Braid is braided with highest-purity, fine-gauge strands of pure copper wire and fea-



Power Inverter Line

Statpower Technologies Corp. (Point Roberts, WA) has introduced a line of dc-to-ac power inverters designed for use by computer users. Its Pocket Power Inverter and PROwatt 600 permit ac-powered equipment, including laptop computers, printers, fax machines, scanners, monitors and other peripherals to be operated from any 12-volt dc source that has sufficient current-delivery capability, such as the electrical system of a motor vehicle. Both units require a dc input of 10 to 15 volts and output 115-volt modified sine-wave output.

The PC100+ Pocket Power Inverter provides 200 watts peak and 100 watts of constant power to a single ac receptacle. It has an efficiency rating of 90% and no-load current draw of 0.06 ampere. An audible alarm sounds when the input drops to 10.7 volts and automatic shutdown occurs when the input drops to 10 volts, ventilation is inadequate or an overload occurs. This compact 14-oz. unit (it measures 4.5″ × 3.5″ × 1.2″) is said to run most laptop computers and has been tested and approved by such manufacturers as Toshiba, Mitsubishi, NEC and others. $179.95.

The PROwatt 600 is said to provide enough power for a complete mobile office, including simultaneous operation of a computer, printer and fax machine. It is also claimed to provide enough power to operate hand power tools, kitchen appliances and a wide range of electronic equipment. This compact 5-lb. unit (it measures just 10″ × 9″ × 3″) develops 800 watts of continuous power for about 10 minutes to run small microwave ovens and other high-power appliances. It sounds a low-battery alarm when the input drops to 10.7 volts and automatically shuts down when the input drops to 10 volts. The unit also automatically shuts down when over-temperature, overload and short-circuit conditions are detected. It is claimed to be able to safely deliver a surge of 1,500 watts to start high-power equipment. $449.

CIRCLE NO. 38 ON FREE INFORMATION CARD

tures an optimized weave pattern and lowest level of residue impurities on the surface. No oxides or hydrocarbons are released by application of

heat. Ranging in width from 0.03″ (size 1) to 0.21″ (size 6), Fine-Braid is available in 5-, 25-, 50-, 100- and 500-foot bobbins with standard and ESD packaging.

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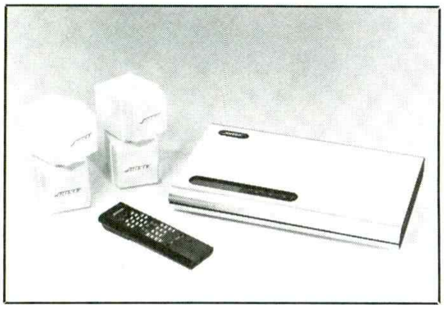
High-Tech Music System

Bose has a new Lifestyle™ Music System that can be tailored to the user's needs. The unobtrusive high-performance system features multi-zone capability and control from anywhere in a home via an r-f remote controller. The system consists of



physically small components. The main component is a Lifestyle Music Center that contains an AM/FM tuner, CD player and microprocessor. Amplifiers are not part of the Control Center; rather, they are built into each speaker system used.

Where top audio performance is required, Bose has the Powered Acoustimass® speaker system that contains a 100-watt amplifier in the bass module and two 50-watt amplifiers in the individual cube speaker arrays. Built-in active electronic equalization provides tonal balance. Patented Dynamic Equalization™ ensures proper tonal balance, even at "background" listening levels. The bass module also has controls for adjusting bass and treble to match the acoustics of a given room. For secondary listening areas, such as a kitchen, bedroom, etc., the Powered Lifestyle Speaker are available. Each contains a single Helical Voice Coil (HVC) driver and its own separate power amplifier, equalization and volume control.

Use of the multiple-room capability makes it possible to create two sep-

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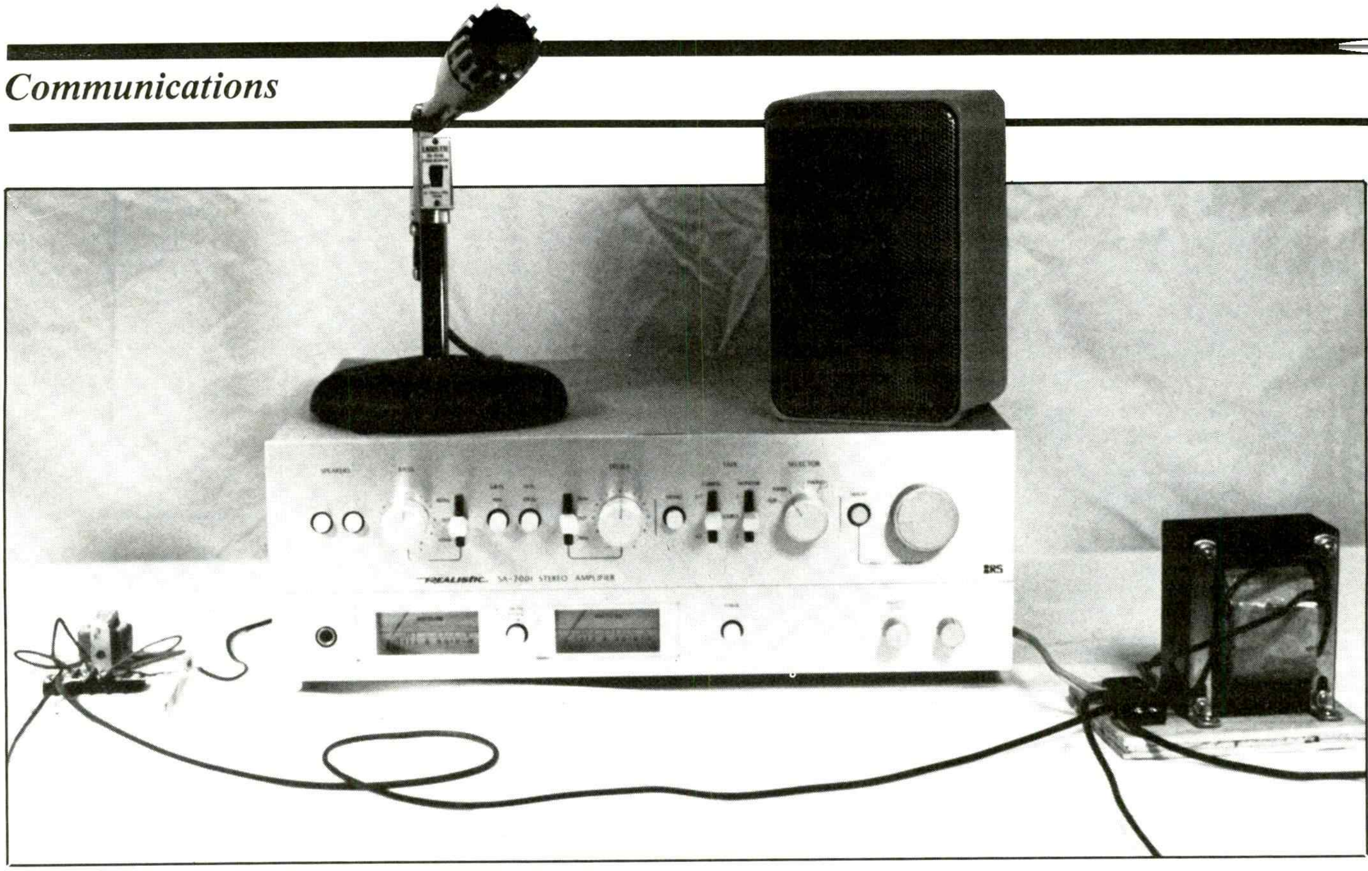

A Ground Communication System

Transmit and receive Morse code and voice signals with this "clandestine" system that uses the earth as the communication medium

By Joseph O'Connell

The technique of communicating through the earth was used to great effect by the French during WWI and amateur radio operators during WWII when they were forced to leave the air. Though through-ground communications came into existence as the result of armed conflict, it has peacetime uses as well and, as a result, never died out. Today, the primary application of underground communication remains as a short-range way to send and receive messages. The very nature of the operation lends an almost-clandestine flavor to the hobby.

If you and a friend live within about a quarter of a mile or so of each other, you can communicate through the earth. This method of communicating does not use radio frequencies and does not propagate through the air as r-f does; thus, it requires no license and no expensive radio gear. In fact, you probably already have all the equipment needed to communicate through the earth on hand. All you need to do is to adapt it for this exciting hobby.

Setting Up a Station

To be able to communicate through the earth, at least two stations must be established. Furthermore, two conductive paths are required to carry voice or code signals between stations.

One conductive path can be the cold-water pipe at the station location, assuming all stations are connected to the municipal water-delivery system and are in common electrical contact with each other. If you live in an area where there is no municipal water system, you can still use this method of communicating, but you will have to establish a good ground system yourself. Later on, we will give full details on how to go about this.

The second conductive path is formed by driving a metal stake into the ground at each station's location. The conductive path then exists between the stations, through the earth.

A third conductive path can be added to each station, in the form of an extra stake driven into the ground to eliminate the push-to-talk arrangement encountered in simplex communication techniques.

Shown in Fig. 1 is an illustration of the simplest ground-communication arrangement. This particular setup offers the easiest way to try out this communication technique. It uses only a cold-water pipe for ground and one additional stake.

When setting up a ground system, you can use the cold-water pipe in your home if it goes to a municipal water-delivery system. If there is no municipal water system in your community, you must drive a separate stake to make the required ground connection. If you must use a separate ground stake, drive it into the ground so that it goes as deep and touches as much earth as possible. Typically, a 4-foot length of galvanized steel pipe, rod or angle iron should be minimum length for the stake. Drive the stake all the way into the ground with a heavy hammer.

For an even better ground, it is advisable that you dig a hole and bury some sheet metal or other conductive materials at the bottom of the hole, touching moist earth to provide a large surface contact area. Thoroughly wet down the hole and refill it with the removed soil. Solidly tamp down the soil and saturate it with water. Then drive the stake into the midst of the buried conductive material to obtain good electrical contact.

If you use a steel rod or pipe, be sure to fasten a cross-piece to the top of it, as shown in Fig. 2. This cross-piece has nothing to do with the communicating ability of the system. Rather, it provides a convenient handle for pulling up the stake if you relocate it in the event you encounter buried rock or other obstacles that cannot be penetrated while driving the stake. Do not be surprised if you have to make two or more tries at driving the stake to have it go all the way into the ground. In most locations, especially where the soil is tightly packed and has a high clay content, more than one try is to be expected.

Locate the signal or "hot" stake as far away from the cold-water pipe (or stake) ground as possible. Consider not only where the water pipe enters your house from the municipal supply, but also how it runs out to the pipe in the street. In addition, when

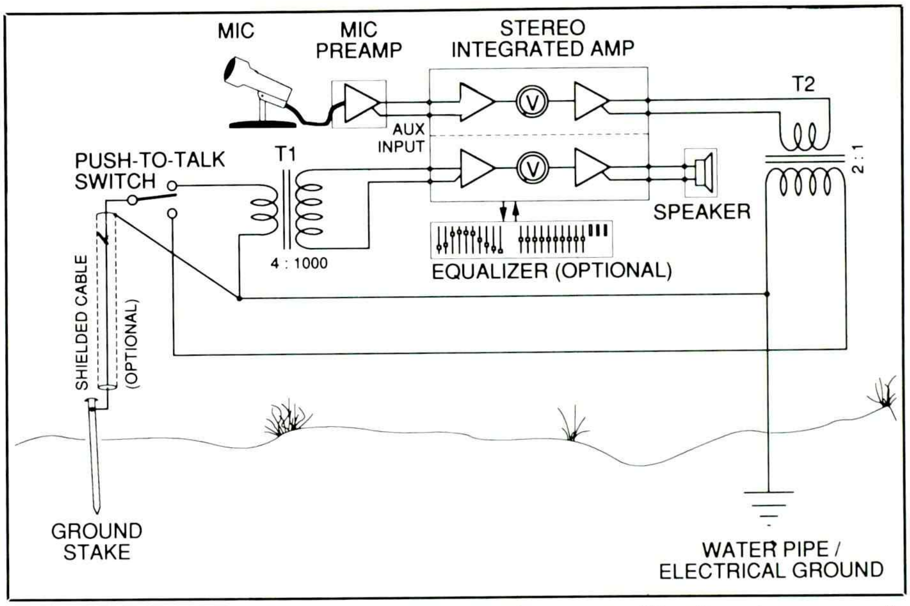

Fig. 1. How to set up an earth station using a one "hot" stake approach.

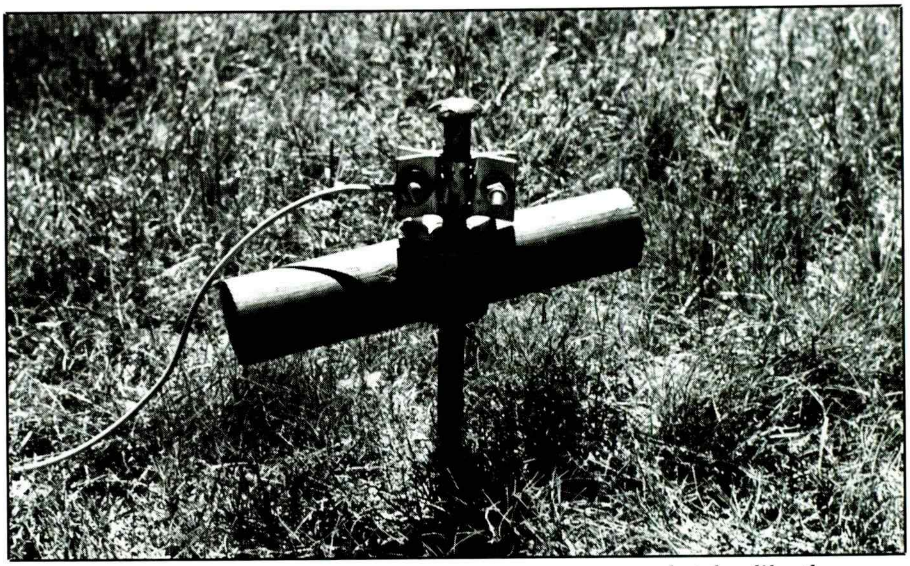

Fig. 2. Be sure to provide some way to remove your ground stake, like the cross-piece shown at the top of the stake in this photo, in case it must be relocated.

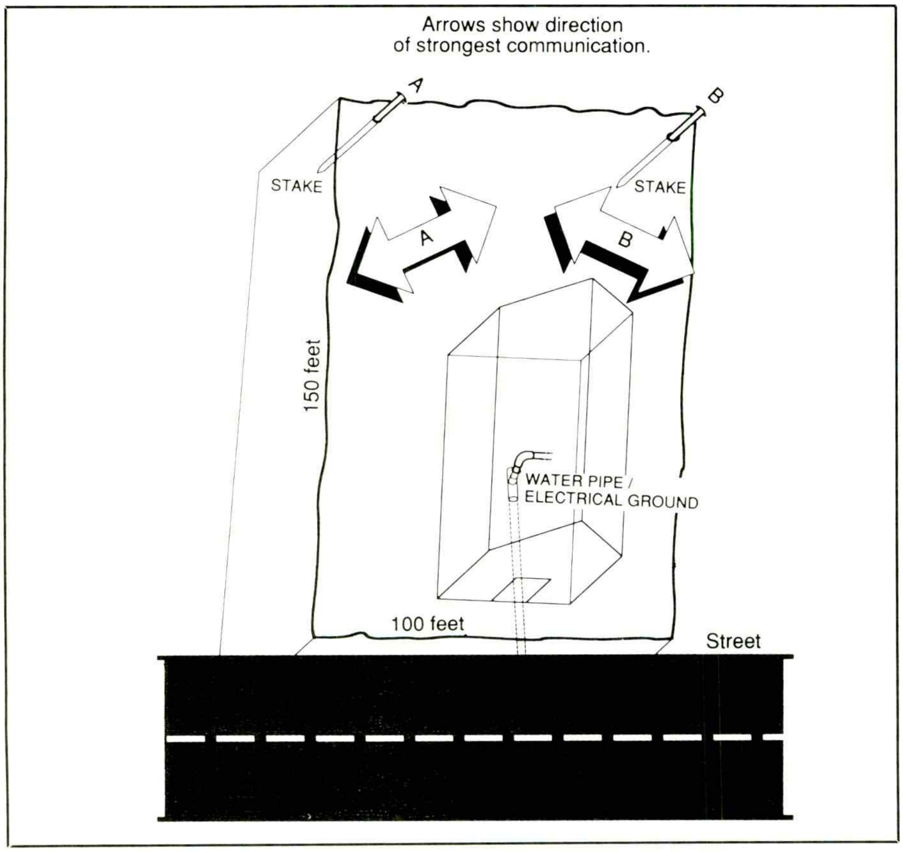

Fig. 3. Aerial view diagram of a typical suburban plot shows direction of strongest communication for two different "hot" stake positions relative to the ground used in the system.

using a cold-water pipe as a ground, take into consideration your neighbors' cold-water pipes and treat them in the same manner, since they are in electrical contact with your own. You also want the stake and water-pipe ground arranged so that a line connecting the two will be perpendicular to an an imaginary line between your and your friends' houses. Figure 2 shows how the direction of strongest communication depends on the location of the stake and cold-water pipe.

Check the quality of the ground stake by measuring the impedance between it and the water-pipe (or stake) ground. The measured impedance should be between 20 and 60 ohms at 1 kHz. The lower the impedance figure, of course, the better the ground. Measure the impedance in *both* directions (that is, take a reading and then reverse the meter leads to obtain a second reading) and take the average of the two readings. This two-reading cancels out the effect of any direct current flowing between the two grounds.

Owing to the fact that ground communication is at low audio frequencies, no fancy transmission line is required. You can run ordinary heavy-duty speaker-type zip cord between the "hot" stake and your house; likewise if you had to drive a separate ground stake in lieu of using a cold-water pipe as a ground. Because you will be pumping 40 watts or more of power into the earth, use at least 18-gauge zip cord.

The line between the "hot" stake and your house will be at nearly ground potential and is not likely to pick up interference, unless it passes near a very powerful source of r-f or other electromagnetic radiation. If you encounter excessive electrical interference, use heavy-duty shielded cable between the "hot" stake and your house.

In addition to the stake(s) and transmission line, you need a stereo integrated amplifier and a few other components to complete your station, as illustrated in Fig. 1 and specified in the Bill of Materials. One amplifier channel is used to amplify the output from a microphone for transmission, the other to amplify the signal from the ground during reception.

The best amplifiers to use for ground communication have separate left- and right-channel volume controls that permit you to leave transmission volume at maximum while allowing you to adjust receive volume as needed. In the absence of separate volume controls, you can use the balance and volume controls to obtain roughly the same effect. Of course, for maximum communication distance, use the most powerful amplifier you can get your hands on.

Both transmission and reception require impedance-matching transformers. These increase communication range and isolate the electronic equipment from the small dc current that almost always flows between earth grounds.

For reception, you must match the low impedance of the ground to the high input impedance of most amplifiers. Use a transformer that offers good fidelity, such as a small speaker output transformer. Connect its 4- or 8-ohm secondary winding across the tie points to the earth and its 1,000-ohm primary winding across the input to the amplifier.

For transmission, the transformer needed has less of an impedance difference to contend with. However, this transformer must be able to safely handle the high output power of the amplifier being used. Though a transmit transformer is not absolutely essential, it helps the amplifier develop its full rated power into the

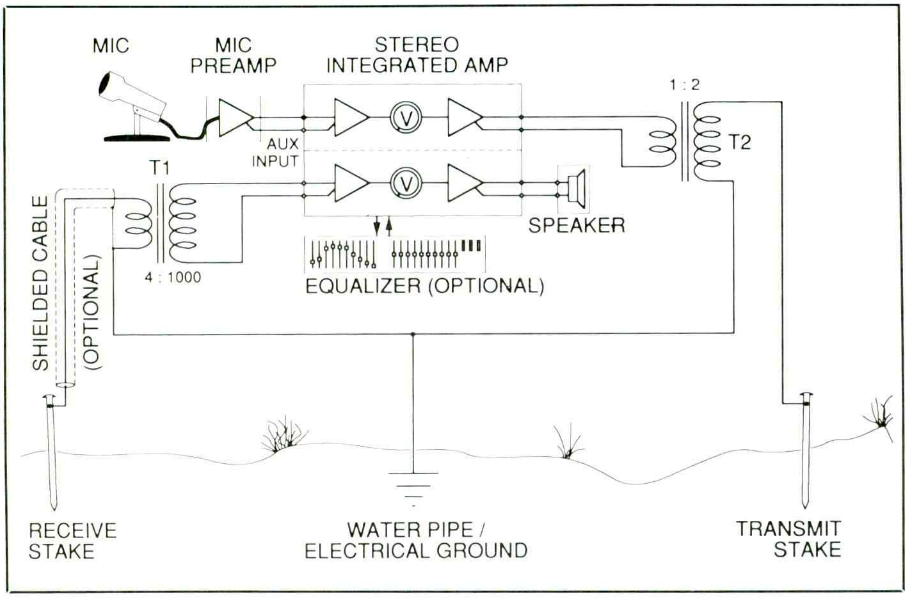

Fig. 4. How to set up an earth station using two "hot" stakes to provide simultaneous transmit/receive operation.

higher impedance of the earth.

This author has had a great deal of success using power transformers with 50- to 70-volt secondary windings. With their 117-volt primaries, such transformers offer an impedance ratio of about 1:2, which is almost ideal for matching the 8-ohm output of the amplifier to the 30-ohm impedance of the earth. Regardless of its secondary voltage rating, the transformer must be able to safely handle the power developed by the amplifier. Any transformer with a secondary current rating of 5 amperes or more should work. However, be sure you can connect an oscilloscope across the output while you are transmitting so that you can check to make sure the transformer is not saturating on signal peaks.

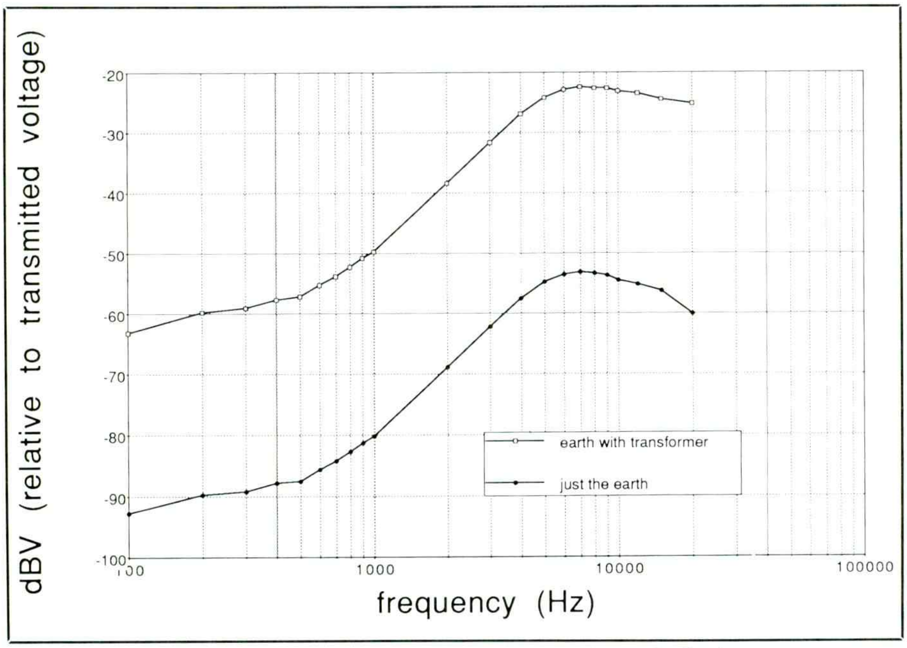

Fig. 5. Frequency-response plots of the earth made during tests.

So far, only the one "hot" stake configuration has been discussed. This approach requires a push-to-talk switch that alternately connects a single "hot" stake between the transmitting and receiving transformers, as shown in Fig. 1. Without this switch to disconnect the receiving section when you transmit, the amplifier would be damaged or you would get tremendous feedback.

Good switches for this application are spdt microswitches that require very little effort for switching and have contacts that can safely carry the full transmitting power developed by your amplifier. You can use such a switch as-is or connect to it a lever that is easier to press than is the tiny button typically supplied on these switches.

Use of separate transmit and receive "hot" stakes allows you to communicate without having to constantly push a switch to talk and release it to listen. Such an arrangement is illustrated in Fig. 4.

Having more than one "hot" stake also allows you to orient your stakes in relation to the water pipe to permit you to transmit and receive in different directions. The two stakes shown in Fig. 3 have different optimal directions for communication, based on their positions in relation to the water-pipe ground. Either stake could be used with the one "hot" stake method to communicate in its own optimal direction. Alternatively, both stakes could be used with the two-stake method to communicate with an earth station located straight behind them.

You may be able to improve reception by installing tone controls or a graphic equalizer in the receiving half of the system. Even with just simple bass and treble tone controls, it should be possible to reduce much of

BILL OF MATERIALS

Integrated stereo amplifier—Rated to deliver 40 watts or more per channel (see text)
Microphone—With table stand and shielded output cable
Microphone Preamplifier—required only if stereo amplifier does not have a built-in microphone preamplifier (see text)
Graphic Equalizer—useful for eliminating hiss, 60-Hz hum and other noise (optional—see text)
Speaker—to match the receive output of amplifier
T1—Audio impedance-matching transformer (see text)
T2—5-ampere or more power transformer with 50- to 70-volt secondary (see text)
Stakes—Galvanized-steel rod, pipe or angle iron (see text for number required)
Push-to-talk switch—Momentary-action spdt microswitch with retrofitted lever (required only for single "hot" stake setup—see text)
Shielded cable—For reception side of system only if transmission cable picks up excessive electrical interference; otherwise, use ordinary heavy-duty speaker zip cord
Miscellaneous—Interconnects; hardware; solder; etc.

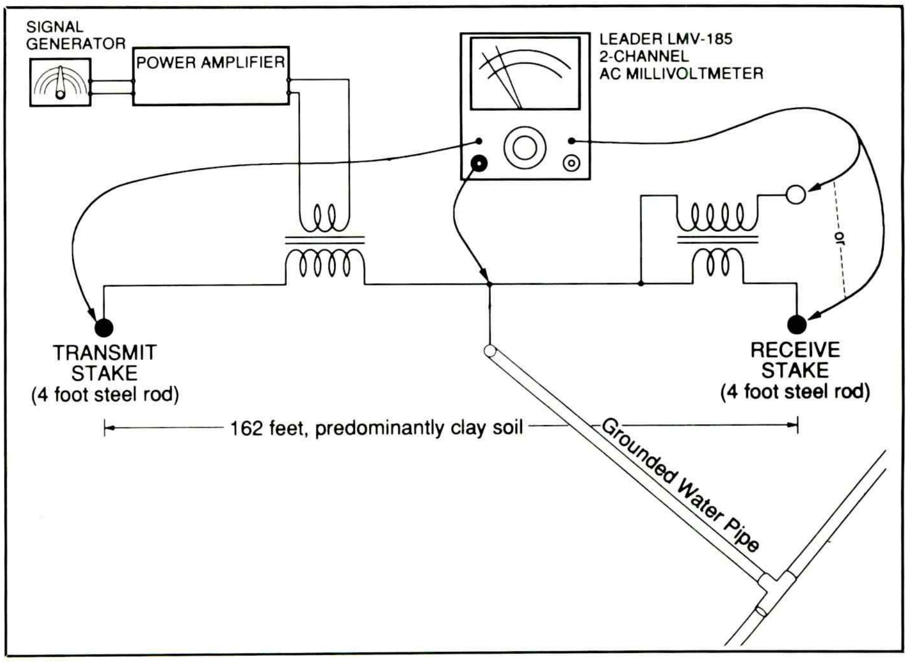

Fig. 6. Arrangement author used to obtain plots shown in Fig. 5.

the 60-Hz hum and high-frequency "hash" that the receiving stake will pick up, without compromising the quality of the voice signal.

Notes on Range

Usable range with the methods discussed in this article can be from a few hundred feet to a few miles. Actual range depends on so many factors that no accurate estimate can be given for any specific location. Range depends on type of soil, proximity of water pipes to your stakes, number of water pipes in a network and other electrically grounded objects between stations, transmit power, size and type of earth stakes used, and whether or not you use an equalizer to improve reception clarity.

Range for Morse code transmission is considerably greater than for voice. With code, intelligibility does not suffer so much in the presence of noise. Also, you can select a transmit frequency that corresponds to a peak in the frequency response of the earth.

Different frequencies travel farther through the earth than do others, as illustrated by the plots in Fig. 5. To obtain these plots, transmission of audio frequencies was measured through 162 feet of soil that was predominantly clay, using the setup shown in Fig. 6. There was a water-pipe ground between the two stakes that acted as a partial short-circuit to signals traveling between them.

The two plots in Fig. 6 show the response as measured directly at the stake and passing through a transformer. The slight high-frequency

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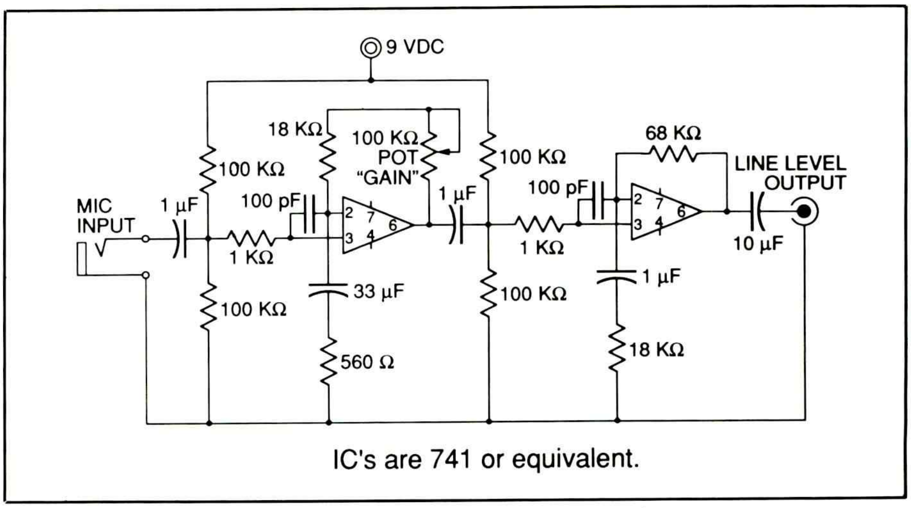


Fig. 7. Schematic diagram of a simple build-it-yourself microphone preamplifier.

Deep-Notch Resonant Filters

Practical advice for designing these extremely useful electronic filter devices

By Douglas A. Kohl

Notch filters are used in a variety of electronic devices ranging from audio to video to general communications. To be effective, they must be carefully designed to yield high-Q performance at the frequencies of interest. In this article, we will detail the theory and practical approach to designing effective deep-notch filters.

Filter Characteristics

An ideal notch filter passes zero signal voltage over a very narrow bandwidth. At all other frequencies, the filter passes the signal without having an effect on it. In actual practice, however, some signal voltage always passes through the filter at the notch frequencies.

One technique commonly used in active notch filters built around op amps is to subtract a portion of the input signal from the output of a frequency-modified stage.

By matching a fraction of the input signal to equal the voltage present at the notch frequency, the depth of the notch effect from the overall filter output at the notch frequency and the output can approach zero voltage.

You can apply the same principle to resonant LC filters that operate at much greater (r-f) frequencies than do most op-amp notch filters. A simple series resonant filter like that shown schematically in Fig. 1(A) exhibits a low output voltage, E_o, at the resonant frequency: $f_{notch} = 1/(2\pi\sqrt{LC})$. At resonance, notch voltage is *not* zero, due to the effective wire resistance, R_w, in the inductor and other coil and capacitor losses. Output voltage E_o is the result of voltage-division action of *R1* and *R2*. Therefore, E_g is the input signal applied to the filter, as illustrated in Fig. 1(B).

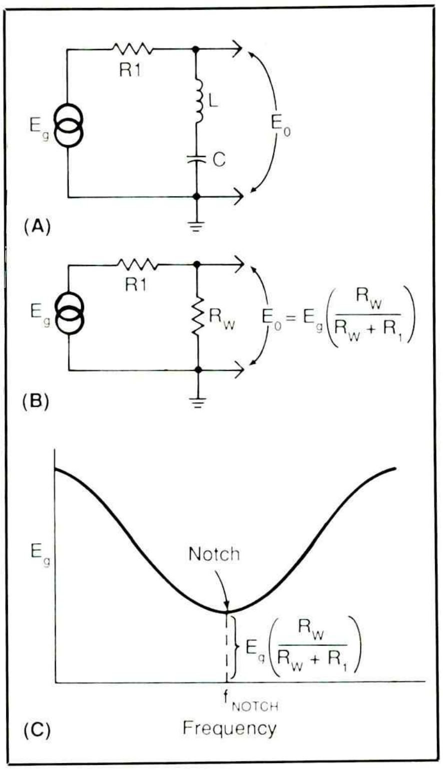


Fig. 1. A conventional series resonant circuit and its equivalent circuits.

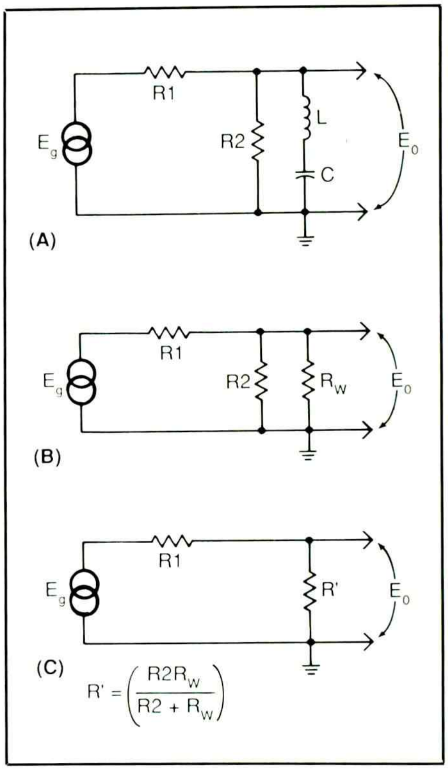


Fig. 2. A high-Q series circuit filter and equivalent circuits at resonance.

Note in the Fig. 1 filter that capacitor and inductor reactances cancel each other out at resonance, leaving only R_w effectively in the circuit. Below resonance, capacitive reactance becomes much larger than R_w and the divider fraction in the formula in Fig. 1(C) approaches 1.0. This makes E_o nearly equal to the input. Similarly, at frequencies beyond resonance, inductive reactance increases and E_o increases.

Q Versus Notch Depth

In a series resonant circuit like that shown in Fig. 1(A), the current that flows at resonance must pass through coupling resistor *R1*, as well as the source of voltage, which itself has some internal resistance. These addi-

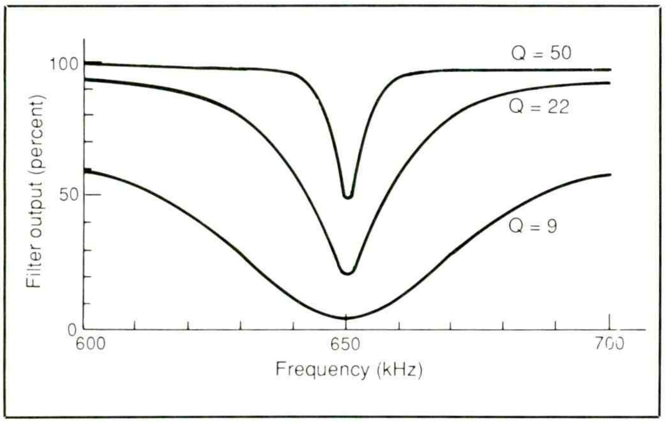


Fig. 3. Frequency responses of high-Q series filter circuits.

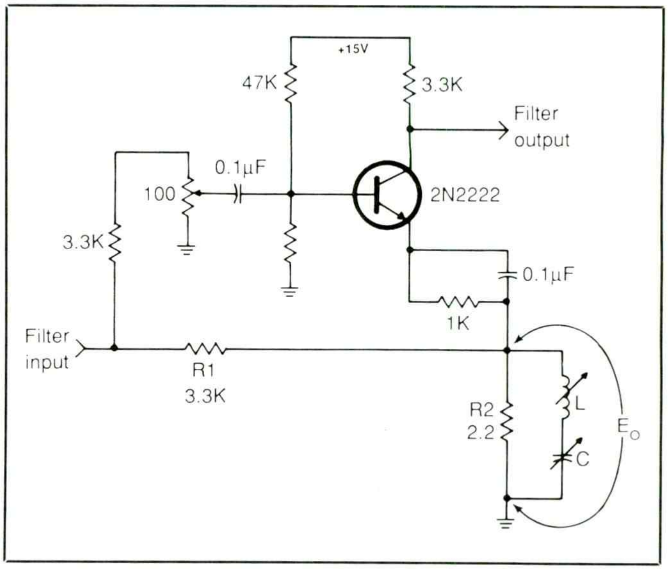


Fig. 4. Schematic diagram of a typical notch filter circuit.

tional resistances lower the Q of the circuit. This effect can be calculated as follows:

$$Q = X_L/\text{All circuit losses}$$

$$= (2\pi f_n L)/(R_w + R1 + R_g)$$

In this formula, X_L is inductive reactance and R_g is the internal resistance of the signal source.

To increase the Q of the circuit and make the notch narrower in frequency ($Q = f_{notch}/\text{bandwidth}$), an additional resistance, *R2*, must be added to provide a low-resistance path for the circulating current between the capacitor and inductor at resonance. In Fig. 2(A), the smaller in value *R2* is made, the higher the Q of the circuit. At resonance, the circuit acts as though coil resistance R_w is in parallel with *R2*, as illustrated in Fig. 2(B). The effect of combining *R2* and R_w into one equivalent resistance is shown as *R'* in Fig. 2(C).

In practical applications, the value of *R1* must be much greater than that of *R2* to make the input resistance of the filter high. Thus, $V_o = E_g \times (R'/R1)$. This would make E_o in the notch much smaller than E_g.

Results of the Fig. 2(A) circuit are shown in Fig. 3. The bandwidth of the notch is smallest for highest Q condition (*R2* with a value of 10 ohms). However, the output voltage

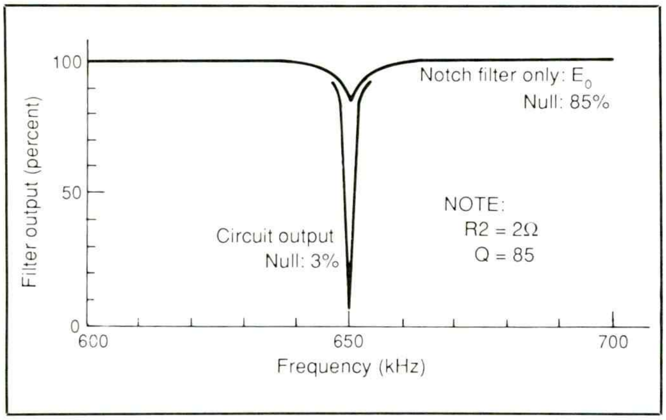
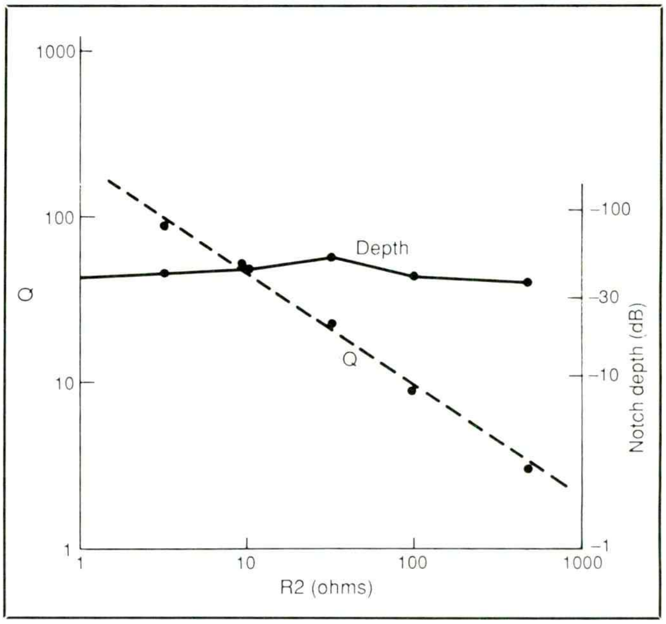


Fig. 5. Depth-of-notch improvement of typical notch filter circuit.

Fig. 6. Graph shows circuit performance for Q values from 8 to 98.



at resonance is relatively high, which means that the depth of the notch is shallow.

When the value of *R2* is 100 ohms, the Q of the circuit is decreased to 9, but output voltage at the notch is much smaller. The circuit design problem then becomes a matter of a narrow bandwidth with a shallow notch or a wide bandwidth with a deep notch. The circuit shown schematically in Fig. 4 provides a solution to this dilemma and has both a narrow bandwidth and deep notch.

Practical Circuit

In Fig. 4 the series circuit with E_0 discussed above and the voltage dropped across it are identified. When *R2* has a small value to achieve high Q, E_0 at resonance is about 85 percent of what it is at frequencies below and beyond the notch, as shown by the upper curve of the normalized frequency response in Fig. 5. Even though it has very high Q, the depth of the notch is so shallow that it would be a very poor filter without the rest of the circuitry shown in Fig. 4. The phase of the notch voltage at E_0 is the same as that of the input signal to the filter.

In this circuit, a common 2N2222 general-purpose transistor extracts the difference between the input signal and E_0, which cancels out E_0 from the output at the notch frequency. To be able to do this, a 100-ohm potentiometer is provided for adjusting the level of input signal that appears at the base of the transistor to exactly match the E_0 voltage present at the emitter of the transistor at resonance. The output voltage of the filter at the center of the notch will typically drop to less than 3 percent, as illustrated by the lower curve in Fig. 5.

To change the notch frequency, either *L* or *C* can be changed. Since Q varies with frequency, it is also necessary to readjust the potentiometer to achieve deepest null performance at each different frequency.

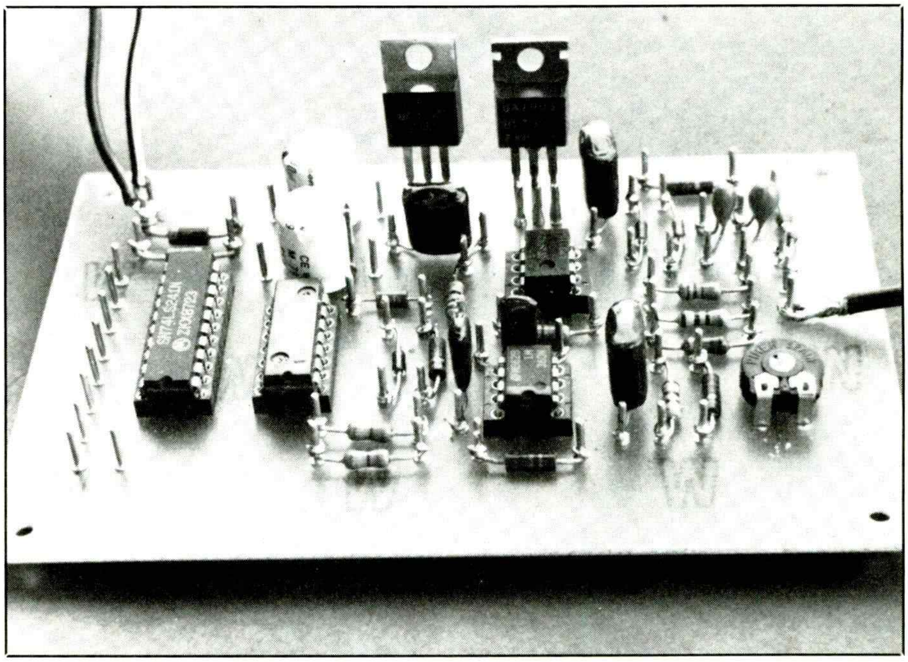
Maximum attainable Q from a notch filter depends on the loss characteristics of both the inductor and the capacitor chosen for the circuit. Experimental data presented in Fig. 6 show the effect on the Q of the circuit as the value of *R2* is varied. The coil used in the Fig. 4 circuit is a common air-core r-f inductor.

The circuit can be adjusted to provide a deep notch that exceeds 30 dB over a wide range of Q values or bandwidths. The voltage-divider loss at the series resonant circuit, E_0, was restored at the filter circuit output, due to the gain of the transistor. **ME**

Non-Composite Video Adapter

Provides a sync separator and sorts the vertical from from horizontal sync pulses to permit a non-composite video monitor to work with a current computer

By Steve Pence



If you haunt flea markets, hamfests and computer-swap meets, you've probably run across some nice video monitor with an extremely low price tag. What you thought was a bargain, however, often turns out otherwise when you get it home and find you can't stuff normal video down its throat. Your bargain buy is likely to be a non-composite video monitor that wants the horizontal and vertical sync pulses already separated from the video. Or perhaps you upgraded the video card in your PC and are left with composite video out, which your old non-composite monitor can't use. If you're in this boat, don't despair. The Non-Composite Video Adapter described here can put the "bargain" back into your purchase.

Our Adapter provides all you need —a sync separator and a circuit that sorts the vertical from the horizontal sync pulses. Though TV receivers get a composite signal over the air and have these circuits built into them, most computers generate video and sync separately and, thus, have no need to combine them into a composite signal only to have them separated again by the monitor. If the separator circuitry is left out, the computer can directly drive the scanning circuits in the monitor, which makes the monitor cheaper to build.

Monitors in General

There are literally hundreds of non-composite video monitors on the surplus market, practically no two of which operate identically. However, there are some general things they have in common and some basic configurations we can look at.

Two broad categories are prevalent: those that accept digital video and those that accept analog video. With digital video, you have only two brightness elements—black and white. In these monitors, the electron beam that paints the picture on the CRT screen is either on full blast and lighting up the phosphor screen or is cut off altogether. An analog monitor, on the other hand, can produce shades of gray (or green or amber or whatever the color of the phosphor), as well as reproduce a digital signal.

Digital monitors normally require a 5-volt TTL-level drive signal on the video input. If you trace the input video signal to a TTL IC, you have a digital monitor on your hands. If there is only a transistor or two between the video input and the CRT, you probably have an analog monitor. The sync inputs, however, will just about always require a TTL level whether the monitor is digital or analog in design.

At this point, you can forget about any kind of logic or consistency. Signal requirements for sync inputs are not standardized. Sometimes the input signal must be normally low and go high on sync, at other times, vice-versa. Often, vertical must be one way and horizontal the other. Our

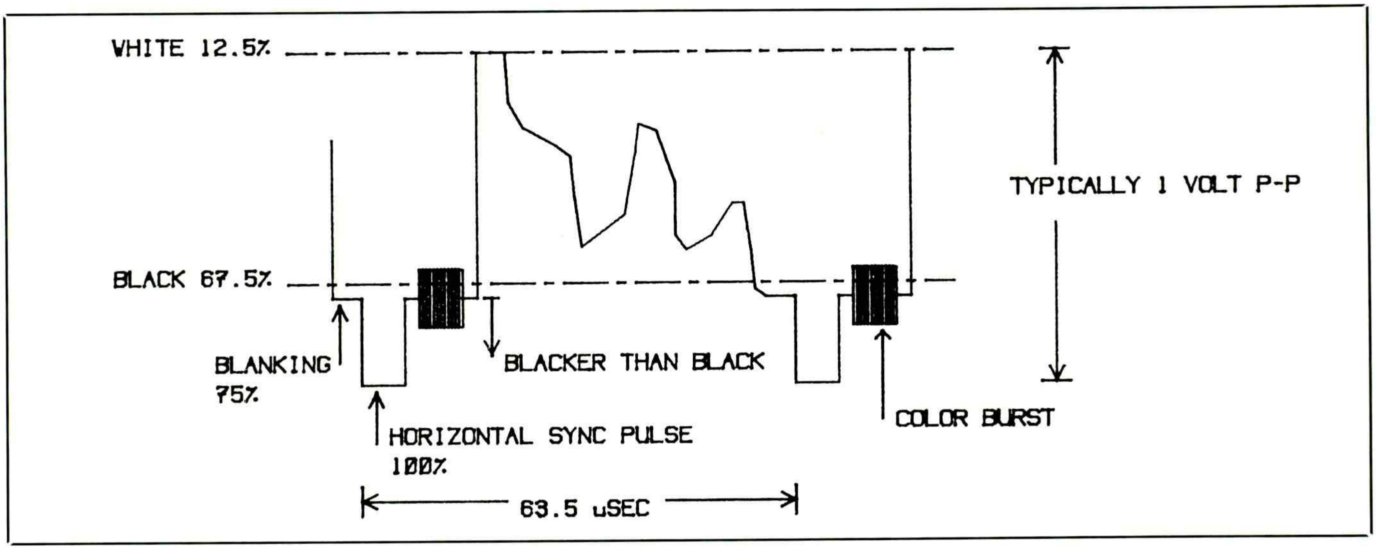


Fig. 1. Composite video signal consists of video, blanking and sync pulses.

Non-Composite Video Adapter project offers a solution to this problem by making all possible combinations available. You simply mix and match as needed.

How It's Done

The composite video signal, as shown in Fig. 1, consists of video, blanking pulses and sync pulses. The sync pulse level represents blacker than black. Blanking level corresponds to black. Everything more positive than blanking represents varying shades of gray between white and black. The objective is to separate all this into its component parts. The circuit for doing so consists of four basic parts: a dc restorer, sync separator, horizontal and vertical separator and high-speed comparator for digital video.

When the analog video signal is applied to the circuit shown in Fig. 2, the first requirement is restoration of the dc component. Basically, dc restoration forces all sync pulse tips to align at the same dc level—in this case, about 100 millivolts above ground. The dc restorer is made up of *C1*, *C2*, *D1*, *D2*, *R2* and *R3*.

The negative-going horizontal sync pulse tips cause *D1* to conduct and rapidly charge *C1* and *C2*, which are connected back to back to form a non-polarized capacitor. For the rest of the waveform (the time between sync pulse tips), *D1* is reverse-biased, forcing *C1* and *C2* to discharge through *R3*. The discharge current creates a bias voltage across *R3*. This current is proportional to the average value of the video signal.

As the video signal level varies, the bias voltage varies, forcing the tips of the sync pulses to line up at the same level. Resistor *R2* and diode *D2* bias the anode of *D1* at 0.65 volt. Therefore, *D1* begins conducting when its cathode approaches 150 to 200 millivolts or less. This forces the sync pulse tips to line up at about this level.

With the sync tips clamped to a known level, they can be separated from the video using LM311 comparator *IC1*. Trimmer potentiometer *R5* is set to produce 0.175 volt at the junction of *R4*, *R5* and *R6*. When the input signal on pin 3 of *IC1* is less than 0.175 volt (which it is during sync pulse time), the output of the comparator is high. When the video signal is greater than 0.175 volt (which it is anytime except sync pulse time) the output is low.

Since *R6* pulls the output of *IC1* to +5 volts when it is high, the sync pulses are converted to a logic level signal and the video portion is discarded. This can be more readily visualized by examining the timing diagram given in Fig. 3.

The next step is to split the horizontal pulses from the vertical pulses. This is done with dual D-type flip-flop *IC2*. The first section of *IC2* is configured as a one-shot multivibrator. When the output of *IC1* goes high, it triggers *IC2A*. The Q output follows the D input and goes high. As soon as the Q output goes high, *C3* begins charging through *R9*.

When the potential across *C3* reaches approximately 2.5 volts, it forces *IC2A* to reset, bringing the Q output low again. When the Q output goes low, *C3* rapidly discharges through *D3*, making the circuit ready to accept another trigger. Thus, for every trigger signal on pin 3, the Q output goes high for a period of time determined by the *R9/C3* time constant. The values of these components are selected to provide a period that is a few microseconds wider than a horizontal sync pulse. At the Q and not-Q outputs of *IC2A* are fully separated complimentary horizontal synchronizing pulses.

Flip-flop *IC2B* is a duty-cycle detector for vertical sync. Since the

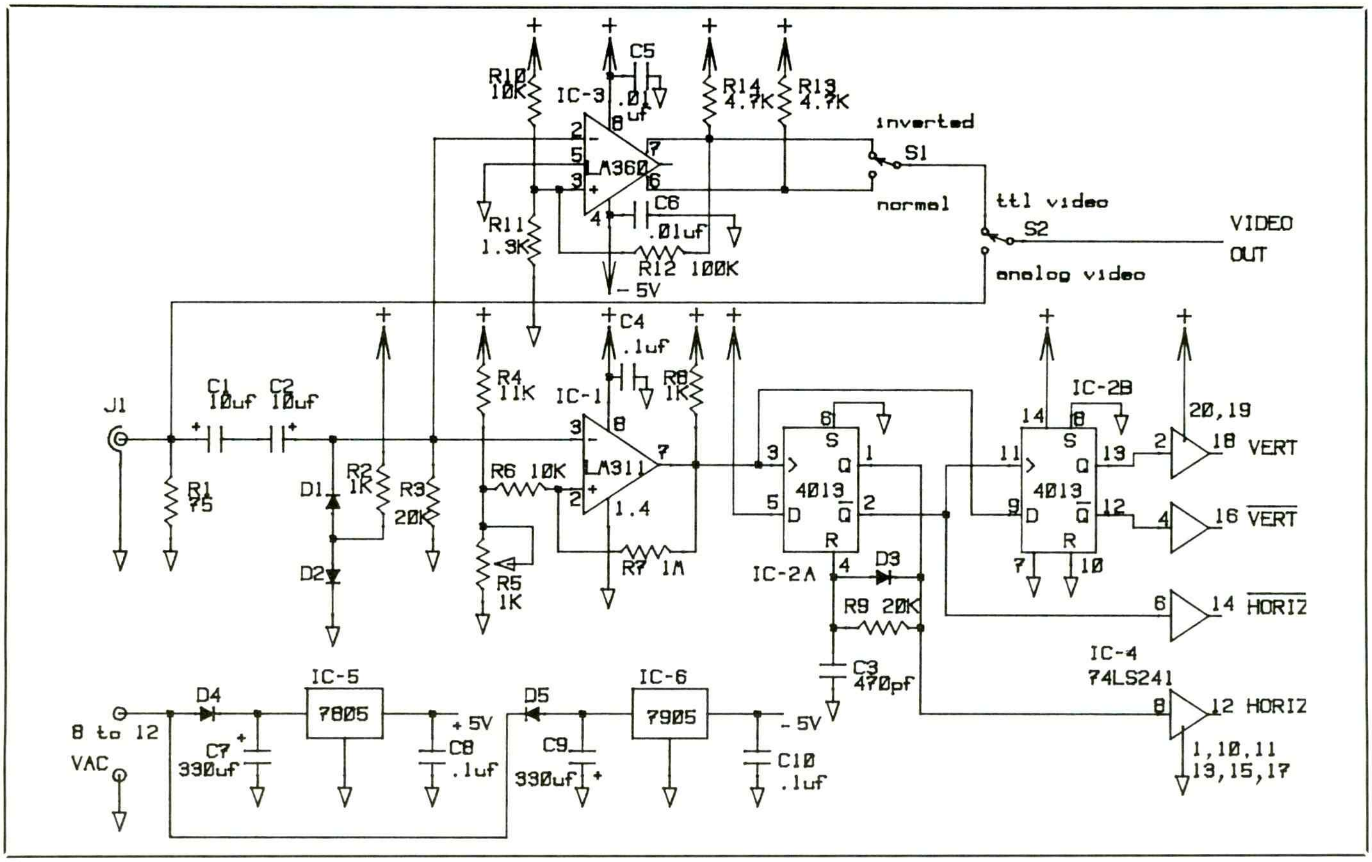


Fig. 2. Complete schematic diagram of circuitry used in Non-Composite Video Adapter. Only component not shown is ac power transformer, which can be a plug-in wall-type unit.

CLOCK input at pin 11 of *IC2B* is driven by the not-Q output of *IC2A*, it is triggered at the end of the time-out period when the not-Q output goes high. Note that the D input of *IC2B* is driven by the separated sync signal. Therefore, the D input of *IC2B* will always be low when it receives a clock pulse (remember that the time-out period is longer than the sync pulse period). This means then that the Q output of *IC2B* will remain low after each horizontal sync pulse.

The duty cycle of a vertical sync pulse is much wider than that of the horizontal pulse; so pin 9 of *IC2* will still be high when the one-shot section times out and the trigger is applied to pin 11. The Q output of *IC2B* will follow the D input, which this time is high, placing a high on pin 13 and a low on pin 12. It remains in this condition until a narrow equalizing

PARTS LIST

Semiconductors

D1,D2,D3—1N4148 or 1N914 switching diode
D4,D5—1N4001 or similar silicon rectifier diode
IC1—LM311 voltage comparator
IC2—CD4013 dual D-type flip-flop
IC3—LM360 voltage comparator
IC4—74LS241 octal buffer/line driver with 3-state output
IC5—7805 fixed +5-volt regulator
IC6—7905 fixed −5volt regulator

Capacitors

C1,C2—10-µF, 16-volt tantalum or electrolytic
C3—470-pF ceramic
C4,C8,C10—0.1-µF ceramic or polyester
C5,C6—0.01-µF ceramic or polyester
C7,C9—330-µF, 25-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1—75 ohms
R2,R8—1,000 ohms
R3,R9—20,000 ohms
R4—11,000 ohms
R6,R10—10,000 ohms
R7—1 megohm
R11—1,300 ohms
R12—100,000 ohms
R13,R14—4,700 ohms
R5—1,000-ohm pc-mount trimmer potentiometer

Miscellaneous

J1—Phono jack
S1,S2—Spdt slide or toggle switch (optional—see text)
Printed-circuit board or copper-clad single-sided pc blank (see text); 8-to-12-volt transformer or plug-in wall-type transformer; press-fit terminal pins (Mouser Cat. No. 574-K24C; two 8-pin, one 14-pin and one 16-pin DIP IC sockets (Mouser No. 562-IC-308-SGT, 562-IC-314-SGT and 562-IC-320-SGT, respectively); bus wire and Teflon sleeving or Wire Wrap wire (see text); solder; etc.

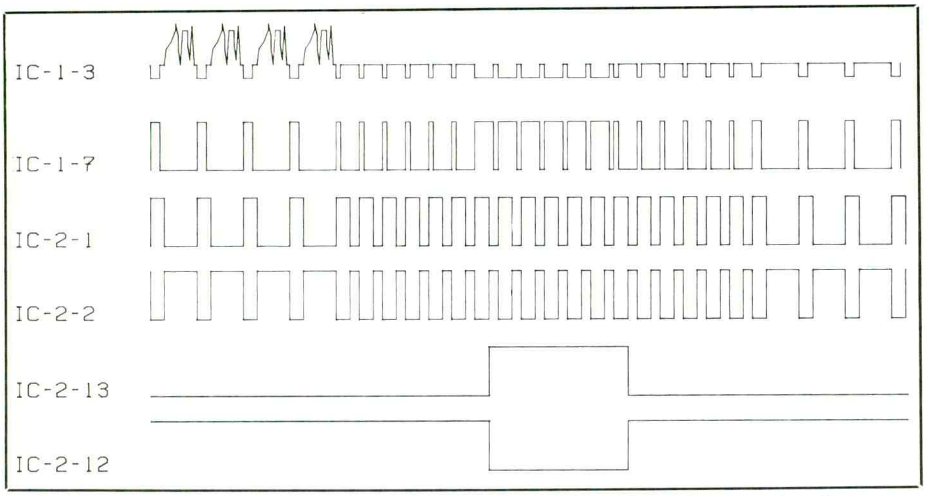


Fig. 3. Signal waveforms that appear at various locations in circuit.

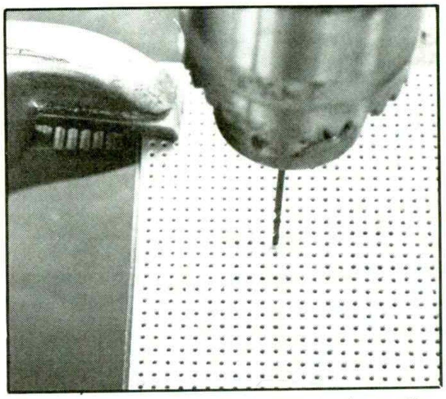


Fig. 4. To ensure that IC sockets fit properly, clamp piece of perforated board with holes on 0.1" centers to pc blank to serve as drilling guide.

pulse is received at the end of vertical sync. This results in a series of complimentary vertical sync pulses. Buffering and TTL-compatible output drive are provided by *IC5*.

If you have a digital monitor, you must convert the analog video to digital video. High-speed comparator *IC4* provides this function. Comparator action here is identical to *IC1*, except the switching point is approximately 0.6 volt instead of 0.175 volt. This slices the standard 1-volt peak-to-peak video signal at about the 50-percent point. The LM360 also provides TTL-compatible complimentary outputs.

The polarity of the video signal required is determined by the number of video amplifier stages in the monitor. If it is an odd number of stages, you need one polarity; if it is an even number, you will need the opposite polarity. You can choose what ever you need with *S1*. Switch *S2* allows you to select between ANALOG and TTL video.

Construction

Just about any traditional wiring technique can be used to build the project. Component layout is not critical. The circuit can be built on perforated board that has holes on 0.1-inch centers using bus wire and sleeving or Wire Wrap methods to interconnect the components. Alternatively, you can design and fabricate a double-sided printed-circuit board (the top of the board will be used as a ground plane). Whichever method you choose, however, make sure bypass capacitors *C5* and *C6* are located as close as possible to *IC4*.

The prototype of the project was built on single-sided copper-clad printed-circuit blank using press-fit pins and IC sockets. This is a fairly fast and easy method of building a circuit board. It provides about the same quality as a printed-circuit board with a ground plane and permits operation at frequencies up to several megahertz. Press-fit pins are available from Mouser Electronics (Part No. 574-K24C), among other sources, at a cost of about $40 per 1,000. Though this cost may seem high at first, the package contains enough pins to build about 20 projects of this size, making the cost per project around $2. Mouser also carries Wire Wrap pins, if you prefer, that are priced somewhat lower.

Layout of the components that make up the circuit should initially be planned on tracing-paper weight graph paper that has 10 squares per inch. The layout is best done with the view from the top (component side) of the board. Once the layout is done, flip over the graph paper to get a soldering-side view and pencil in the wiring pattern. Use the hand-drawn artwork directly as template for locating the centers for the holes to be drilled for the press-fit pins.

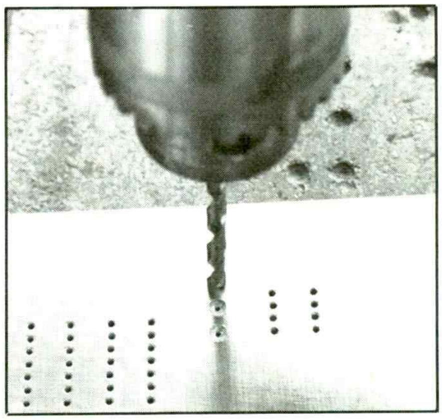


Fig. 5. Tip of No. 27 drill ground almost flat removes circle of copper for both terminal pins and IC pins.

Tape the graph paper, back side up, over the copper-clad side of the pc blank, and use a center-punch guide for marking the mounting pin holes. A scratch awl can be used as a center punch. The copper provides a convenient ground plane, reducing the chances of oscillation and other problems caused by stray inductance.

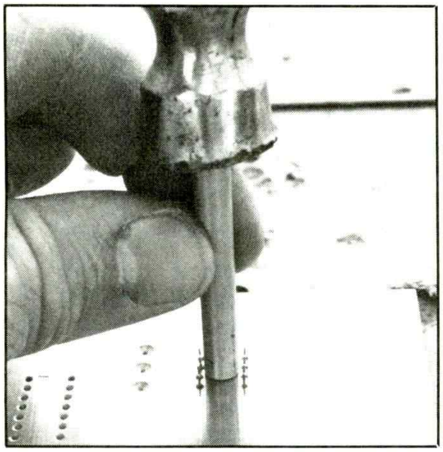


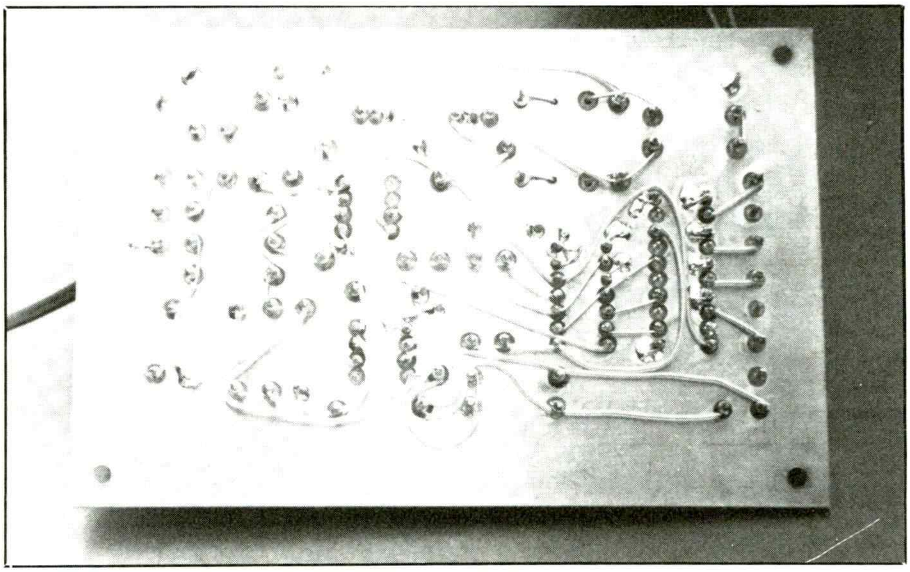
Fig. 6. After all holes are drilled and terminal pads are cleared of copper, IC sockets install by pounding them into place on board.

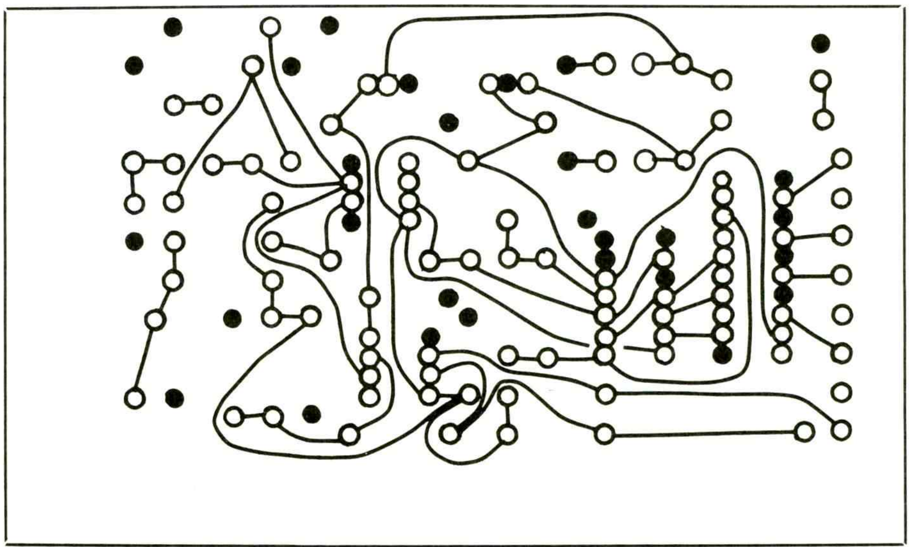
Once the copper side of the board is center punched, use a No. 58 bit to drill holes in all marked locations. To assure accurate drilling for the IC sockets, temporarily clamp a piece of perforated board that has holes on 0.1-inch centers with vise grips to the pc blank, as shown in Fig. 4. Use the perforated board as a drilling guide. When you are finished drilling the holes for the sockets, remove the perforated board and proceed to drilling press-fit terminal holes.

To keep the component pins from shorting to the copper cladding, grind a No. 27 drill bit so that it is almost flat and use this to cut away the copper at each terminal and IC pin site (except of course, those that are supposed to be grounded). You can also use a ball-shaped carving bit and Dremel Moto-Tool to clear away the unwanted copper. The procedure using the drill bit is shown in Fig. 5.

To obtain solid mechanical mounting for them, the IC sockets used in the prototype were the Hi-Rel pc-mount type with machined contacts available from Mouser. The board hole for pin 1 of each IC socket was drilled with a No. 55 bit, the other IC holes with a No. 54 bit. This makes pin 1 a very tight fit and keeps the sockets from falling out of the board. In fact, the fit is so tight that the sockets had to be pounded into place on the board with a hammer and ¼-inch rod (the shaft from an old rotary switch or potentiometer works well), as shown in Fig. 6. If you use another type of socket, you will have to devise your own method of securing them to the board.

Pressing the component pins into place can be accomplished in a number of ways. For example, you can cut off the end of an old soldering iron tip and drill a No. 56 hole down the center. Plug in the iron and use the heated tip to press the pins into place. Alternatively, you can use a T handle made from ⅛″-diameter aluminum or brass rod to press the pins in by hand. If you have a drill press, you can also use it (turned off, of





Interconnections are made using bus wire and sleeving (photo). If proper pins and sockets are employed you can use Wire Wrap techniques. Wire runs and soldering points are illustrated in drawing (solid black dots indicate points soldered to copper cladding).

course) as an arbor press.

Use the wiring side layout shown in Fig. 6, and refer back to Fig. 2 as necessary, to wire together the components by the point-to-point technique. Use 26 AWG buss wire and clear Teflon sleeving or 26 or 28 AWG Wire Wrap wire.

When wiring is done, turn over the circuit-board assembly and install the components according to Fig. 2. On the right side of the board, you should have an unused pin between the two vertical outputs and between the two horizontal outputs. The horizontal and vertical inputs of your monitor connect to these two pins, which allows you to quickly jumper to either polarity of sync signal during set-up maneuvers. When the correct combination is found, you can solder in permanent jumpers.

Checkout & Use

When you are finished assembling the project, there should be no ICs in the sockets. At this point, check for connections you missed soldering, poor soldering and solder bridges, the last especially between the closely spaced IC socket pins. Solder any missed connections, reflow the solder on any suspicious connections an clear solder bridges.

Connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to any point in the circuit that is supposed to be at ground potential. Power up the project and touch the "hot" probe of the meter to the OUT pins of *IC5* and *IC6* and note that your readings should be +5 and −5 volts, respectively. If you do not obtain either or both readings, power down and rectify the problem before proceeding.

Once you are certain that the power-supply section is operating properly, touch the "hot" probe of the meter to pin 8 of the *IC1* socket, pin 14 of the *IC2* and pin 8 of the *IC3* socket. In all three cases, your reading should be +5 volts. Similarly, touching the "hot" probe of the meter to pin 4 of the *IC3* socket should yield a reading of −5 volts.

Touch and hold the "hot" probe of the meter to the junction of *R4* and *R5*. Adjust the setting of *R5* for a reading of +0.175 volt. Power down the project and allow the charges to bleed off the filter capacitors in the power-supply section. Then carefully install the ICs in their respective sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets.

Connect a source of composite video to *J1* (this can be the output of a computer, VCR, video camera, etc.) and power up the circuit. If you have an oscilloscope handy, check to see if there is a vertical sync pulse at pin 18 of *IC5*. If you see this pulse on the CRT screen, use this to trigger the scope, and check the other outputs for the proper waveforms. If you do not have a scope, connect the project to your monitor and try various combinations of normal and inverted sync until you get a stable raster.

If no combination of connections in the absence of a scope seems to work, you may have one of two problems. Either the project is not working properly and requires complete checkout to rectify the problem or you have a monitor with non-standard sweep rates. If the latter, there is very little you can do other than modify the monitor sweep circuits to operate at the proper frequency.

In most cases, you will build this project for use with one specific monitor. If this is the case, *S1* and *S2* are optional since only one video format and sync combination will be required. Hence, you can just hard wire whatever is needed and often mount the circuit-board assembly inside the monitor.

If the power supply in your monitor provides positive and negative voltages, you can eliminate the power transformer or power adapter in the project. Regulator *IC5* accepts inputs between 8 and 32 volts, and *IC6* accepts inputs between −8 and −32 volts.

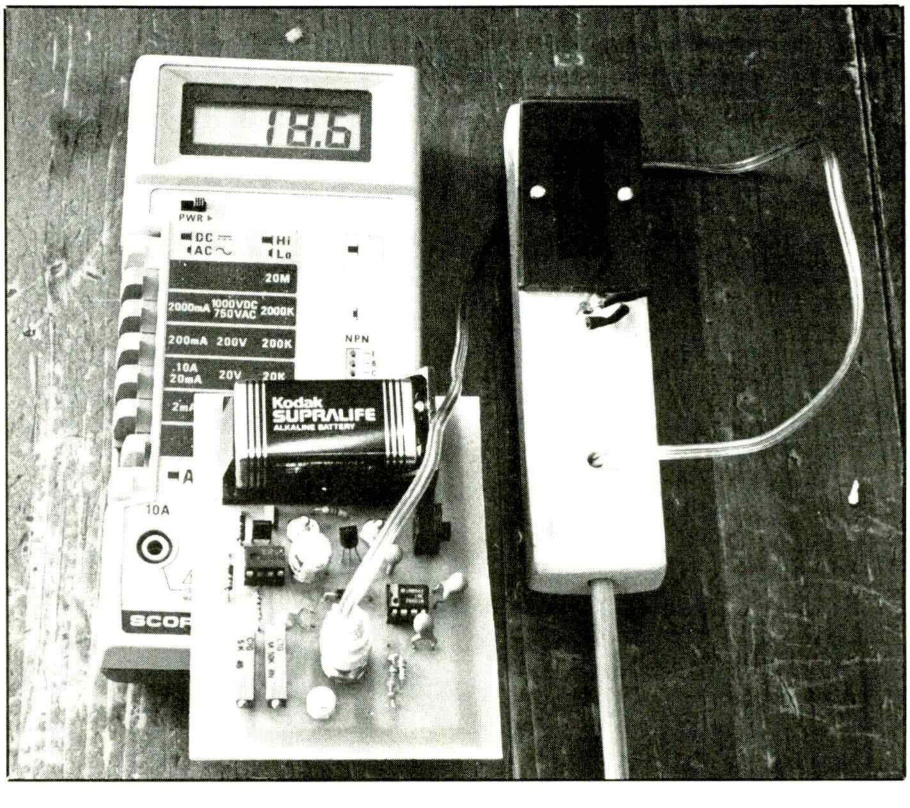
If you have an analog monitor, it may already have a 75-ohm termination resistor on its input. If it does, you should not install *R1* on the circuit-board assembly; otherwise, you will end up with a double termination and about half the normal video signal level needed. If you do not know for sure that this termination resistor is in place, check the input resistance of your monitor with an ohmmeter.

Add Light-Meter Modules To Any Digital Voltmeter

(Part 1)

Simple project gives you a choice of two sensitive and accurate adapters to use with a digital voltmeter or multimeter for direct display of light level

By Tom Fox



More than 40 percent of easuring visible light levels is far from a trivial procedure. Part of the problem is that a plethora of terms is used to express light measurements, including the traditional ones like lumens, candelas and lux, to name just a few. Newer terms like foot-candles, standard candles and candlepower add to an already confusing situation. In this article, we present details for building two light meter adapter types that can be used with any digital voltmeter or multimeter that has a 200-millivolt full-scale range to provide highly accurate direct-read display of light levels foot-candles and lux.

In this first installment of a two-part article, we discuss the methods employed for measuring light, the nature of light and operation of the project circuits. Next month in the concluding installment, we will focus on construction of both versions of the project and how to check it out and calibrate it.

Measuring Light

Before discussing how the circuitry for this project works, you should read the "Nature of Light" box elsewhere in this article to familiarize yourself with the meanings of the terms used here.

Two basic electronic sensors are used for measuring light. These are photovoltaic, using silicon and selenium sensors, and photoconductive, using cadmium-sulfide and cadmium-selenide sensors. Each sensor type has advantages and disadvantages.

Commercially available photoconductive cells have several advantages over photovoltaic cells. They're very sensitive to low light levels, and cells like Clairex's No. CL909L have a spectral response that closely matches that of the human eye. Additionally, commercial photoconductive cells have guaranteed characteristics that aid in designing circuits and helps simplify the calibration procedure. Few photoconductive cells, however, respond linearly in intense light above 100 foot-candles (fc), which complicates the design of a simple light meter like the ones to be described.

In contrast, selenium cells are photovoltaic in nature. They generate a voltage when light strikes them. The spectral response of selenium closely follows that of the human eye. Huygen Corp.'s famed Weston Photronic Cell is a selenium barrier layer cell that was specifically designed to measure light. This cell and the company's Viscor filter provide an almost perfect match to the standard CIE curve.

Having both types of light sensors at hand gives you a choice of the best of both worlds.

The Photronic cell is an excellent sensor choice for designing an extremely accurate light meter. Its main disadvantage is its cost, which ranges from $153 for the No. 594-GB to $370 for the No. 856-YYV. Vactec is apparently still making selenium cells. The surplus market also occasionally offers selenium cells. Moreover, plenty of International Rectifier's famous No. B2M "sun batteries" should still be floating around.

One of the problems with selenium cells is locating them—especially inexpensive ones. In contrast, locating silicon photovoltaic solar cells presents no problems; most electronic parts distributors sell them. A minor disadvantage is that the silicon cell is inherently physically fragile. (Selenium cells have an aluminum or steel back plate that makes them physically durable.)

The chief difficulty with silicon solar cells is that their peak response is in the infrared range between 800 and 900 nm. This can be significantly reduced by use of a special filter that absorbs infrared radiation but passes radiation at 780 nm and shorter wavelengths. A gelatin filter can sometimes be used, and a camera type 80A blue filter can also be effective. Even a simple piece of glass helps.

Unless a proper filter is used, a light meter built around a silicon cell will register a higher reading when pointed at a hot light source than when pointed at a cooler surface, such as a cloud. However, if you restrict your light measurements to "normal" sources, this is only a minor problem.

In the past, light meters were essential equipment for taking quality photos. Most modern cameras, however, are automatic or have built-in light metering. If you're serious about photography, though, you'll still want a good-quality light meter.

Another common use for a light meter is to check the illumination in a room. A room in which the illumination is too bright can be more uncomfortable than one where the light intensity is not considered sufficient. Table 1 lists general recommended illumination for various situations. Notice that for electronic testing and coil winding the recommended illumination is 100 (fc).

A light meter is also quite useful if you grow indoor plants or have a greenhouse. Assuming properly balanced light (red, green and blue wavelengths), most foliage plants will grow with a daytime light intensity of just 100 fc. Fuschia, dieffenbachia and wandering Jew do well at 200 fc; vegetable seedlings generally need at least 700 fc; and flowering plants require 1,000 fc. Generally 2,000 foot-candles is sufficient for sun-loving plants.

Few plants really want (or can make use of) light intensities above 3,000 fc. Foliage plants whose ancestors grew beneath the thick canopy of the Amazon jungle do better with light intensities of 100 to 500 fc. If you grow citrus plants indoors, you can survey your house with a light meter to find the "brightest" area that will provide you with the biggest "ponderosa" lemons. A light meter can also be used in outdoor gardens to find the "brightest" shady areas.

Table 1

Illumination Levels

Type	Light (fc)
Office	
conference room	30
regular work area	100
designing, detailed drafting	200
Electric equipment testing	100
Machine shop	
rough bench work	50
fine work	500
extra-fine work	1,000
Home	
living room	5
kitchen work	50 to 100
Major-league baseball	
outfield	100
infield	150
School	
auditorium	20
classroom	50 to 100
Restaurant	
subdued	3 to 15
bright	10 to 30
fast-food	50 to 100
kitchen	70
Stairway, elevator	20
Public rest room	30
Hospital	
emergency room	2,000
television stage	2,300
autopsy table	2,500
morgue	20
Moonlight	about 0.04
Bright overcast sunlight	about 1,000
Direct sunlight (maximum)	9,000

About the Circuits

Two light meter modules are described here. One uses a silicon cell, the other a selenium cell. Both are designed to plug into a digital multimeter that has been set to the 200-millivolt dc full-scale range so that each millivolt corresponds to 1 fc.

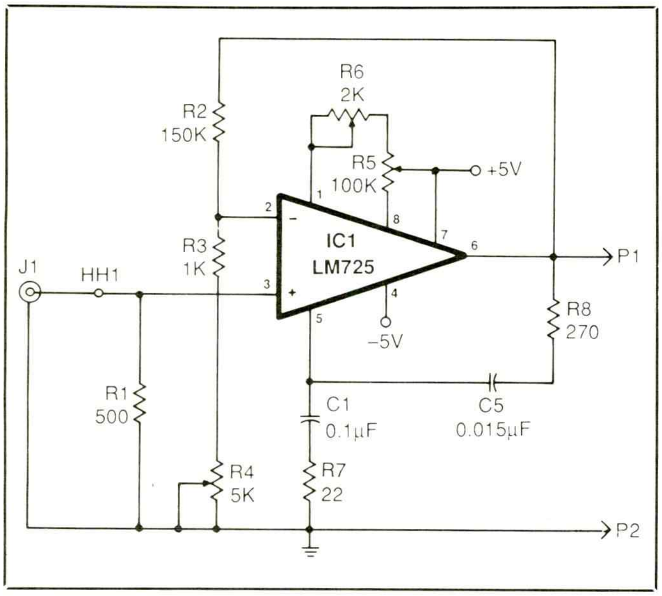


Fig. 1. Schematic diagram of basic circuitry for silicon solar-cell version of project.

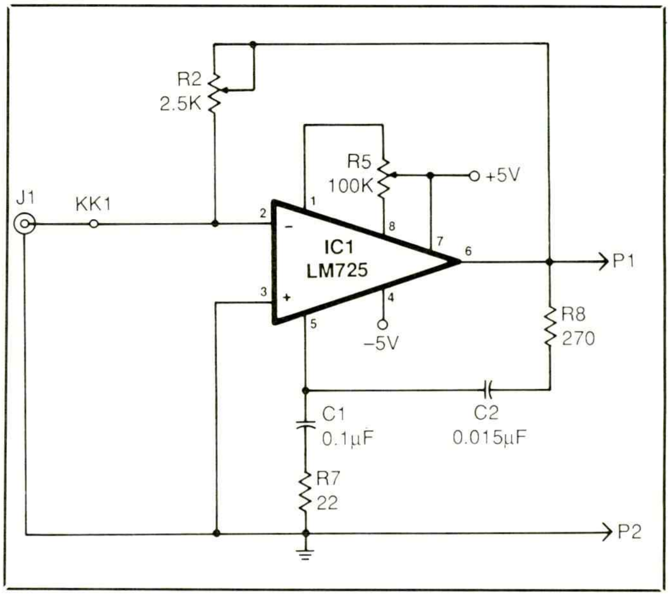


Fig. 2. Schematic diagram of basic circuitry for selenium-cell version of project.

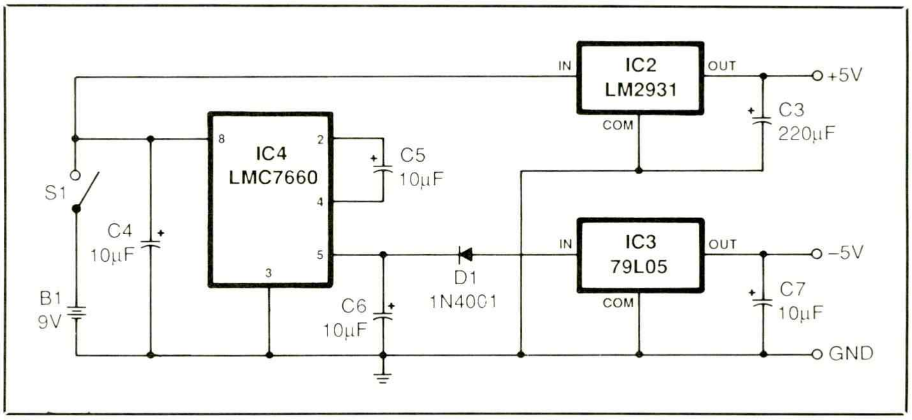


Fig. 3. Schematic diagram of power supply used with both versions of project.

Despite the problems cited for it, one meter module uses a silicon photovoltaic cell for two good reasons—low cost and ready availability. If compared to the CIE curve, its accuracy can be significantly increased with use of a suitable high-pass or band-pass filter that blocks infrared radiation with a wavelength longer than 780 nm.

If an incandescent lamp is used to calibrate it, the module will be quite accurate when taking readings under this type of light. With a simple epoxy-glass filter, its accuracy appears to be within 5% from 1 to several hundred fc and within 10% up to 1,500 fc. Beyond 1,500 fc, its curve tends to flatten out, which means when it is registering 2,500 fc, actual light intensity might be closer to 3,000 fc.

If you can obtain a selenium cell, our second module will be of interest. This module has approximately the same accuracy rating as the silicon cell module but is fundamentally more accurate since the selenium cell does not respond to infrared radiation from hot objects. If you *must* have an accurate light meter, place an ultraviolet filter in front of the selenium cell, which is sensitive to wavelengths as short as 250 nm. Windowpane glass will stop wavelengths shorter than 300 nm, and a UV camera filter should stop all ultraviolet wavelengths.

Let us now discuss operation of each module in turn.

• *Silicon Solar-Cell Module.* Operation of this module, the basic circuit for which is shown schematically in Fig. 1, relies upon photovoltaic sensor *PC1*, whose current output is almost linearly related to the intensity of the light that falls on its sensitive surface. The open-circuit voltage of *PC1* does not change significantly with different light intensities. (It is close to 0.5 volt.) If measured with a zero-resistance milliammeter, however, the current is almost 500 times greater at 5,000 than at 10 fc.

This circuit employs a resistor that converts the current generated by *PC1* to a voltage. This voltage is subsequently amplified by a noninverting operational amplifier that is calibrated so that 1 fc of light generates a 1-millivolt output, which is fed to the

PARTS LIST

Semiconductors
D1—1N4001 or similar silicon rectifier diode
IC1—LM725CN or equivalent 8-pin operational amplifier (see text)
IC2—LM2931Z-5.0 fixed +5-volt regulator
IC3—79L05ACZ fixed −5-volt regulator
IC4—LMC7660IN switched-capacitor voltage converter

Capacitors
C1—0.1-μF, 25-volt ceramic disc
C2—0.015-μF, 25-volt ceramic disc
C3—220-μF, 25-volt electrolytic
C4 thru C7—10-μF, 25-volt electrolytic

Resistors (¼-watt, 5% tolerance)
R1—0.5 ohm (see text)
R2—150,000 ohms (see text)
R3—1,000 ohms
R4—5,000-ohm pc-mount 15-turn trimmer potentiometer
R5—100,000-ohm pc-mount 15-turn trimmer potentiometer
R6—2,000-ohm pc-mount trimmer potentiometer (Digi-key Part No. 36C23)
R7—22 ohms
R8—270 ohms

Miscellaneous
B1—9-volt alkaline battery
P1,P2—Pc/chassis-mount banana plug
PC1—Silicon photovoltaic solar cell (Edmund Scientific Cat. No. T37,332 or equivalent)
1—Pc/chassis-mount phono jack (Digi-Key Part No. 576K-ND or similar)
S1—Pc-mount spst slide switch (Digi-key Part No. SW100-ND or similar)
Printed-circuit board (see text); pc-mount 9-volt battery holder (Digi-Key Part No. BH9V-PC-ND or similar—see text); 8-pin sockets for DIP ICs; 2-conductor cable; phono plug for sensor cable; filter (optional—see text); materials for sensor carrier and calibration setup (see text); machine and wood hardware; hookup wire; solder; etc.

Note: For selenium-cell version of project (Fig. 2), substitute a selenium solar cell for PC1 (see text), change the value of R2 to 2,500 ohms, and eliminate R1, R3, R4 and R6. Magicland (see below) has a PR13 lamp with a measured output, instructions and test sheet suitable for light meter calibration for $6 (Michigan residents, please add 4% sales tax).

Companies Mentioned

Clairex Electronics
Mt. Vernon, NY 10550
914-664-6602

Digi-Key Corp.
701 Brooks Ave. South
P.O. Box 677
Thief River Falls, MN 56701-0677
1-800-344-4539

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007-1380
1-609-547-8880

Huygen Corp.
Box 316
Wauconda, IL 60084
708-381-4050

Magicland
4380 S. Gordon
Fremont, MI 49412

Vactec, Inc.
10900 Page Blvd.
St. Louis, MO 63132
314-423-4900

input of a digital voltmeter (or multimeter set to the dc-volts function) for direct-read display.

In Fig. 1, *PC1* is shown connected in parallel with 0.5-ohm resistor *R1*. The voltage generated across this resistor, due to the current generated by *PC1*, is applied to the noninverting (+) input of LM725 instrumentation-type op amp *IC1*. (While the LM725 was designed for low offset voltage and high open-loop gain, it is an "old style" op amp; some of the latest "super op amps" may perform even better. The LM607, for example, will probably work in the circuit without modification.)

Gain of the Fig. 1 circuit is controlled by *R2*, *R3* and *R4*, the last providing the means for adjusting the gain over a range of values. Final calibrated gain value depends upon the particular cell being used.

A few rough calculations may make operation of the module a bit clearer. Assume the cell produces 0.25 ampere under full direct sunlight conditions and that the filter used with the cell does not significantly reduce the light intensity. Further assume full sunlight is 10,000 fc. Therefore, 250 mA/10,000 fc, or 0.025 mA/fc, which produces 0.0125 millivolts per fc when flowing through 0.5 ohm. Consequently, the gain of the circuit must be set to 80 to obtain 1mV/fc, which is achieved with *R4* set to about 900 ohms.

Trimmer controls *R5* and *R6* permit you to set the circuit for a zero output when the input is zero (*PC1* is dark). Fifteen-turn trimmer *R5* permits coarse zeroing, while trimmer *R6* permits fine zeroing. Capacitors *C1* and *C2* and resistors *R7* and *R8* make up a frequency-compensation network that overcompensates the circuit to increase stability.

• *Selenium-Cell Module.* This circuit, shown schematically in Fig. 2, uses a somewhat different technique to convert current to voltage than is used in the Fig. 1 circuit. This technique directly uses the unique features of an op amp and is generally viewed as superior to simply amplifying the voltage drop across a resistor. The Fig. 1 circuit works okay because of the high output of the silicon solar cell. If it were to be used with a low-output selenium cell, its gain would have to be so great that significant errors, due to offset voltage and offset current, would result.

In Fig. 2, the selenium cell is shown connected directly across the inputs of the op amp, which appears to the cell as a short circuit, despite the fact that in an ideal op amp input current is zero (infinite input resistance). This "imaginary" short circuit is the result of the incredibly high gain of the op amp. Briefly, assume the op amp is ideal and has infinite gain, which for 725 op amp is greater than 3,000,000. Thus, the op amp will develop a finite output voltage with zero input voltage. This zero input voltage means a dead short between the output terminals of the selenium cell.

The output voltage at pin 6 of *IC1* is equal to the output current of the selenium cell output current times the resistance of *R2*. Since the current cannot flow into the op amp, it must flow through *R2*. Keep in mind that the voltages at pins 2 and 3 are basi-

The Nature of Light

Radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and others are merely different types of electromagnetic radiation. The electromagnetic spectrum is divided into a multitude of wavelengths, ranging from miles to less than a billionth of an inch.

Physicists generally agree that light is a type of particle called a "photon"—a quantum particle associated with the electromagnetic field that has no rest mass or charge. It's usually more convenient to think of light as a wave, with properties similar to radio waves. The major difference between the two is that, instead of measuring wavelength in terms of meters, as in radio, you measure light in terms of nanometers (billionths of meters, abbreviated nm). Figure A shows the electromagnetic spectrum and where light fits into it, as well as the physical significance of color.

Early in the scientific age, candles were used as the primary means of generating artificial light. So, when it was time to give light intensity a quantity value, the common candle was chosen as the standard. The first "standard" candle was about 1 inch in diameter. With the realization that thickness alone wasn't sufficient to standardize the light from a candle, the "official" candle was made a bit more standard.

The standard candle was formally defined as the luminous intensity in a horizontal direction of the flame of a standard spermaceti candle, which was made from the wax of the sperm whale. These candles were to weigh six to the pound and burn at a rate of 120 grains per hour.

In 1948, the standard candle became the New International Candle (NIC), which is based upon the light given off by platinum at its melting point of about 3,191° F. The new candle was renamed "candela" and is about 1.9% smaller in diameter than the old candle, which is within the uncertainty range of most light meters and, thus, not signifi-

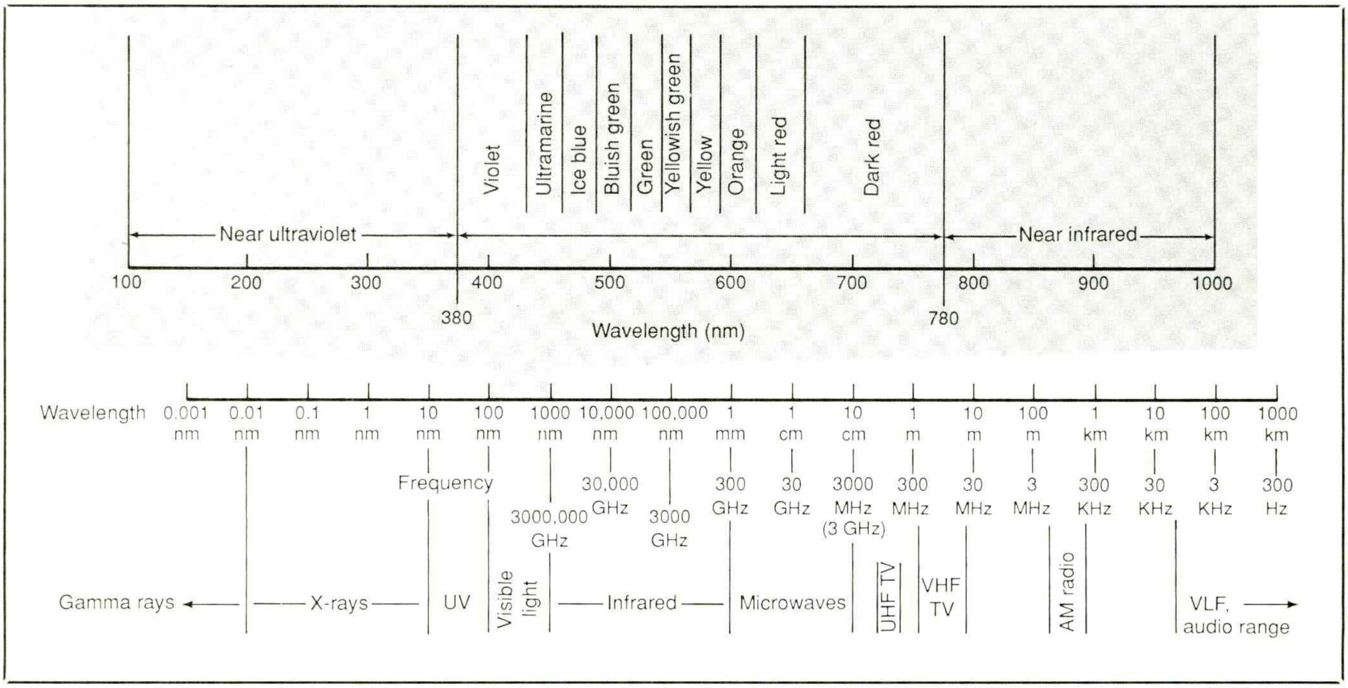


Fig. A. The electromagnetic spectrum, including the visible-light portion.

cally zero. Calibration is accomplished using *R2*. The only other difference between this circuit and the previous one is that *R6* has been eliminated because it is not needed.

The circuitry needed for powering either module is shown schematically in Fig. 3. Here, switched-capacitor voltage regulator *IC4* converts the 9 volts dc from battery *B1* to the required −9 volts. Diode *D1* is required with some types of 7660 ICs. Negative voltage regulator *IC3* outputs −5 volts from the −9 volts delivered by *IC4*. Finally, *IC2* is a low-power +5-volt regulator.

Coming Next Month

This concludes our discussion on measuring light, the nature of light and how the circuits work. Next month, we will conclude with construction, checkout and calibration details. **ME**

cant except in very critical applications. (The NIC is officially defined as 1/60 the luminous intensity of a square centimeter of a blackbody radiator at the 2,046 K temperature of freezing platinum.)

Though candela is the new "official" term for the New International Candle, we will continue to use the term "candle" since it is still used in new manufacturer literature, including the Clairex Electronics *Optoelectronics Designers Handbook*, which contains an excellent discussion on light measurement.

To understand the mechanics of measuring light, it is important that you know the meanings of the terms commonly used in this area.

• *Foot-candles and Lux.* These are units of illumination (or luminous incidence). Although not technically precise, 1 fc is the illumination produced 1 foot from a source of light equivalent to one candle in luminous intensity. Similarly, one lux (meter-candle) is the illumination produced 1 meter from a source of one candle.

Though the "candle" is the most fundamental of the basic units of light measurement, light meters don't measure light in terms of candles, at least not directly. They are calibrated in foot-candles (fc), meter-candles (lux) or phots (rarely used).

A common candle with a flame about 1.5 inches high has an intensity of about one candle. One foot from this candle, the illumination is 1 fc; at 2 feet, the illumination is 1/4 fc; at 3 feet, the illumination 1/9 fc. (One meter from this candle the illumination is one lux.)

From the foregoing, illumination is inversely proportional to the square of the distance from the source. That is, fc $= H_{CP}/D^2$, where H_{CP} is the Horizontal Candle Power of the source and *D* is the distance between the source and point of measurement. Thus, the light intensity 5 feet from a 20-candlepower (cp) source is 20/25 = 0.8 fc. Six inches from this 20-cp source, the light intensity is 20/(0.5 × 0.5) = 80 fc, and at a 1-inch distance, it is 20/[(1/12) × (1/12)] = 2,880 fc!

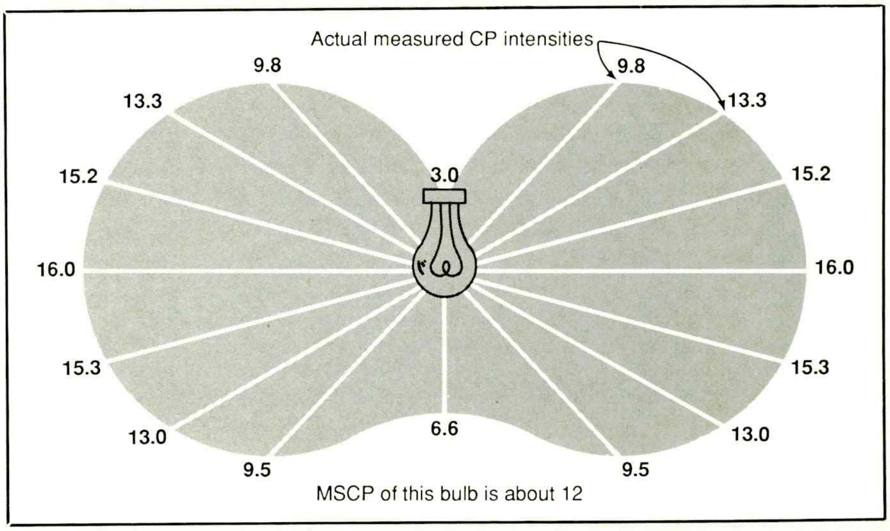


Fig. B. Luminous intensities in different directions of an incandescent lamp. MSCP of this lamp is about 12. This data was adapted from American Electrician's Handbook, *Ninth Edition.*

Theoretically, light intensity rises to infinity at 0 distance from the source. In reality, no matter how close the measuring distance is to the source of a multi-trillion-watt source, illumination level can never reach infinity. Nevertheless, if the sensor of a wide-range light meter is placed against the envelope of a 300-watt bulb, the light meter will jump off range! (Do *not* perform this experiment! Some sensors can be damaged with the intense heat and/or light.)

• *Lumens.* The lumen is the unit of luminous flux, which is viewed as the "power" of visible light and is analogous to radiant power measured in watts. As an analogy to hydraulics, lumens would be equivalent to gallons per minute. Keep in mind, however, that the lumen unit describes the brightness sensation created in the human eye by light. For this reason, the lumen is a *relative* term and not absolute like gallons per minute.

If you examine a package of light bulbs, in addition to wattage, average lumens is usually listed. GE's 100-watt crystal-clear light bulbs, for example, are rated at 1,750 average lumens. Like "candles," lumens are a basic unit used in light measurement and are exactly the same in the English and Metric systems.

It may not be immediately obvious

. . . continued from previous page.

The Nature of Light

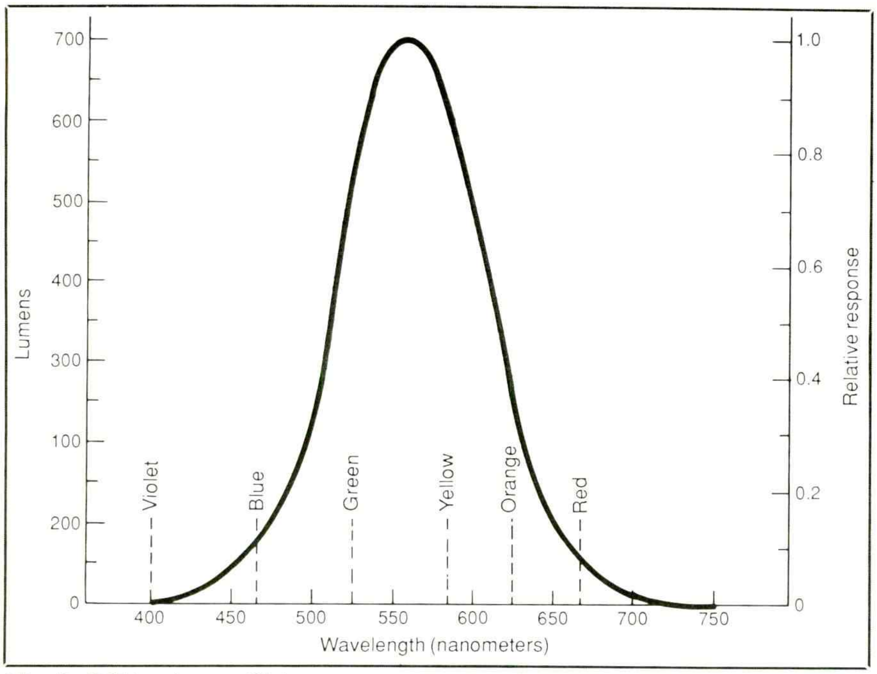


Fig. C. CIE luminous efficiency curve. Lumen scale assumes 1 watt of radiant power at all wavelengths.

that lumens and candles are related. A point source of light with an intensity of 1 candle radiates 4π lumens of luminous flux. Now recall that the surface area of a sphere is $4\pi r^2$. With a radius of 1, the surface area of the sphere is just 4π. Therefore, it would, seem reasonable that 1 candle $\times$ 4π should have some significance and that the total amount of light emitted by a source must pass through this imaginary sphere of unit radius whose surface area is 4π. Early light engineers who discovered this relationship saw it as the total amount of light "lumens."

The basic definition of the lumen is $4\pi \times$ cp. In real life, a spherical photometer is used to measure the average candlepower of a lamp. The obtained figure is then multiplied by 12.57 to obtain the lamp's lumen output. Some technical literature on light measurement can be confusing by incorrectly implying that candles (or candelas) are defined by lumens. If you read the literature, keep in mind that the universally agreed upon standard is the New International Candle (candela). The most useful technical literature is from manufacturers of light sensors.

Some technical literature refers to the meter-candle (lux) as lumens per square meter. When the English system of measurement is recognized, it is referred to as lumens per square foot instead of the more readily understood foot-candle. Such literature is correct, but lumens per square meter is not "intuitive." (Note: One phot is one lumen per square centimeter.)

You can estimate the candlepower of light bulbs expressed in terms of standard candles simply by dividing the lumen rating of the bulb by 12.57. Doing this for a 100-watt, 1,750-lumen bulb, you get about 139 cp, which implies that a light meter 1 foot from this bulb should measure 139 fc. In an actual test using an accurate light meter, 200 fc was measured at a horizontal distance of 1 foot from such a bulb.

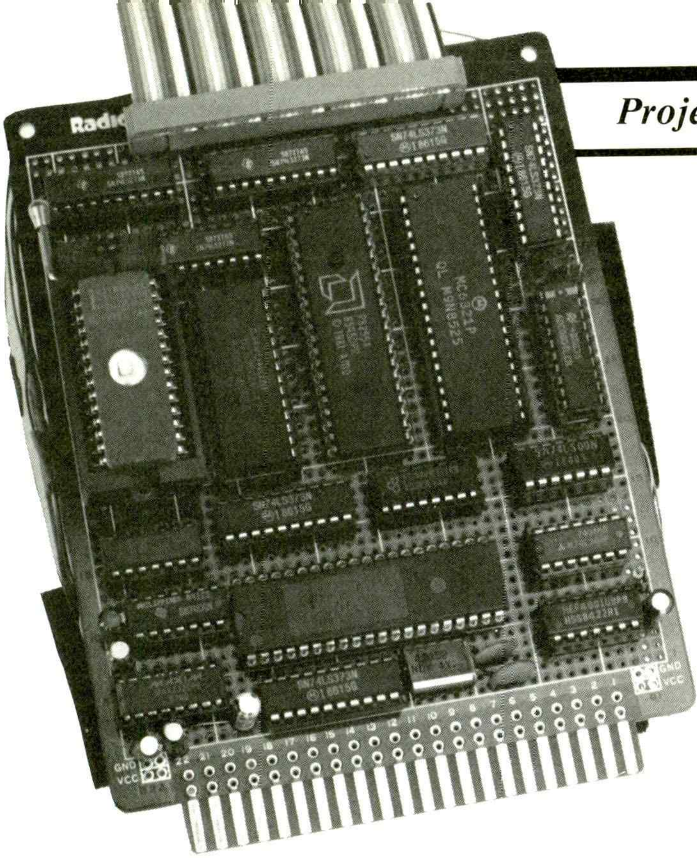
Several reasons are possible for the discrepancy between the calculated and actually measured figures. One is that new bulbs produce more light output (at constant voltage) than do old bulbs, and the lumen rating is an average of the light output of the bulb over its lifetime. The greatest discrepancy occurs because the calculation assumes a point source of light radiating evenly omnidirectionally.

An actual bulb radiates most of its light in the horizontal direction (the direction measured). It has been found that the light intensity is about $1/3$ above the average when measured in the horizontal direction. Knowing this, you can make a revised calculation: candlepower (in the horizontal direction) = $1{,}750/12.57 \times 1.33 = 185$, which is close to the measured output of 200 fc (see Fig. B).

Keep in mind here that when measuring light, you aren't really concerned with total radiant power. This is true even when restricted (when measuring radiant power) to visible-light electromagnetic radiation in the violet range at 380 nanometers to the dark red range at 780 nanometers. (A nanometer, abbreviated nm, is 1-billionth of a meter).

Figure C, shows the standard CIE (Commission Internationale de l'Eclairage) curve, which represents the average response of the eye of many individuals and is assumed to be the "normal" response. The curve peaks at about 555 nm in the greenish-yellow region. At this point, 1 watt of radiant power produces 685 lumens of visible light. Notice that the relative response at 650 nm (red) is only about $1/10$ that at 555 nm, means that 1 watt of radiant power at 650 nm produces only about 68 lumens of visible light.

Question: Which produces more lumens, a 10-cp red light at 650 nm or a 10-cp yellow bug light at 580 nanometers? The answer is that both produce the same number of lumens. Remember that candlepower deals with visible light and, thus, automatically takes into consideration the eye's response to light. If the question rated the light bulbs at 10 watts of radiant power (not electrical consumption) at the colors mentioned, the yellow light would have produced roughly seven times as many lumens as the red light.



I/O Add-On Enhances Micro-Sys

Add-on expands controller capabilities of a popular single-board computer project published here last year

By Michael Swartzendruber

The Micro-Sys platform that appeared under the title "Microprocessor Control With BASIC" in the April and May 1989 issues of *Modern Electronics* generated a lot of interest and may well have been the first single-board computer (SBC) many readers built. While the Micro-Sys article explained basics of constructing the engine of a potentially powerful control system, it did not describe how to expand its input/output (I/O) capabilities. The add-on option presented here adds greatly to the system's utility.

Our I/O circuit adds to the Micro-Sys 24 output lines, 16 input lines and 4 programmable interrupt lines. It also buffers the four timer interrupts, DMA interrupt and PWM output of the 8052AH, making them accessible to the outside world. This add-on accessory is an economical eight-chip assembly that gives the Micro-Sys enthusiast nearly unlimited potential in using this SBC for controller applications.

Overall Circuit Description

The input/output enhancement scheme for the Micro-Sys, shown in Fig. 1 and Fig. 2, employs two popular I/O control chips: an 8255 Programmable Peripheral Interface (PPI) for output control and a 6821 Programmable Interface Adapter (PIA) for input control. The 8225 has three eight-bit ports (24 lines), while the 6821 has two eight-bit ports and four handshake control lines that can be programmed as interrupt pins.

This two-chip method of I/O implementation was chosen while considering these options: Both chips are programmable and can be set to a variety of bit-by-bit input and output combinations. To exploit the bidirectional nature of these chips, however, bidirectional octal buffers would have to be used. While this is not too difficult to accomplish, it would require much more control logic than the Micro-Sys has available. Also, since this circuit was designed for use with the Micro-Sys, it is better to try to keep the add-on control logic to a minimum and capitalize on the logic that already exists in the original design.

Since the 6821 offers programmable interrupts, it seemed natural to select this chip as an input controller. During system initialization, a control word is written to the the chip's data direction control registers that set all pins as inputs.

A second 6821 could have been implemented as an output controller. The initialization routine would simply be slightly modified to write a data word to the chip's data direction control registers to place it in an all-pins-output mode. This would give the Micro-Sys 20 output control lines. This is where the 8255 can offer a more powerful option with no real system overhead cost. Since the 8255 offers 24 lines that can be configured

PARTS LIST

- IC16,IC17,IC18—74LS273 octal D-type flip-flop with clear
- IC19—8255 programmable peripheral interface
- IC20,IC21,IC22—74LS373 octal D-type transparent latch
- IC23—6820/6821 peripheral interface adapter
- Misc.—Circuit board (see text); sockets for all ICs; Wire Wrap or soldering hardware (see text); multi-conductor ribbon cable; Wire Wrap wire or hookup wire; etc.

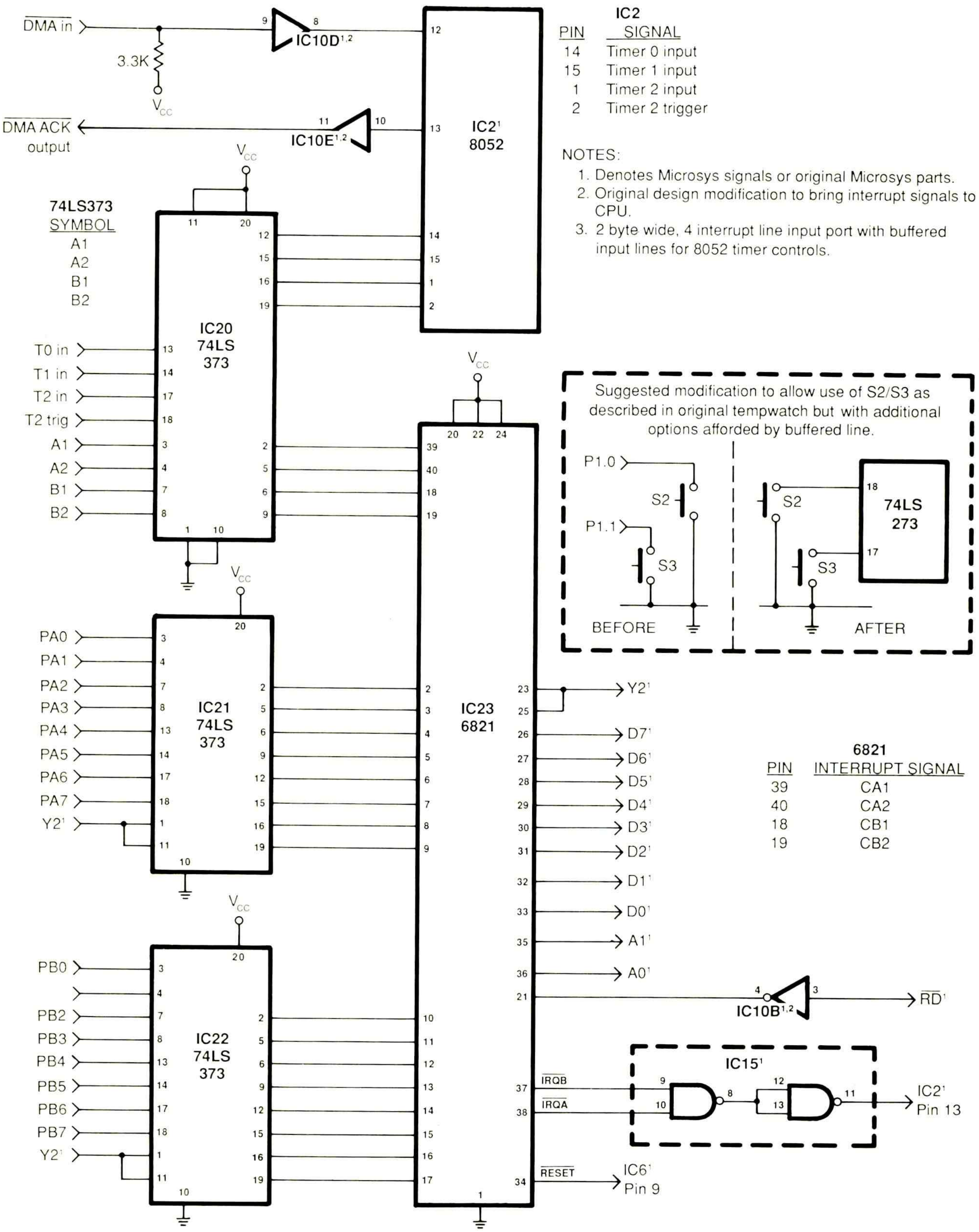


Fig. 1. Input circuitry details.

About the I/O chips

The 8255 Programmable Peripheral Interface (PPI) and 6821 Programmable Interface adapter (PIA) used to implement the input/output (I/O) functions in the add-on circuit presented in the main article are among the most widely used in the eight-bit world. Here is a brief introduction of both chips. If you require more information, you should refer to manufacturer data books.

The 8255 is an industry standard I/O chip made by a number of IC manufacturers. It can be programmed in 27 different input and output combinations. Mode of operation is set by writing an eight-bit control word to a control register. This circuit uses a mode 0 option that specifies all lines as outputs.

Writing of the control word is done during system initialization. Some more experienced users may wish to explore the possibility of using other modes of operation this chip has to offer. To do so, however, may require that the 74LS273 buffer chips specified in the main aerticle be replaced with bi-directional octal transceivers. Additional control logic tied to the RD and WR lines of the processor will have to be utilized to control the direction of the octal transceivers.

The 6821 is another industry standard I/O interface chip. Each of its bits can be individually configured as input or output lines by setting or reseting bits in the data direction control register. In this respect, the 6821 is more versatile than the 8255, whose bit direction resolution is at best a nibble wide. In this circuit, all bits are defined as inputs. The interrupt/handshake lines can be programmed to respond to a rising or falling edge. The interrupts can be programmed to be disabled altogether. Refer to the interrupt option value chart in the main article if you wish to customize your initialization code to suit your specific needs.

as all outputs, as opposed to the 20 lines of the 6821, it is just as simple to write the system initialization routine for the 8255 as it is for the 6821. On this basis, therefore, an 8255 was selected for output control.

Since the 8255 does not latch data at its output pins, three octal latches are coupled to the 8255 so that a control state can be set and "frozen" until a new control state is desired. The TTL buffers also have more drive capability than the 8255.

The 74273s shown as *IC16*, *IC17* and *IC18* in Fig. 2 were selected because they have a CLEAR line that is tied to the system RESET line. This means that when the Micro-Sys is first powered up, the 24 output lines will come up in a logic zero state. This is very desirable because it would not be advisable to have these control lines come up in a random state whenever the Micro-Sys is first turned on. If a random state on power-up were permitted, whatever these control lines were connected to would come up in a random state of action. Also, the outputs can be reset to a low state when the system is reset.

Input signals to 6821 *IC21* in Fig. 1 are connected through 74LS373 octal buffers *IC16*, *IC17* and *IC18* to protect the PIA chip from potential damage from external sources. Since three octal latches (which provide 24 buffers) were required to accommodate the 20 input lines of the 6821 PIA (two eight-bit ports and four interrupts), four buffers are available for other use. These extra lines are used to buffer the four timer interrupt inputs on the 8052AH. In addition, two of the hex buffers of the original design are removed from the V+ bus and used to buffer the PWM output and the DMA request input on the 8052 microcontroller chip.

This add-in circuit makes use of some of the idle gates of the Micro-Sys SBC, a decision that was made so that the design would be as economical as possible (the gates were already present but not used). Consequently, the original Micro-Sys circuit requires very little modification. This is not required, though. If you are not concerned about power consumption and do not mind buying a couple of logic chips, you can also install additional logic support chips.

In essence, this I/O add-on circuit exploits the decoding provided by the 74LS138 (*IC3* in the original Micro-Sys SBC) 3-line to 8-line decoder/demultiplexer. The unused Y2 and Y3 lines are used in the I/O circuit as chip-select signals for the 6821 and 8255. The two chips connect to the address, data and control bus signals in the usual manner.

This is very simple for the 8255, since it belongs to the 8052 family of components; so both chips use the same set of control lines and reset methods. The 6821 requires some extra logic to transform the 8052 control signals into signals that approximate those the 6821 expects to "see." As you can see, however, this additional logic is minimal. (See the "About the I/O Chips" box for more details on the 8255 and 6821.)

The 8052 and the 8255 both reset with a positive-going reset control pulse. The 6821 and the 74LS273 buffers require a negative-going reset, which is why they connect to the OR gate input of the reset circuit. On power-up, this point is low until the capacitor charges to +5 volts. The OR gate inverts this process, to provide the 8052 correct reset pulse.

Since the 6821 is used only as an input controller, it needs only to recognize the READ control line. The 8052 RD line is negative-true and the 6821 expects to see a positive-true signal on its RD control pin. That is why the RD signal from the 8052 is inverted and input into the 6821.

The 74LS373 input buffers that connect to the eight-bit input ports of the 6821 are enabled by Y2. This is the same signal used to select the 6821. This was done to disable the latches when the port is not being read and to latch the data word when a read operation is made.

The third 74LS373 has its chip and

output enables wired so that the latch is transparent and follows the latch input. This is desired because this octal buffer is used to isolate the external world from the CMOS. However, interrupt lines, by their nature and use in control systems, must have instant access to the interrupt processing circuitry.

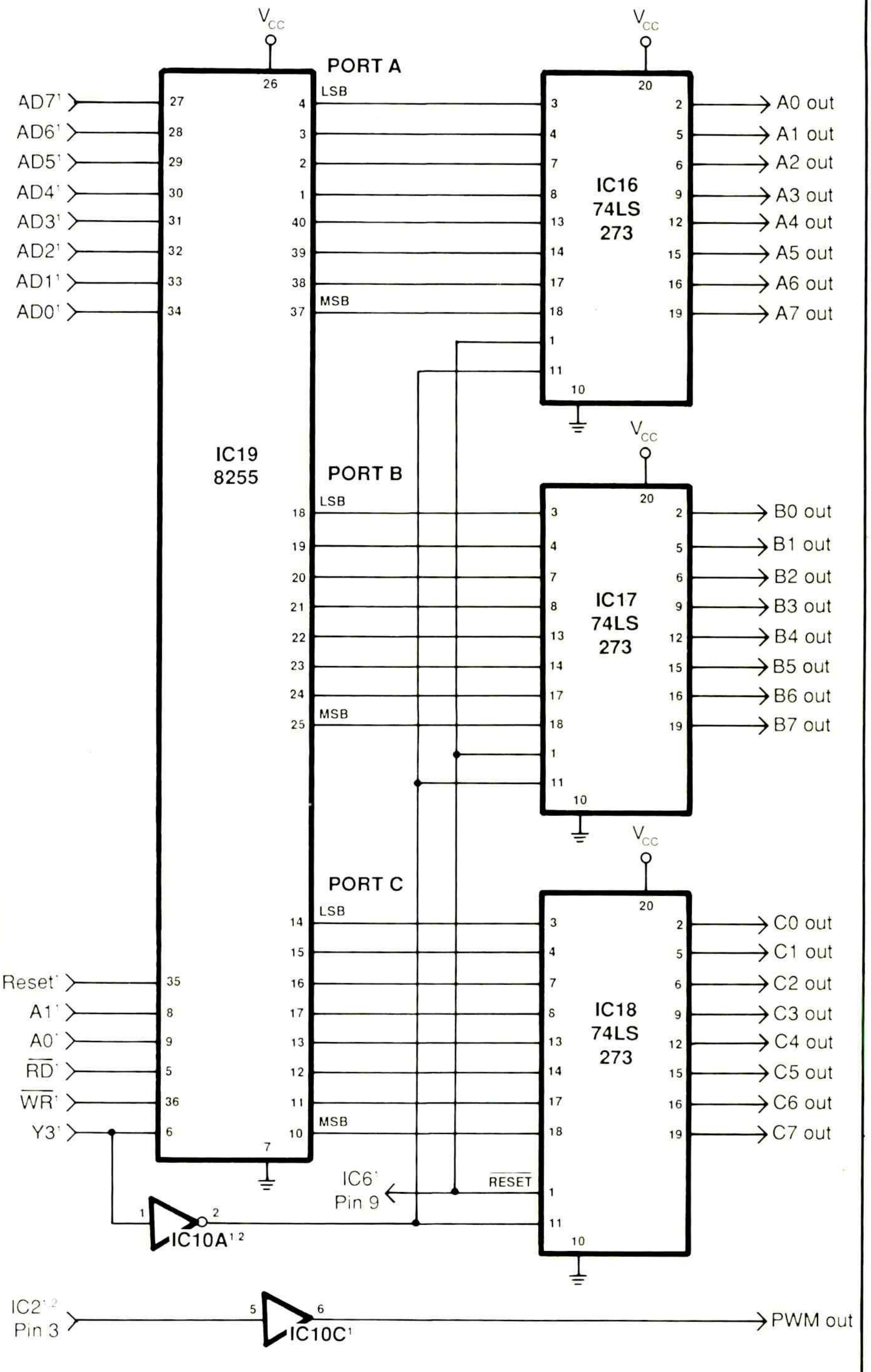
Four of these interrupt lines go directly to the CPU. The other four interrupt lines (CA1, CA2, CB1 and CB2) are processed through the 6821. If either of the "A" interrupt lines is asserted, the the IRQA output of the 6821 will fall. The IRQB output responds to the "B" interrupt lines. Both interrupts are ANDed so that the CPU gets an interrupt whenever any of the four interrupt lines is asserted.

Construction

The I/O add-in circuitry can easily be assembled using perforated board that has holes on 0.1-inch centers and Wire Wrap or soldering hardware. Make sure you use sockets for all ICs, regardless of your choice of construction technique. You can also Wire Wrap the connections between the Micro-Sys SBC and I/O circuit-board assemblies.

If the card on which you assembled the Micro-Sys is not large enough to accommodate the interface circuitry, use a separate card for the I/O interface, as was done for the prototype shown in the lead photo. Then when making connections between the two assemblies, keep the distance between them as short as possible.

Should you decide to make use of the uncommitted gates on the Micro-Sys board, make sure you remove the wires that tie these gates to the V+ bus. When removing any connection, make certain that the correct one is being worked on and that no other connections are accidentally removed or affected by your change. If you think this is too complex an approach, it may be better to incorpor-



NOTES:
1. Microsys signals or original Microsys parts.
2. Optional original design modification to bring buffered PWM signal to output port.
3. 3 byte wide bit programmable output port for Microsys SBC.

Fig. 2. Output circuitry details.

ate the additional logic chips into the Input/Output circuit.

Since the original Micro-Sys SBC has the LCD control switches connected to pins 1 and 2 of the 8052 and the interrupt buffer also connects to the same pins, a modification to the original Micro-Sys is suggested. That is, remove the switch connections from P1.1 and P1.0 and reconnect them as follows: move *S2* to pin 18 of the 74LS373, and move *S3* to pin 17 of the 74LS373. This modification allows the switches to keep the same functions they had in the original Micro-Sys and also allows the buffered P1.0 and P1.1 inputs to be used for other purposes. If this modification is not made, potential damage to the buffer and erratic operation of the switch functions may result.

A normally-open momentary-contact pushbutton master system-reset switch must also be added between pin 9 of *IC6* and circuit ground.

Initialization

To initialize the system, refer to the flow charts, control word option charts (where appropriate) and code listings. These routines can be called at any time, either at system initialization or whenever the services of the I/O chips are required. They must be executed before any data can be exchanged through the I/O ports. Once the configuration routine is run, the I/O channels can be accessed, read from and written to simply by calling their addresses. The control registers can be rewritten at any time if needed.

The line numbers in the following routines are much higher than they are likely to be in an application. They are numbered in this manner here for illustrative purposes only.

In the following initialization routine for the 8255, all 24 bits are set up as output bits. The routine writes a configuration control word to the control register on-board the chip.

```
1000 REM 8255 INITIALIZATION ROUTINE
1010 XBY(06003H)=128 : REM 128 SETS ALL BITS AS OUTPUTS
1020 END
```

This two-line routine is simple and direct. The control register of the 8255 chip is located at hex address 06003 and is the fourth and highest register on the chip. The "A" port resides at hex 06000, the "B" port at hex 06001 and the "C" port at hex 06002. The next routine illustrates how to output a data word to each of these ports for Micro-Sys control functions:

```
1100 REM SAMPLE DATA OUTPUT TO 8255 PORTS
1110 FOR WORDOUT=0 TO 255 : REM START A COUNTER
1120 XBY(06000H)=WORDOUT : REM WORD TO PORT A
1125 FOR PAUZA=1 TO 300 : NEXT PAUZA : REM DELAY LOOP
1130 XBY(06001H)=WORDOUT : REM WORD TO PORT B
1135 FOR PAUZB=1 TO 300 : NEXT PAUZB : REM DELAY LOOP
1140 XBY(06002H)=WORDOUT : REM WORD TO PORT C
1145 FOR PAUZC=1 TO 300 : NEXT PAUZC : REM DELAY LOOP
1150 NEXT WORDOUT : REM INCREMENT COUNTER
1160 END
```

This routine is a simple loop counter. It starts with a count of zero. It then outputs the same data word to port B and pauses. It then puts the same data word on port C and pauses. Finally, it increments the counter and loops again until a count of 255 (FF) is reached.

This routine can be used with a diode array (cathodes to ground and anodes to output buffers through current-limiting resistors) to display the data words of the experimental output word generator. This program also demonstrates the ease of output control with the 8255.

Initialization of the 6821 must now be performed. The following routine for this sets the 16 data bits as dedicated inputs:

```
2000 XBY(05004H)=0 : REM PORT A DATA DIRECTION REGISTERS SET FOR ALL BITS AS INPUTS
2010 XBY(05005H)=0 : REM PORT B DATA DIRECTION REGISTERS SET FOR ALL BITS AS INPUTS
2030 XBY(05006H)= * : REM CONFIGURE PORT A TO APPLICATION
2040 XBY(05007H)= * : REM CONFIGURE PORT B TO APPLICATION
2050 END
```

Lines 2000 and 2010 set up ports A and B, respectively, as all input bits. Refer to the Table to determine the value to place into register 05006H and 05007H (ports A and B configuration control registers, respectively).

Values to Place in Port A Configuration Control Register

Enable Port	Enable Interrupt Cx1	Select Active Transition	Enable Interrupt Cx2	Select Active Transition	Register Value
Y	Y	H to L	Y	H to L	11
Y	Y	L to H	Y	L to H	29
Y	Y	H to L	Y	L to H	27
Y	Y	L to H	Y	H to L	13
Y	N	X	N	X	2
Y	Y	L to H	N	X	5
Y	Y	H to L	N	X	3
Y	N	X	Y	H to L	10
Y	N	X	Y	L to H	26
N	X	X	X	X	0

Note: x is A or B, signifying Register A or Register B. X is a don't-care state.
L to H is low-to-high transition. H to L is high-to-low transition.

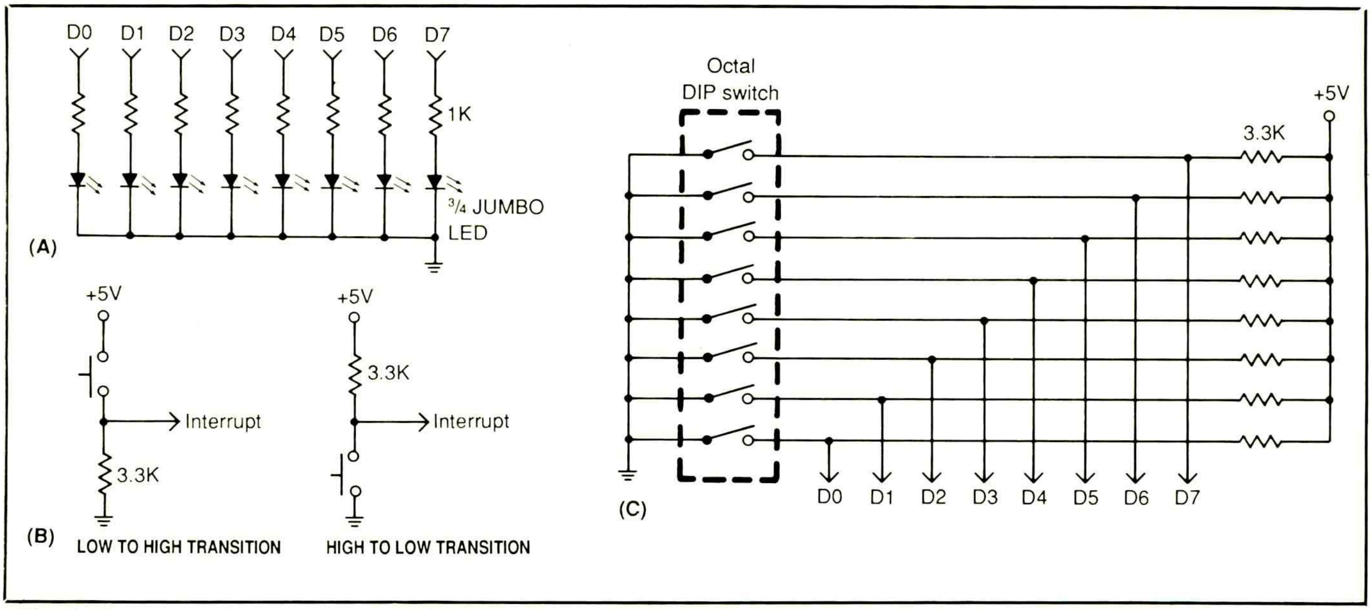


Fig. 3. Example of LED array (A) that can be used to exercise output port. One array is shown; three arrays are required in full implementation. Momentary-contact pushbutton switches (B) can be used to exercise interrupt inputs. One of two DIP-switch assemblies (C) that can be used to exercise the input ports.

From the Table, two register values must be selected. One value chosen will be for the port A configuration control register at address location 05006H. The second value is chosen for the port B configuration control register at address 05007H.

Note the range of interrupt possibilities offered by this chip, which is one of the main strengths of this particular chip. Also note that to enable the ports for any data transfer, a minimum value of 2 is required in the configuration control port. To disable the port, you can write a zero to the configuration control register. You must then reconfigure the chip to resume data exchange. After the configuration routine has been completed, use the following routine to input data from this port:

```
2100 PORTA=XBY(05004H) : REM
PORT A INPUT WORD
2120 PORTB=XBY(05005H) : REM
PORT B INPUT WORD
```

You can use a DIP switch to exercise the input ports. Momentary-contact pushbutton switches can be used to exercise the interrupt inputs. Remember to connectr all test jigs to the buffers—*not* the peripheral chips—to avoid damage to the devices.

You may have noticed that the port A register has the same address as the port A data direction register. After the port configuration register has a value of at least 2, the output registers are enabled and the chip internally switches the address (05004H in this case) from the data direction register to the output register. The same is true for port B. Because of this, the sequence that the initialization routine requires for this chip must be: first set the data direction register and then set the configuration register to enable the output registers.

Testing the I/O system for proper operation is a relatively easy thing to do. LED arrays can be connected to the output buffers, as in Fig. 3(A), and a short program written to output a variety of bit-on/bit-off combinations (a binary counter for instance) at the three output ports. Two DIP switches can be used as an input port exerciser, as in Fig. 3(B), and a short program written to repeatedly read the port. A third routine can be created to read the DIP-switch settings and then output the same pattern at the output ports. Finally, pushbutton switches can be used, as in Fig. 3(C), to emulate interrupt signals.

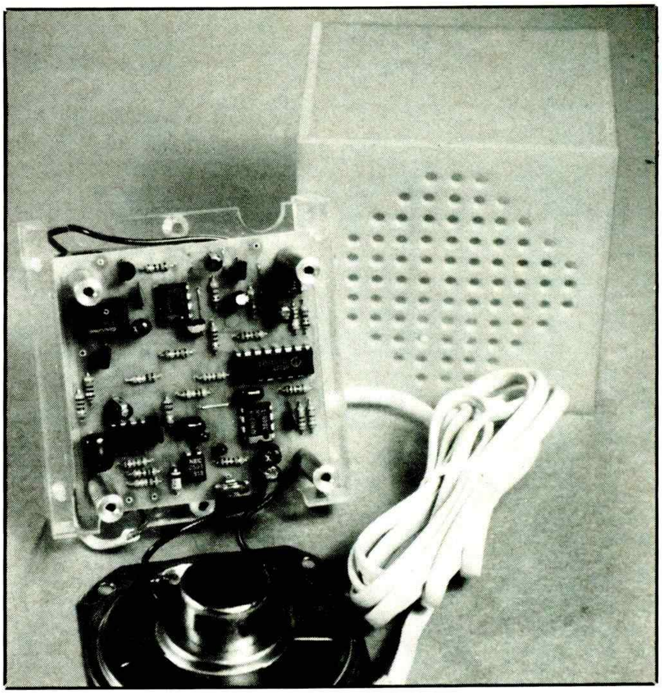
Summing Up

The I/O add-on described here for the Micro-Sys single-board computer has 50 I/O lines. The 24 output lines offer 16-million output combinations! The PWM output is useful for motor speed control. With this add-on circuit, the Micro-Sys now has nine interrupt lines with three major priority levels.

Keep in mind that the Micro-Sys still has its analog input. It also now has 16 input lines that provide 65,536 different input combinations.

With the addition of I/O facilities, the Micro-Sys has now become a full-blown I/O engine. The "horsepower" of the upgraded Micro-Sys I/O engine is ready to be taken into the real world, where it will give you a degree of control you probably never imagined you would ever have. **ME**

Super Tunes for Telephones



Device gives your phone more answering appeal by playing a different melody each time it rings

By W. Schopp

The electronic chirp that now alerts you to an incoming telephone call is somewhat of an improvement over the bell, but even the sound of a chirp can jangle nerves after a while. A change from the chirp to the Melody Ringer described here could make your day more pleasant.

Our Super Tunes Melody Ringer is a small unit that plugs into your telephone line and plays a short tune each time your telephone rings. It plays a selection of 12 tunes; so that each time you receive a call, a different melody is heard. Among the tunes available are: "American Patrol," "Brother John," "My Darling Clementine," "London Bridge" and others.

Completely self contained, including its own 6-volt dc power source, the Melody Ringer can easily be moved from one telephone instrument to another. When the instrument with which the project is used is taken off-hook, the melody stops. Battery life is quite long since three of the four cells used are effectively disconnected from the circuit when the unit is not playing a tune. The fourth cell maintains the memory in the melody chip and draws only microamperes of current.

About the Circuit

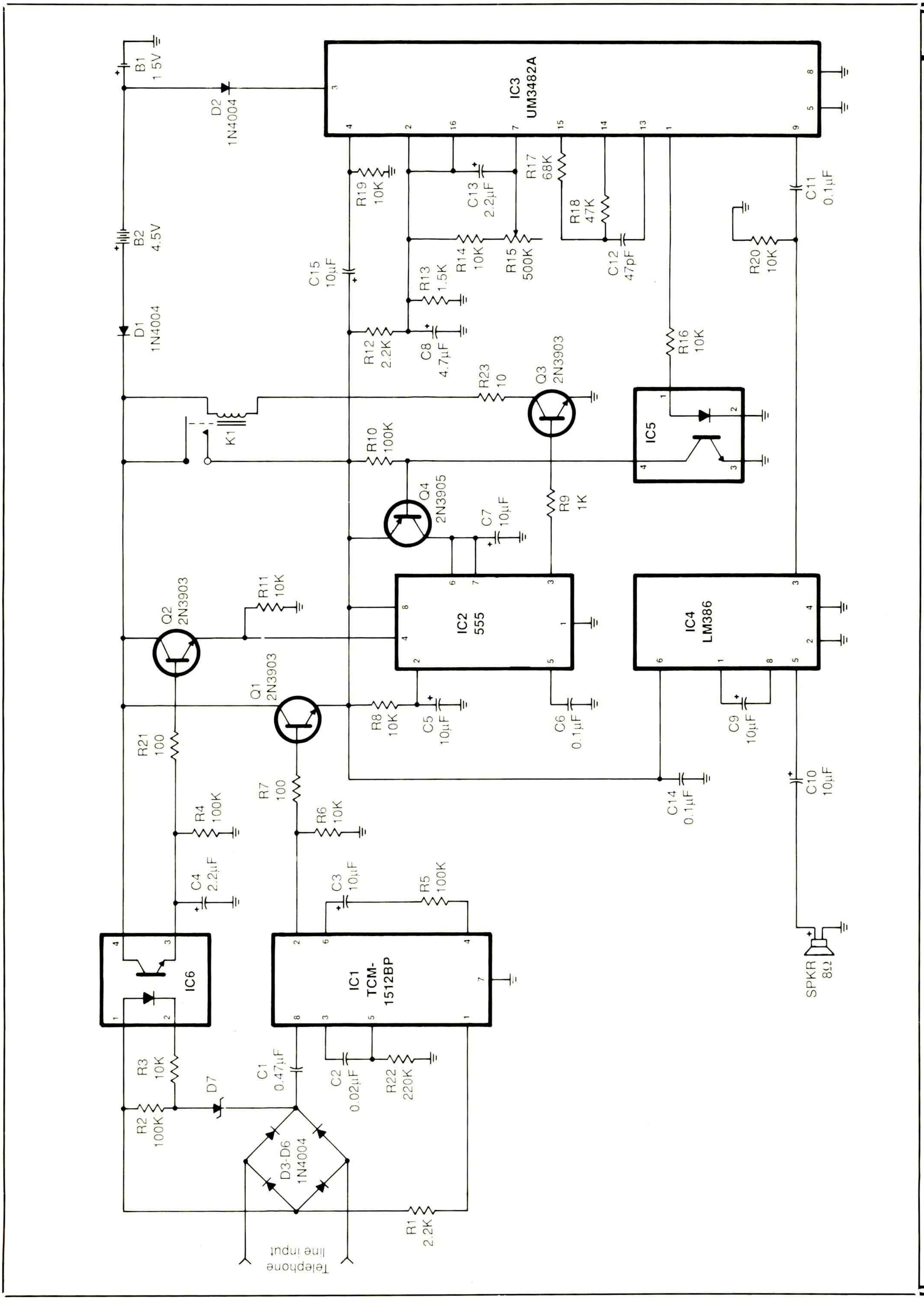
Before discussing circuit operation, let us briefly review what occurs on the telephone line and how it is affected by use of the telephone instrument. When the telephone is on-hook, approximately 48 volts appears on the line. Lifting the receiver is off-hook, drops this to about 7 volts. The voltage on the line is impressed on the green- and red-insulated conductors, with green at positive (+) and red at negative (−).

The ring signal is an interrupted dc voltage that has peaks of 90 to 150 volts with an interruption frequency of around 20 Hz. When you pick up the handset, this pulsating voltage is also present during dialing. Hence, the input sensing circuit of the Super Tunes project had to be designed to trigger the circuit into operation only on the incoming ring signal—not on the dial pulses.

In reality, the Super Tunes circuit does not distinguish between incoming ring pulses and outgoing dial pulses on the line. Instead, it disables the ability of the triggering circuit to turn on the melody-producing section while the phone is off-hook. This prevents the melody from playing every time you pick up the phone to dial a number.

As shown in Fig. 1, the circuit used to sense the ring signal is a special chip designed for this purpose. This Texas Instruments TCM1512BP, shown as *IC1*, uses a minimum of outboard components. The input telephone line connects across the bridge network comprised of *D3* through *D6*. This bridge configuration prevents the line input from being accidentally cross-connected. The pulsating ring signal is coupled across *IC1* by *C1* and *R1*.

Outboard components *C2*, *C3*, *R5* and *R22* provide filtering and "anti-tinkle." During the time a ring signal is present, a positive voltage with reference to ground is produced on pin 2 of *IC1*. This voltage turns on *Q1*, which momentarily supplies operating power from the positive bus to



B1 1.5V
B2 4.5V
D1 1N4004
D2 1N4004
IC3 UM3482A
R19 10K
C13 2.2µF
R17 68K
R18 47K
C11 0.1µF
C15 10µF
R13 1.5K
R14 10K
R15 500K
C12 47pF
R20 10K
R12 2.2K
C8 4.7µF
R16 10K
R23 10
Q3 2N3903
K1
R10 100K
IC5
Q4 2N3905
C7 10µF
R9 1K
R11 10K
Q2 2N3903
IC2 555
IC4 LM386
Q1 2N3903
R21 100
R8 10K
C5 10µF
C6 0.1µF
C9 10µF
C14 0.1µF
C10 10µF
R7 100
R4 100K
R6 10K
C4 2.2µF
C3 10µF
R5 100K
IC6
IC1 TCM-1512BP
SPKR 8Ω
R3 10K
D7
C1 0.47µF
C2 0.02µF
R22 220K
R2 100K
D3-D6 1N4004
R1 2.2K
Telephone line input

Fig. 1. Complete schematic diagram of Super Tunes telephone melody ringer circuitry.

the rest of the circuit.

When power is momentarily applied to the circuit, 555 timer chip *IC2*, turns on with a negative pulse to pin 2, provided by *R8* and *C5*. This timer is a standard circuit that has been modified to a latch by removing the resistance from the RC network and replacing it with *Q4*. When turned on, *IC2* latches until *Q4* turns on and allows *C7* to charge.

When *IC2* is turned on, a positive voltage is produced on pin 3. This turns on *Q3* and energizes relay *K1*. Uninterrupted power is then supplied to the circuit through the relay contacts, keeping power supplied to the circuit between rings when *Q1* is turned off.

When power is applied to the circuit, a positive pulse to pin 4 of *IC3* triggers this melody chip into operation. This chip operates on 1.5 to 3 volts dc. The voltage-divider network consisting of *R12* and *R14* drops the 6-volt supply potential to a safe operating level for *IC3* at pins 2 and 16. The network consisting of *R14*, *R15* and *C13* changes the modulation of the chip to sound like an organ, piano or mandolin. The tone can be modified by adjusting *R15*.

The network made up of *R17*, *R18* and *C12* sets the speed or tempo of the playback. Making *C12* larger in value slows the beat, while decreasing the value of this capacitor speeds up the beat.

Pin 1 of *IC3* is an output flag. It goes high at the end of the selected tune and is used to turn on *Q4* and drop out *IC2* at the end of the selected tune. When pin 1 goes high, it turns on the LED inside optical isolator *IC5*. This causes the phototransistor inside *IC5* to turn on. In turn, *Q4* turns on to charge *C7* and drop out *IC2*, which causes *K1* to deenergize. If the phone is still ringing at the end of the tune, the next tune will be triggered on and played.

To keep track of which tune was last played and the next tune on the menu, a voltage must remain on the memory of *IC3* at all times. This voltage is supplied from the single AA cell identified as *B1*, through *D2* to pin 3. The output from pin 9 is coupled to low-voltage amplifier *IC4*, which now provides driving power to speaker *SPKR*.

So far, we have covered turning on the melody when the phone rings and allowing it to play the selected tune to the end. One does not usually wish to have the tune play after picking up the handset. Therefore, a method was needed to turn off the melody when the handset is lifted from the cradle. This is accomplished with *IC6* and *Q2*.

Keep in mind that when the phone is on the hook there is about 48 volts dc on the line. This voltage is divided by 15-volt zener diode *D7* and resistor *R2*. The voltage across *R2* is further reduced by *R3* and is then used to turn on *IC6*. With *IC6* turned on, *Q2* is turned on and supply voltage is present on the RESET pin 4 of *IC2*. When the phone is taken off-hook, line potential drops to 5 volts and *D1* can no longer conduct. The LED inside *IC6* turns off, in turn, turning off *IC6* and *Q2*. When *Q2* is turned off, the reset voltage on pin 4 is removed and *IC2* turns off.

Construction

The entire circuit, except battery and speaker, can be assembled on a board

PARTS LIST

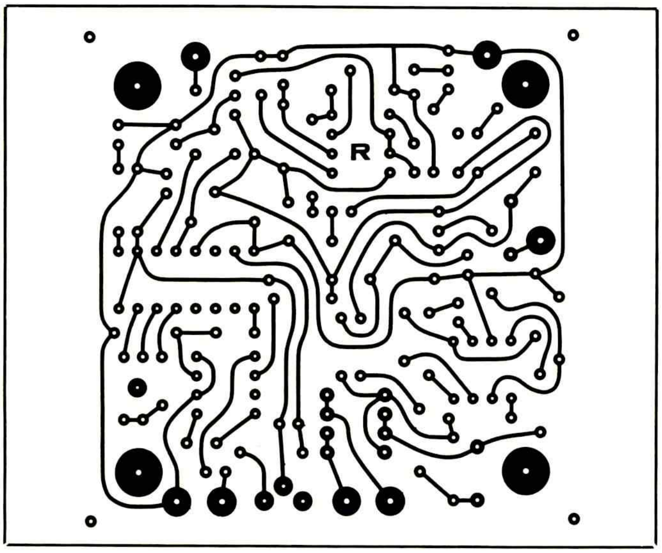
Semiconductors
D1 thru D6—1N4004 or similar power rectifier diode
D7—15-volt, 1-watt zener diode
IC1—TCM1512BP telephone ring detector (Texas Instruments)
IC2—555 timer
IC3—UM3482A melody chip (see Note below)
IC4—LM386 operational amplifier
IC5,IC6—Optical coupler (Digi-Key Cat. No. PS2501-NEC or similar)
Q1,Q2,Q3—2N3903 or similar general-purpose npn silicon transistor
Q4—2N3905 or similar general-purpose pnp silicon transistor

Capacitors
C1—0.47-µF, 100-volt ceramic disc
C2—0.02-µF, 50-volt ceramic disc
C3,C5,C7,C9,C10,C15-µF, 25-volt electrolytic
C4,C13—2.2-µF, 35-volt electrolytic
C6—0.01-µF, 50 -volt ceramic disc
C8—4.7-µF, 25-volt electrolytic
C11,C14—0.1-µF, 25-volt ceramic disc
C12—47-pF, 50-volt ceramic disc

Resistors (¼-watt, 5% tolerance)
R1,R12—2,200 ohms
R2,R4,R5,R10—100,000 ohms
R3,R6,R8,R11,R14,R16,R19,R20—10,000 ohms
R7,R21—100 ohms
R9—1,000 ohms
R13—1,500 ohms
R17—68,000 ohms
R18—47,000 ohms
R22—220,000 ohms
R23—10 ohms
R15—500,000-ohm, miniature trimmer potentiometer (Digi-Key Cat. No. K0A55)

Miscellaneous
B1—1.5-volt alkaline AA cell
B2—Three 1.5-volt alkaline AA cells in series
K1—5-volt dc spdt micro-miniature relay (Aromat No. HD1E-M-DC5V; available from Newark Electronics as Cat. No. 46F5743)
SPKR—2.5" 8-ohm speaker with mounting holes on 2" centers (Mouser Electronics Cat. No. 25SP105 or similar)
Printed-circuit board or perforated board with holes on 0.1" centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (see text); AA-cell holder; Y adapter; telephone cable; machine hardware; hookup wire; solder; etc.

Note: UM3284A melody chip is available for $5.95 from Electronic Enterprises, 3305 Pestana Way, Livermore, CA 94550.



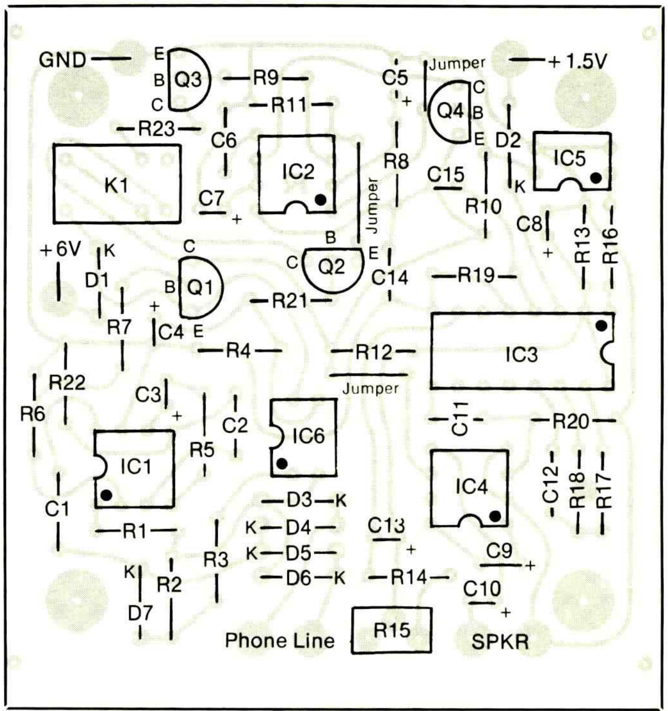


Fig. 2. Actual-size etching-and-drilling guide for fabricating printed-circuit board.

Fig. 3. Wiring diagram for pc board. Use this as a guide if you point-to-point wire the circuit on perforated board.

that measures only 2½ by 2½ inches. Alternatively, you can use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware.

If you decide to use a pc board, use the actual-size etching-and-drilling guide shown in Fig. 2 to fabricate it. From here on, we will assume pc construction. If you use point-to-point wiring, make suitable adjustments in the following procedure.

Install the components on the board exactly as shown in Fig. 3. Start by installing and soldering into place the IC sockets. Do *not* plug the ICs into the sockets until after you have performed voltage checks.

Next, install the fixed resistors, diodes, capacitors and transistors. Make certain that the diodes and electrolytic capacitors are properly oriented and that the transistors are properly based before soldering their leads into place. Finally, install and solder into place the trimmer potentiometer and miniature relay.

Strip ¼ inch of insulation from both ends of five 3-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at all ends and sparingly tin with solder. Plug one end of these wires into the B1, B2 and SPKR holes and solder into place.

You have a choice of connecting and soldering the telephone extension cord directly to the indicated pads on the circuit-board assembly or using a modular jack into which the cord plugs. If you go the latter route, prepare two more 2-inch-long wires as above and solder one end of each wire into the PHONE LINE holes on the board. The other ends of these wires will then be terminated in the modular jack that will mount on the project's enclosure.

You can use any enclosure that will accommodate the circuit-board assembly, speaker and battery (and modular jack, if used) to house the project. Machine the enclosure as needed. That is, drill mounting holes for the circuit-board assembly and battery holder and a series of small holes through which the sound from the speaker can escape. Also, if you are using the modular jack, cut a suitable opening for it. Deburr any holes drilled through metal.

If you wish to duplicate the enclosure shown in the lead photo use ⅛-inch-thick acrylic sheet stock and acrylic cement. Mount the plastic four-cell battery holder inside a bottom channel that also serves for mounting the circuit-board assembly and speaker. Make this channel from three pieces of ¼-inch-thick plastic and slip it into the bottom of the cemented-together enclosure.

Two sides of the enclosure can be screwed into the sides of channel to secure together case and channel. Mount a bottom plate the same size as the top plate to the side pieces of the channel to cover the battery. Finally, drill a series of holes in the top plate to permit the sound from the speaker to escape.

You can stack the speaker on top of the circuit-board assembly with the components using 1-inch threaded spacers as shown. The speaker and circuit-board assembly can then be mounted inside the cubical enclosure, the 3-inch-square by 2½-inch-high dimensions of which still leave room for the four AA cells that make up *B1* and *B2* on the bottom.

The four-cell plastic battery holder arranges the cells side-by-side. When wiring the cells, be sure to have them all in series with each other and tap the one nearest the common (−) terminal to provide the 1.5 volts that will keep alive the memory of the melody chip. Keep in mind that soldering must be done quickly to keep from overheating the spring and melting the plastic enclosure it is attached to. Bring the battery wires up to the board through cutouts on the sides of the battery channel piece.

Checkout & Use

With no ICs plugged into the sockets, place four fresh alkaline AA cells in the battery holder. Observe proper polarity. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to the negative (−) terminal of the battery holder.

Touch the "hot" probe of the meter to pin 3 of the *IC3* socket. The meter should indicate approximately +1.5 volts. Temporarily jumper from the cathode of *D1* to the + lead of *C15*. Then touch the "hot" probe of the meter to pin 8 of the *IC2* and pin 6 of the *IC4* sockets. In both cases, you should obtain a reading of approximately +6 volts.

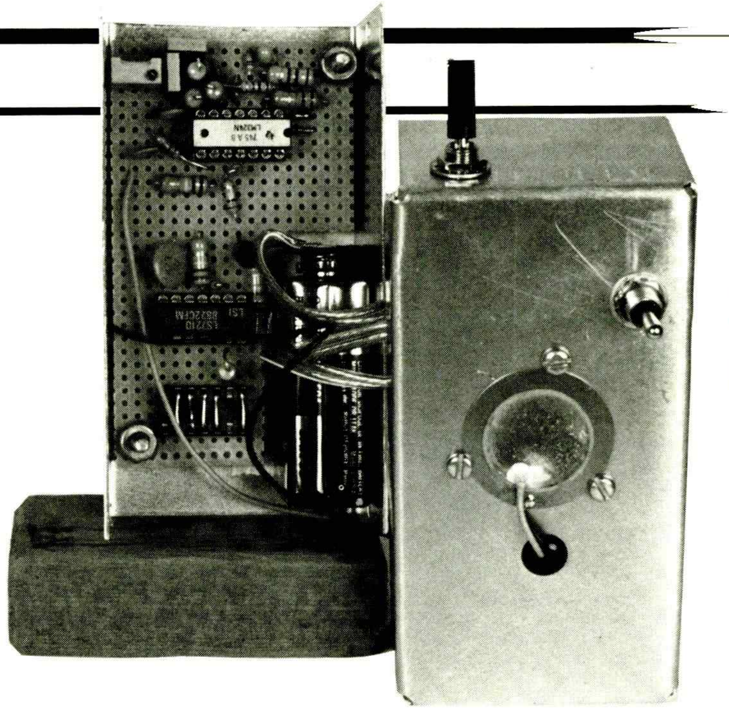
If you fail to obtain the proper reading at any of the specified points, remove the cells from the battery holder and troubleshoot the circuit to correct the problem.

When you are certain that the circuit has been properly wired, remove the cells from the battery holder and install the ICs and optical isolators in their various sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between devices and sockets.

Plug a duplex modular connector into the wall jack and the telephone instrument into one of its jacks. If you mounted an optional modular jack on the project, plug one end of the extension cord into it. Otherwise, route the extension cord through a hole in the enclosure and solder the red- and green-insulated conductors to the PHONE LINE pads on the circuit-board assembly. Plug the other end of the cord into the other connector jack at the wall box.

When the Super Tunes melody ringer is installed, it will start playing a tune on the first ring. It plays the tune only once for each call, unless ringing persists after the tune is complete. The next tune is then played. When the handset is picked up, the melody stops. **ME**

Project



An Infinite Snooze Alarm

Select the duration of a snooze period up to 31 minutes as many times as you wish to without the one-hour restriction normal for clocks and clock radios

By Ron Peterson

Drifting in and out of sleep in the morning is one of the greater pleasures in life. Hitting the snooze button on an alarm clock or clock radio lets you spend those extra minutes back on your cozy little cloud. Many people, however, press the button again and again to continue their dream excursions. But there's a maximum snooze time lurking, usually one hour. So if you kit the snooze button just once too often, the alarm will no longer be activated and you can oversleep.

The Infinite Snooze Alarm described here overcomes this problem. It will keep you snoozing for as long as you please without worrying about reaching the snooze limit of your alarm clock. As long as you continue to press the snooze button, the project will continue sounding its pleasant chime alarm when the snooze period you chose is reached. It'll stop when you disable power. You can select a period between audible alerts from 1 to 32 minutes or more and change them whenever you wish.

To use the Infinite Snooze Alarm, you simply place it beside your regular alarm clock or clock radio. When the alarm sounds, you turn it off and flip the power switch on the project. From then on, you can hit the project's snooze button as many times as you like. An added bonus is that you can choose the type of sound your snooze alarm will make. With the circuit built as described, you get a pleasant bell-chime sound, but we also tell you how to obtain other sounds.

Uses for the Infinite Snooze Alarm include exploring how you dream, scientific research on dreaming or sleeping habits and general-purpose timing applications, in addition to just plain everyday snoozing. You can customize and elaborate upon the circuit as you wish.

About the Circuit

Shown in Fig. 1 is the schematic diagram for the time-delay portion of the Infinite Snooze Alarm circuit. A variable time delay of long duration is achieved by *IC1*, an LS7210 integrated-circuit timer chip. This timer chip has a built-in clock whose frequency of oscillation is set by the values selected for *C1*, *R1* and *R2*.

Grounding pins 1 and 2 of *IC1* configures the timer chip in its one-

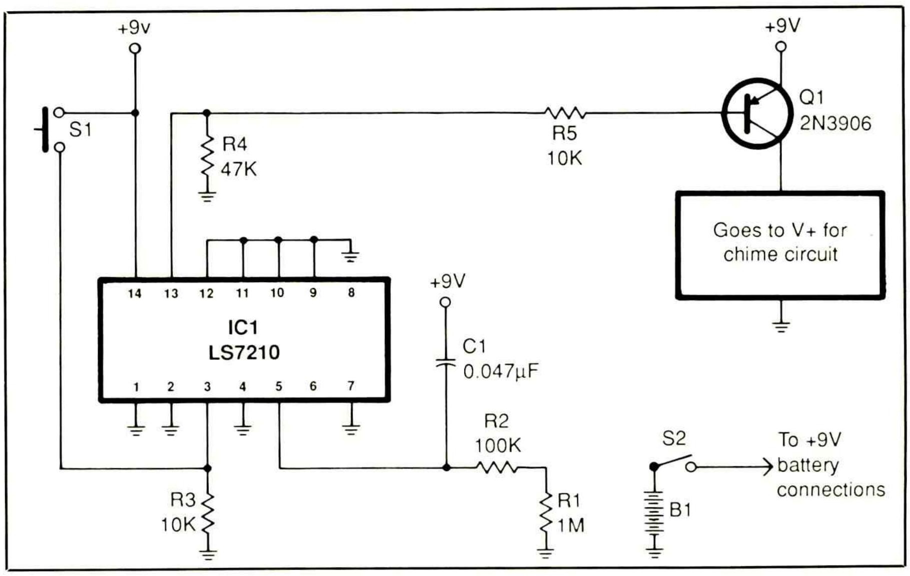


Fig. 1. Schematic diagram of Delay section of the Infinite Snooze Alarm.

shot mode (similar to the one-shot mode of the 555 timer chip). In this mode, a negative-going edge fed to pin 3 of the chip triggers the delay. (If you are interested in a detailed explanation of the different operating modes of the LS7210, buying your chip from Radio Shack gets you a four-page explanation of how this IC operates.)

Closing *S1* pulls pin 3 of *IC1* high, while opening the switch lets this pin return to low (as a result of *R3* being in the circuit). This action triggers the time delay period countdown.

There is a second reason for the existence of *R3* in the circuit. This resistor also causes the timer to enter its delay mode immediately upon power-up of the project. Hence, there is no need to press and release *S1* when power is first applied.

Connections made to pins 8 through 12 of *IC1* set the duration of the time-delay period by grounding specific pins of this chip as follows:

Pin	Adds Minutes
12	1
11	2
10	4
9	8
8	16

To set an 8-minute snooze time, for example, you would ground only pin 9. For a 20-minute snooze, you would ground both pin 8 and pin 10 (grounding of any one or more pins produces a period that is the sum of the individual periods assigned to each pin of *IC1*). By grounding all five pins, you can obtain a maximum delay period of 31 minutes with the component values shown in Fig. 1 and specified in the Parts List. If you desire longer times, you can try doubling the capacitive value of *C1*, which doubles the delay period available with the grounding of each pin.

Output pin 13 of *IC1* is connected to internal circuitry that requires an external resistor to provide the needed load for completing the circuit. This is provided by *R4*. The pin 3 output is used to turn on and off *Q1*.

PARTS LIST

Semiconductors
D1,D2—1N914 or similar switching diode
IC1—LS7210 programmable digital delay timer (Radio Shack Cat. No. or similar)
IC2—LM324 quad operational amplifier
Q1—2N3906 or similar general-purpose silicon pnp transistor

Capacitors
C1—0.047-μF ceramic disc
C2—2-μF, 35-volt tantalum
C3,C4—0.001-μF ceramic disc
C5—0.005-μF ceramic disc
C6,C7—0.1-μF ceramic disc

Resistors (¼-watt, 5% tolerance)
R1,R10,R11—1 megohm
R2,R6,R7,R8,R12,R13,R19—100,000 ohms
R3,R5,R18—10,000 ohms
R4—47,000 ohms
R9—68,000 ohms
R14,R15—56,000 ohms
R16—15,000 ohms
R17—100,000-ohm, 10-turn trimmer potentiometer (see text)

Miscellaneous
B1—9-volt alkaline battery
PB1—Piezoelectric disc transducer (Radio Shack Cat. No. 273-073—see text)
S1—Normally-open, momentary-contact spst pushbutton switch
S2—Spst slide or toggle switch
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for IC1 and IC2; suitable enclosure (see text); 9-volt battery snap connector and holder; spacers; machine hardware; hookup wire; solder; etc.

Once *IC1* has been triggered into operation, its output goes high and cuts off *Q1*. At completion of the delay period, pin 3 returns to its former low state and sends *Q1* into conduction. When *Q1* conducts, it completes a circuit from the V+ rail of the power source (a 9-volt battery, identified as *B1*) through the transistor to the chime circuit connected to Fig. 1 through the collector lead of the transistor.

Shown in Fig. 2 is the schematic diagram of the chime circuitry. This section consists of three operational-amplifier stages. Op amp *IC2* at the left is configured as a low-frequency pulse generator whose on- and off-times are set by the values of *R9* and *R10*, respectively, in combination with the value of *C2*. With the values specified for these components, this stage produces short pulses at a rate of about one every 2 seconds.

The pulses that appear at output pin 1 of *IC2* are used to trigger the *IC2* op-amp stage in the center of Fig. 2. This second stage is configured as a tuned bandpass filter. Elements *R14, R15, C5, C3, C4, R16* and *R17* set the optimized frequency of the filter. The values of these components are selected to set the filter very close to its resonance point, where it begins to self-oscillate.

Trimmer control *R17* permits precise adjustment of the onset of self-oscillation of the tuned bandpass filter stage so that when a pulse arrives at the pin 6 input of *IC2*, the filter oscillates for a short time and then gradually damps out. This ringing effect produces a waveform that sounds like a bell or chime when reproduced audibly.

To be able to hear the sound generated at output pin 7 of *IC2*, the third and final op-amp stage shown at the right in Fig. 2 is needed. This last stage drives piezoelectric disc *PB1*, which serves as the sound reproducer.

Note in Fig. 2 that the positive supply line is not connected to the battery that powers the timer. Instead, it is connected to this circuit through *Q1* (see Fig. 1) so that the chime remains silent until *Q1* conducts. Hence, the chime circuit uses no power until *Q1* turns on. Consequently, very little power, on the or-

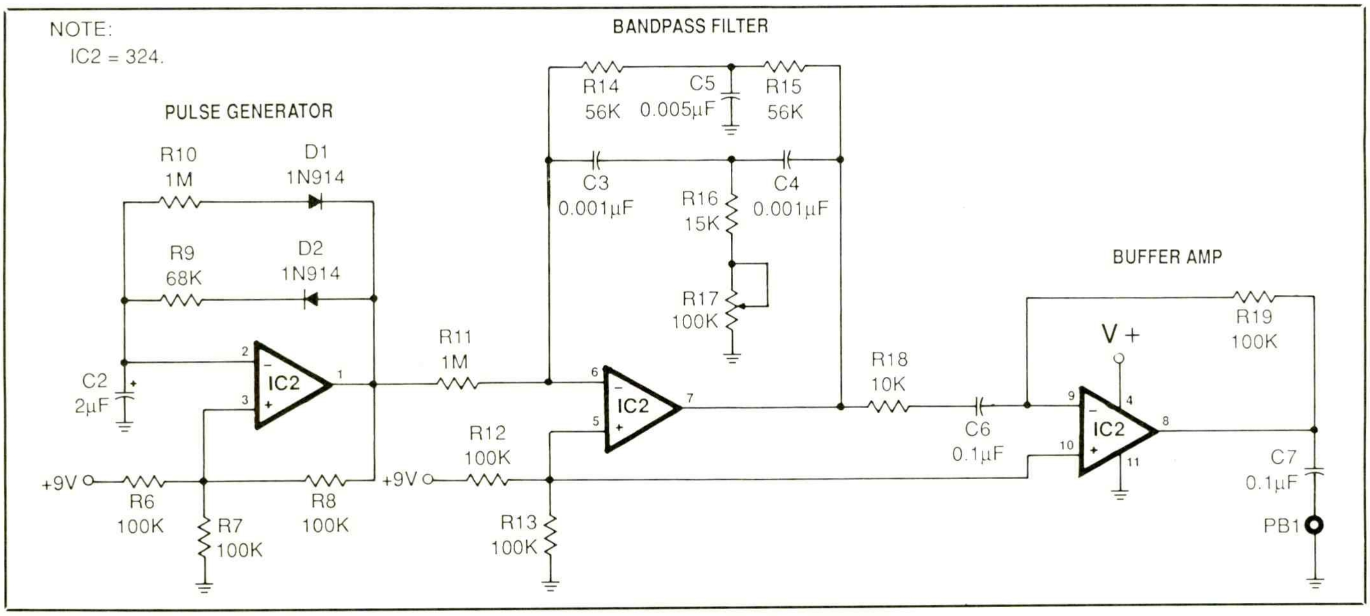


Fig. 2. Schematic diagram of Chime section of project.

der of 4 milliamperes, is drawn from *B1* when the disc is not sounding.

Construction

There is nothing critical about component layout and conductor runs. Therefore, you can use any traditional method of assembly to build this project. If you wish, you can design and fabricate a printed-circuit board on which to mount and wire together the components that make up the circuit. Alternatively, you can point-to-point wire the circuit on perforated board that has holes on 0.1-inch centers with the aid of suitable Wire Wrap or soldering hardware. Whichever way you go, though, be sure to use sockets for the ICs.

Wire first the delay circuit exactly according to Fig. 1. (All components —except the two switches, piezoelectric disc and 9-volt battery—mount directly on the circuit-board assembly. Also, wire the sockets into the circuit.) In Fig. 1, pins 9 through 12 are shown wired to ground for illustrative purposes only.

You will probably want to be able to select a different delay period by jumpering different output pins to ground. Though you can use hard-wired connections for this, it is more convenient if you use five sections of a DIP-switch assembly or an IC socket and jumper wires for the connections from these pins to ground to permit changing the period at any time in the future.

When you have finished building the delay circuit, test it by connecting a light-emitting diode in series with a 1,000-ohm resistor in place of the chime circuit from the collector of *Q1* to ground. Make sure the cathode end goes to ground.

Temporarily attach miniature insulated alligator clips to the leads of a 9-volt battery snap connector and fasten to the connector a fresh battery. Fasten the clip on the end of the negative (–) black-insulated lead of the connector to circuit ground and the clip on the positive (+) red-insulated lead to the V+ rail of the circuit.

When you first power up, the LED may turn on briefly before going dark. When the delay period has elapsed, the LED should light and remain on. The circuit was intentionally designed to operate in this manner so that you will not have to hit the "snooze" button (*S1*) on power-up.

Briefly bridge the *S1* connections with the jumper lead to simulate the closing of the "snooze" button. The LED should now extinguish and then come on again after the delay period has timed out. If you do not obtain these responses, something is wrong with your wiring or component installations. Power down by disconnecting the battery from the circuit. Rectify whatever problem exists before proceeding.

As you perform this test, you may discover that the delay period is not exactly what you selected with the jumpers or switch sections connected between *IC1* and ground. This is the result of variations in the values of the components used. However, it should be within 20 percent of the actual selected time period. If you wish greater accuracy, adjust the value of *R2* by increasing it to lower the clock frequency or decreasing it to raise the clock frequency.

Once you are sure the delay circuit is functioning properly, disconnect the battery and build the chime circuit shown in Fig. 2. Start with the pulse-generator stage, using a socket for *IC2*. When the components for this stage, including seating *IC2* in its socket, have been wired into the circuit, connect a dc voltmeter or multimeter set to the dc-volts function between pin 1 of *IC2* and circuit ground (observe proper polarity) and reapply power from the battery.

Wait for the delay period to time out. The meter reading should now begin jumping up and down at a rate of approximately once every other section. It is better to use an analog meter for this test, though a digital instrument will also work. The up/down meter readings are indications of pulse activity at pin 1 of the pulse generator.

Next, build the filter stage. If you have any difficulty locating the 10-turn trimmer potentiometer specified for *R17*, you can substitute a 20,000-ohm trimmer pot and fixed resistor for it. The value of the fixed resistor must be determined experimentally. However, stay with a 47,000-ohm resistor.

When you finish wiring the filter stage, temporarily connect the piezoelectric disc between pin 7 of *IC2* and ground. Apply power to the circuit via the battery and allow the delay period to time out. When this occurs, you should hear a faint "clicking" sound coming from the disc. (Laying the disc flat on a hard surface will increase the volume of the sound.)

Adjust the setting of *R17* until you hear a steady tone coming from the disc and then back off slightly until the sound just disappears. At this point, you should hear a faint chime sound coming from the disc at regular intervals. If you are using the 20,000-ohm trimmer pot and fixed resistor instead of the 10-turn pot and cannot get the circuit into the range where you can start and stop the tone regardless of the setting of the pot, try using a fixed resistor of greater or lesser value.

You may have to periodically adjust the setting of *R17* as the circuit ages and/or the weather changes. However, you can get around having to do this by using Mylar or polypropylene capacitors in the filter stage.

When you are sure everything is okay up to this point, power down once again and disconnect the disc from the circuit. Now build the buffer-amplifier stage. When you are done, test it by connecting the piezoelectric disc to the free end of *C7* and power up with the battery. Listen once again for the chime sound. This time, the sound coming from the disc should be much louder.

You can use any type of enclosure in which to house the project as long as it is large enough to accommodate the circuit-board assembly and battery internally and has enough panel space for mounting the piezoelectric disc and two switches. The enclosure can be all-metal, all-plastic or a plastic shell with a metal panel.

Machine the enclosure you choose to provide mounting holes for the circuit-board assembly, battery holder, switches and disc. If you drilled through metal, deburr all holes to remove sharp edges and line the entry hole for the leads from the disc with a small rubber grommet.

Mount all components and the circuit-board assembly in place. Use ½-inch metal spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers for the board. Be sure to solidly fasten the piezoelectric disc to the front of the enclosure with machine hardware to obtain maximum volume from it. This done, wire the switches and buzzer into the circuit.

Modifications

There are many ways in which you can alter the basic Infinite Snooze circuit to obtain other effects. Instead of installing the chime circuit, you can substitute a relay (try Radio Shack's Cat. No. 275-005 relay to control up to 2 amperes of current at 117 volts ac) to control power to an external device. For example, you can use it to automatically turn off your stereo system after you fall off to sleep. If you are the type who needs more "punch" from your alarm to get you up, try substituting the high-decibel piezoelectric buzzer for the chime circuit. Radio Shack's Cat. No. 273-070 buzzer puts out an ear-shattering 100 dB of sound!

Another possibility is to alter the tuning of the bandpass filter. By changing the values of *R14* and *R15*, you can obtain from the project a sound like a wood block, a large bell or a bass drum. Here is how to obtain some interesting sounds simply by changing resistance values:

Sound	Value in ohms
Triangle	33,000
Small Bell	47,000
Medium Bell	150,000
Large Bell	470,000
Drum	1M

Remember, though, that *both* resistors must be changed to the *same* value to obtain the proper results.

To tune the filter properly for the larger values of resistance used for *R14* and *R15*, you will probably have to also increase the value of *R17* to 1 megohm or make the value of *R16* larger. Also, keep in mind that the piezoelectric disc is not very good at reproducing sounds with a lot of bass-range frequencies in them (such as drums). Therefore, use a small loudspeaker and extra driving amplifier if you wish to obtain these.

Using the Project

It is very simple to use your Infinite Snooze Alarm. When your alarm clock or clock radio goes off at wake-up time, simply reach over, turn off the clock or radio and flip the project's power switch to "on." Now roll over to get a few more winks of sleep. When you hear the chime sound from the Infinite Snooze Alarm, tap the SNOOZE button on the project. Do this as many times as you wish, without fear of running out of count-down time. But remember that you can still be late for work if you press the SNOOZE button too many times since snooze periods do add up. ME

The Power MOSFET

By Forrest M. Mims III

If asked to select the most important discrete semiconductor component on my workbench, I would immediately reach for a package of power MOSFETs. For more than a decade, the power MOSFET has proved, time after time, that it is almost the ideal semiconductor switch. The input impedance of its gate terminal is on the order of 1,000 megohms. It can switch from off to on and back off again in nanoseconds. Its on resistance can be so low that it must be expressed in milliohms. And it can switch up to hundreds of amperes and up to 1,000 volts.

While the power MOSFET is primarily used for switching applications, it can also be used in a linear mode. This means it can be used to make a very inexpensive power potentiometer and even an audio amplifier.

Having all these capabilities in a moderately priced semiconductor device was once only a dream. Now power MOSFETs are commonly used in power supplies, radio transmitters, amplifiers and virtually all other kinds of power circuits. They are also used to switch current to motors and lamps in appliances, automobiles and aircraft.

The Parallel Connection

Years ago, engineers used to connect two or more MOS transistors in parallel to increase the current they could switch. Today, CMOS gates are often connected in parallel to increase their drive capability.

The parallel connection trick is the key to the MOSFET's remarkable ability to switch hundreds of watts and more of power. Rather than being a single transistor, a power MOSFET is actually an integrated circuit formed from an array of hundreds and sometimes even thousands of individual MOSFET transistors, all of which are connected in parallel.

The density of transistors within the array that forms a power MOSFET can approach a million transistors per square inch (6.45 square centimeters)! The photo of the larger-than-life power MOSFET mask shown in Fig. 1 places this density in perspective. The mask in this photo was used to make a MOSFET that measured only about 0.25 inch (6.35 mm) on a side. The large number of parallel-connected octagonal cells in the array provided an on-resistance of only 80 milliohms.

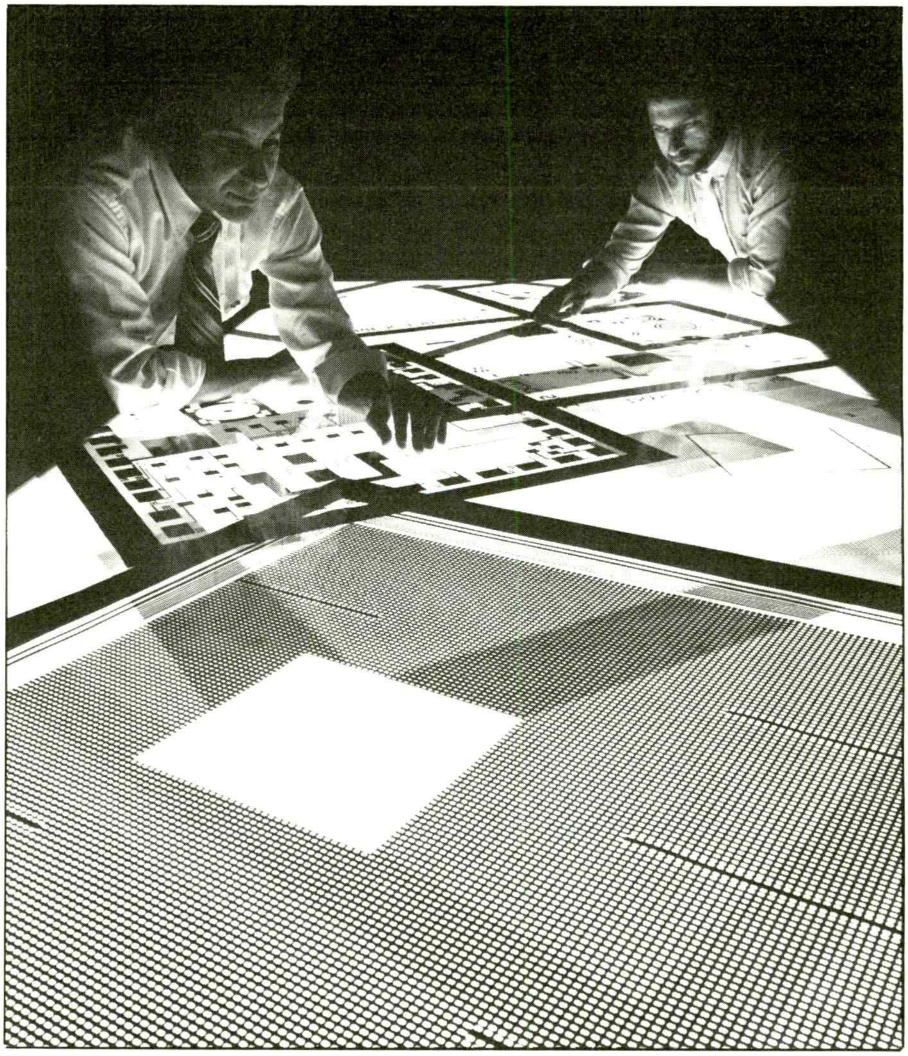


Fig. 1. Mask pattern for a power MOSFET made from thousands of parallel-connected transistors. (Courtesy IXYS Corporation.)

As practical experience reveals and Ohm's law explains, connecting two or more resistors in parallel with each other lowers the resistance of the resulting network. The same applies to the parallel-connected MOSFETs of a power MOSFET. The resistance of three or more resistors (or MOSFETS) connected in parallel is the reciprocal of the sum of the reciprocals of each resistance. In other words, $R_t = 1/[(1/R1) + (1/R2) + (1/R3) \ldots + (1/Rn)]$

Let's plug some numbers into the formula to see what happens. Assume you have a pile of 1,000-ohm resistors. Connect two of them in parallel, and their combined resistance falls to 500 ohms. Connect three resistors in parallel, and the resistance falls to 333.33 ohms. Ten resistors connected in parallel gives a resistance of 100 ohms and 20 a resistance of 50 ohms. Connect 100 1,000-ohm resistors in parallel, and the resistance will fall to 10 ohms; a thousand will yield a resistance of only 0.1 ohm; and so on.

As you can see, a high initial resistance can quickly be reduced to an almost insignificant value if enough resistors are available. That, of course, is the end result of integrating and connecting in parallel hundreds to thousands of MOS transistors on the same chip. If the resistance of a single transistor within the array is, say, 15 ohms, then the resistance of 100 transistors in parallel will be only 0.15 ohm.

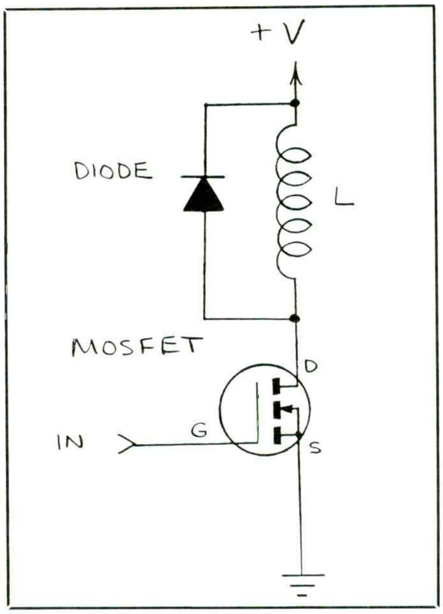


Fig. 2. Protecting a MOSFET with a diode clamp.

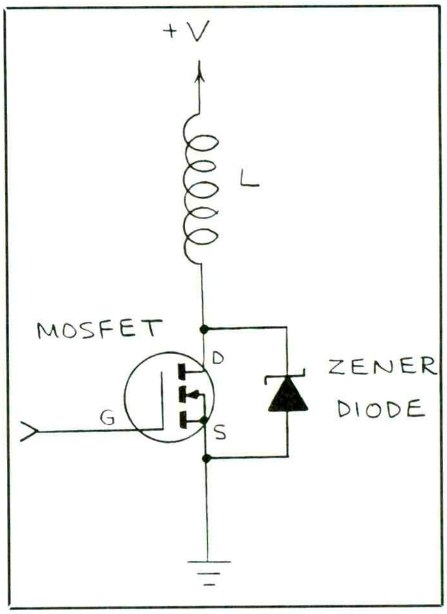


Fig. 3. Protecting a MOSFET with a zener diode clamp.

Power-MOSFET Problem

A power MOSFET, even one that easily switches up to hundreds of watts or more of power, can be almost instantly zapped simply by touching its leads with a finger. The culprit is static electricity that can produce a voltage spike that exceeds the device's ratings. Thus, the same handling precautions used when working with CMOS devices must be used to greatly reduce the static-electricity problem.

Always leave a power MOSFET in an anti-static package or keep it inserted in conductive foam plastic until you are ready to use it. Handle the device by grasping its package instead of its leads. Be sure to ground your body before touching the MOSFET. This will remove any static charge that may have accumulated on your skin.

Power MOSFETs can also be damaged by voltage spikes from soldering irons and test equipment. Therefore, be sure to use a grounded or battery-powered soldering iron and properly grounded test equipment. Even the circuit in which a power MOSFET is used can inadvertently damage the device. For example, a voltage spike across the drain-source channel of a power MOSFET can turn the transistor on when it should be off.

The turn-on problem can occur when a power MOSFET is used to switch an inductive load, such as a solenoid or dc motor. When an inductive load is switched off, current stored in the coil collapses and generates a large voltage spike. This spike can easily be great enough in magnitude to exceed the power MOSFET's breakdown voltage.

Newer so-called "third-generation" power MOSFETs include an internal backwards-connected diode that absorbs transients and protects the device from damage. If possible, you should try to use one of these ruggedized devices in a circuit that might be exposed to switching transients. Units that do not include this provision should be protected from transients with an external diode or special snubber network.

Long before the company they worked for began manufacturing ruggedized third-generation power MOSFETs, several engineers at International Rectifier Corp. addressed the transient problem in great detail in an excellent article for *EDN* magazine ("Apply a Few Design Rules to Avoid Destroying Power FETs" by Steve Clemente, Brian Pelly and Rutton Ruttonsha, May 13, 1981). If you are a serious power-MOSFET user, you might want to look up this article at a good technical library.

Figure 2 shows the traditional way to absorb inductive voltage spikes—a backward-connected diode placed across the inductor that causes the problem. The diode should switch on fast enough to absorb the inductive spike. A Schottky diode will switch faster than an ordinary rectifier diode. In some cases, however, a diode may not provide total protection to very fast rising voltage spikes because of the inductance that is contributed by the leads of the diode.

An option suggested by the International Rectifier engineers mentioned above is connection of a zener diode directly across the MOSFET's drain and source leads, as shown in Fig. 3. As in the previous circuit, the inductance of the zener diode's leads comes into play because of the very fast rise time of the discharge voltage spike. On the positive side, a zener diode responds much more rapidly than a standard rectifier diode.

Yet another possibility suggested by the International Rectifier engineers is shown in Fig. 4. Here a diode-connected snubber network is placed across the MOSFET's drain and source. The values of *R* and *C* should be selected so that the voltage on the capacitor remains nearly constant over a switching cycle.

A final possibility is shown in Fig. 5. Here, a backwards-connected diode across the inductive load is combined with a resistor-capacitor snubber. Unlike the snubber in the Fig. 4 circuit, this snubber is not diode connected. Therefore, it absorbs excessive voltage spikes during the entire switching cycle, not just when the MOSFET is switched off. A drawback in some applications, however, is that this snubber arrangement slows the MOSFET's switching time.

The resistor-capacitor snubber in the Fig. 5 circuit can be connected directly across the inductive load in place of the diode. A good technical article that discussed this arrangement was published in *Computer Design* ("VMOS Transistors Interface ICs to High Power Loads" by Bill Roehr, November 1981).

Some Applications

CMOS logic can directly drive the gate of a power MOSFET, so long as the power-supply potential exceeds around 10 volts. Driving power MOSFETs from a TTL logic level is trickier because of TTL's lower output voltage. Usually a pull-up resistor of around 10,000 ohms is connected between the gate and positive supply rail when a power MOSFET is driven by a TTL logic level. With the preceding in mind, let us discuss a few applications for the versatile power MOSFET.

• *Variable Resistor.* Most applications for the power MOSFET use the device as an on-off switch. However, the power MOSFET is also well suited for use as a high-power variable resistor.

Figure 6 shows a simple circuit that permits current flow through a LED to be controlled by means of a power MOSFET. The resistance of the drain-source channel is determined by the voltage at the MOSFET's gate. This voltage is determined by the voltage divider formed by *R1*, *R2* and *R3*.

When you look at Fig. 6, you might wonder why the MOSFET is even needed. Why not alter the current through the LED by placing it in series with a potentiometer? Of course, this can be done, and it will work fine in the case of a low-power device, such as a LED. However, you will need an expensive high-power potentiometer if the LED is replaced by a high-current load, such as an incandescent lamp or dc motor. The advantage of the MOSFET circuit in Fig. 6 is that it permits an inexpensive potentiometer to control the current through a device that draws high power.

You can use the Fig. 6 circuit to control the brightness of an incandescent lamp or speed of a small dc motor. For example, I tried using the circuit to control the speed of a couple of small dc motors connected in place of the LED. One motor would not function when connected into the circuit. The other worked well, and its rotation could be easily slowed down to a few rotations per second by carefully adjusting *R2*. There's a better way of controlling the speed of a motor with a power MOSFET and is described next.

• *Motor Speed Controller.* The circuit shown in Fig. 6 controls the speed of a motor by altering the available current. This circuit alters the speed of a motor by applying a stream of fixed-amplitude current pulses to the motor at a variable rate. When the pulses are applied at a slow rate, the motor's shaft turns slowly. Rotation rate increases as pulse rate is increased. Since the current during each pulse is constant, this method provides more power to the motor, even when the rotation rate is very low.

The 555 timer in Fig. 7 is connected as a pulse generator whose repetition rate is controlled by *R1* and *C1*. You can experiment with the resistance of *R2* to alter the duration of the individual pulses applied to the motor. You can also increase the value of *C1* to 50 microfarads or more to cause the motor to rotate in a series of brief spurts.

An interesting way to demonstrate the power control provided by a MOSFET is to replace *R1* in Fig. 7 with a cadmium-sulfide cell photoresistor. When the cell is dark, the motor will turn rapidly. When light strikes the cell, the motor will slow appreciably. By carefully controlling the amount of light striking the cell, you can slow the rotation of the motor to a few revolutions per second.

The Fig. 7 circuit can also control the brightness of an incandescent lamp. If

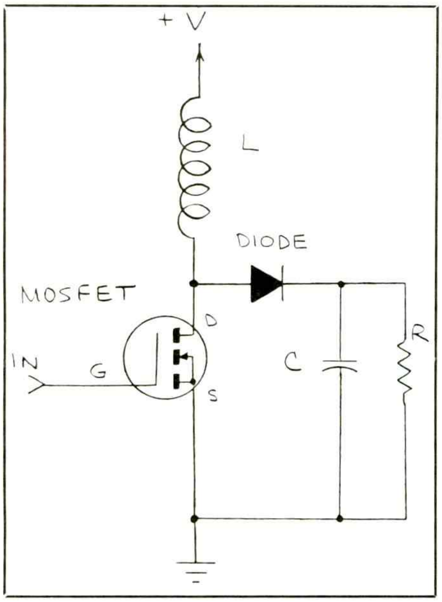


Fig. 4. Protecting a MOSFET with a snubber network.

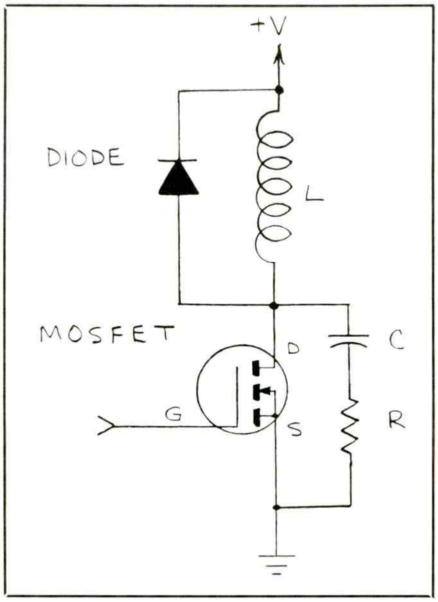


Fig. 5. Modified version of the snubber arrangement in Fig. 4.

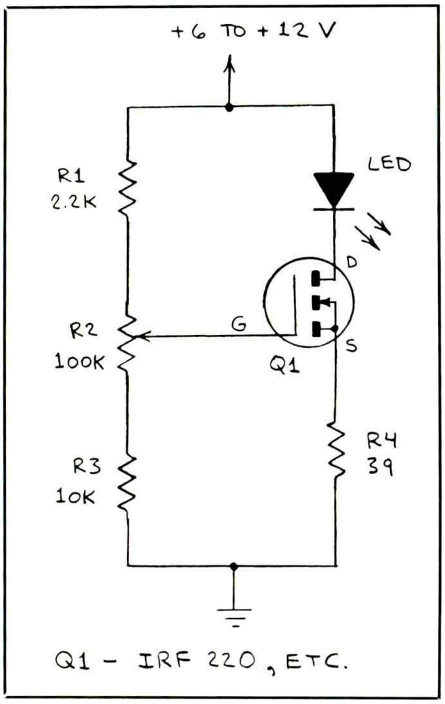


Fig. 6. Power MOSFET variable resistor.

you use it in this manner, just be sure the average current through the lamp does not exceed the lamp's current rating.

• *Speaker Amplifier.* A very simple yet powerful speaker amplifier circuit whose only active component is a power MOSFET is shown in Fig. 8. This circuit is very flexible and, as will be seen shortly, can also form the basis of a very simple light-beam transmitter.

In operation, the signal from a small battery-powered radio or amplifier is coupled into the amplifier by means of transformer *T1*. I used a Radio Shack Cat. No. 273-1380 output transformer in the prototype circuit, but any other with an 8-ohm primary and a 1,000- to 2,500-ohm secondary should work.

Potentiometer *R1* functions as a volume control. Capacitor *C1* provides ac coupling for the incoming signal. The series network made up of *R2*, *R3* and *R4* is a voltage divider that provides enough voltage to the gate of *Q1* to provide a conducting path through the transistor's drain-source channel. The input signal then modulates the current through the channel. The result is a fluctuating current through the voicecoil of the speaker. It is the variations in this current that cause the speaker to generate sound. Resistor *R5* limits the current through the speaker to a safe value.

I tested the prototype circuit with a small transistor radio. When the circuit was powered by 6 volts, the power supply current drain was around 25 milliamperes when *R3* was adjusted for the best sound quality. When the supply voltage was increased to 10 volts, it was necessary to readjust *R3* slightly for best results. Current consumption was then 50 milliamperes, and volume was higher.

If the input signal is too high, the amplified sound will be distorted, perhaps severely. The simplest way to solve this problem is to reduce the level of the incoming signal at its source. Alternatively, you can divert some of the incoming signal to ground with volume control *R1*.

You might want to try modifying this circuit. For example, you can experiment with the value of *R5* to alter the speaker volume. And you can change the value of *C2* to change the circuit's frequency response. If you attempt to modify the circuit for very loud sound output, be sure to mount *Q1* on a heat sink to dissipate excess heat. You should also use a power resistor for *R5*.

• *Light-Wave Transmitter.* The circuit shown in Fig. 8 can be used to form a very simple yet powerful light-wave voice transmitter. All that is necessary is to replace the speaker with a suitable light-emitting diode.

Many kinds of visible red and near-infrared LEDs will work in the Fig. 8 circuit. Recently, I received from Hewlett-Packard a sample of its new HLMP-8150 ultra-high-brightness red LED. Hewlett-Packard's claim that this is the world's brightest LED is no exaggeration. The diode produces a full 25 candelas. This performance is achieved by encapsulating the LED die in a thimble-size clear epoxy package to provide a tightly collimated, brilliant red beam.

Before connecting a LED in place of the speaker, connect a multimeter in series with the positive supply and the LED's anode. Set the meter to its current-measuring function. When you apply both power and an input signal, be sure the metered current does not exceed the LED's maximum rated current.

Most epoxy-encapsulated LEDs are rated for a maximum current of 50 milliamperes. Some near-infrared LEDs, such as the very high-power units made by Opto Diode Corp., can accept a forward current of up to 500 milliamperes when appropriately heat-sinked.

The HP HLMP-8150 LED produces a red spot the size of a dinner plate at a range of several meters. A simple light-wave receiver made by connecting a solar cell or phototransistor to an operational amplifier and a speaker amplifier easily receives the signal at this distance. A large plastic Fresnel lens will collect enough light from the LED beam to permit effective transmission over a considerable distance. You can increase the range even

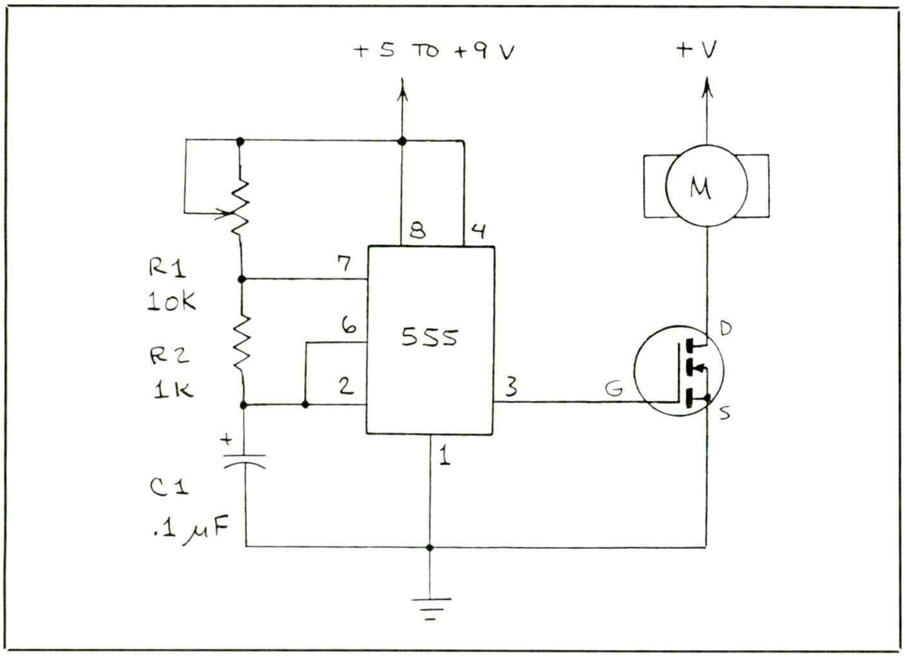


Fig. 7. Power MOSFET motor speed controller.

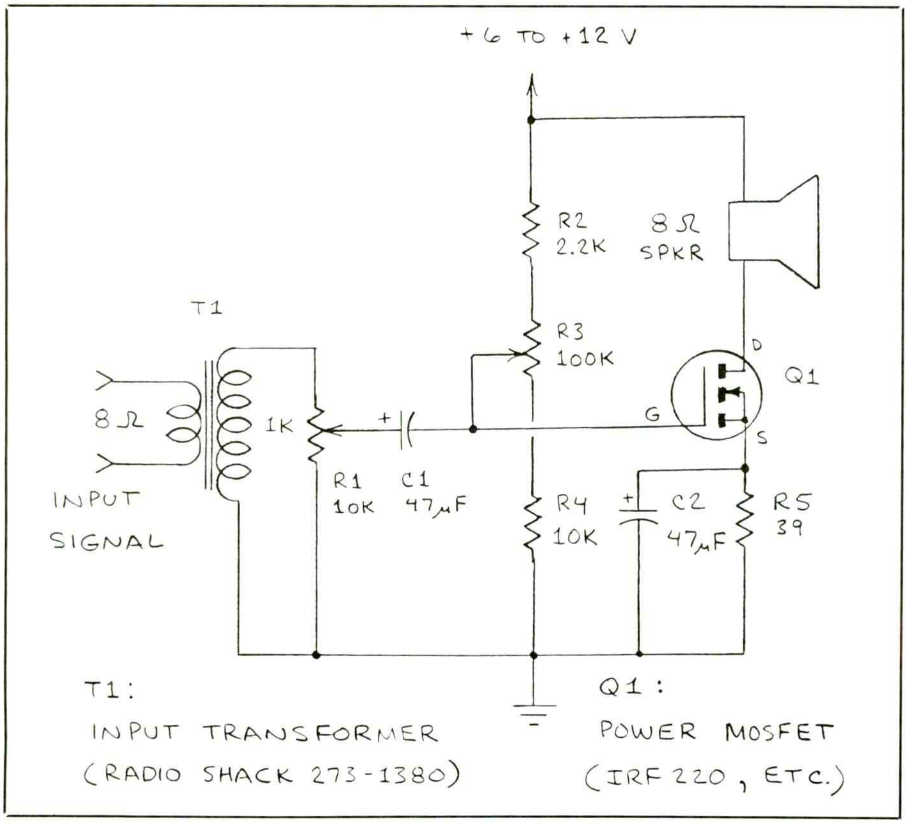


Fig. 8. Power MOSFET speaker amplifier.

more by collimating the beam from the LED with a similar lens.

Some plastic optical fibers are well suited for transmitting the light emitted by red LEDs (but not necessarily the near-infrared radiaton emitted by other LEDs). Many different plastic LED terminations and couplers are available from various manufacturers and electronics parts dealers.

If you are in a hurry or if your budget is limited, you can drill a hole into a plastic LED and insert a plastic fiber and cement it in place. I have used this method many times with excellent results. Be sure the end of the plastic fiber is smooth and clear. Polish it with very fine sandpaper if it is not. Also, try to bore the hole as close as possible to the LED die but stop before penetrating the tiny wire that makes contact with the upper side of the die! Before drilling, be sure to mount the LED firmly in a vise. While drilling, wear eye protection and watch your fingers.

If you are not familiar with light-wave communications circuits and techniques, I have covered the subject in previous installments of this column and in many books. See, for example, *Engineer's Mini-Notebook: Communications Projects* (Radio Shack, 1987) for some very basic tips and circuits.

Going Further

Electronics trade magazines have published many excellent articles on power MOSFETs over the years. In addition to the two cited above, you might want to see "Avoiding dV/dt Turn-On in Power MOSFETS" (Rudy Severns, *Electronic Products*, January 15, 1985) and "Power MOSFETs & IGBTs" (Bill Travis, *EDN*, January 5, 1989). For additional applications circuits, see the August 1986 installment of this column.

If you are not near a library that carries these references, you may want to plan a trip to a nearby engineering college or university. First, call the school's library and ask if the publications you are seeking are on hand. Be sure to ask about the hours the library is open and whether or not copy machines are available. **ME**

A Low-Cost Instrumentation Amplifier, Visible LED Lasers and a Bidirectional FIFO

By Joseph Desposito

This month, we present a new concept in design—a low-cost chopper stabilized instrumentation amplifier. Then we go on to visible light-emitting diode lasers, and end up with a bidirectional FIFO that simplifies inter-processor communication.

Instrumentation Amps

Instrumentation amplifiers are usually found in analog circuitry that must measure voltages and also remove a common mode signal, such as in a low-level amplifying circuit for bridge signals. Although not as versatile as operational amplifiers, there are many areas where a low-cost instrumentation amplifier could be used as a circuit component. In audio circuits, for example, instrumentation amps can remove ground noise when translating signals from one component to another. In power supplies, an instrumentation amp can act as a current monitor, or in combination with resistors and capacitors, can be a frequency-shaping circuit. These amplifiers can also be used just to change signal ground reference levels without introducing error.

By far the most popular instrumentation amplifier is an operational amplifier and four 1-percent resistors. One of today's high-performance op amps, when combined with some 0.1-percent resistors, makes an instrumentation amplifier with little or no trimming needed for reasonable performance, so long as low input resistance and resistor accuracy limitations are tolerable.

Some of the requirements for a good general-purpose instrumentation amplifier are offsets comparable with precision amplifiers, stable well-controlled gain, and high common-mode rejection. An advantage of a real instrumentation amplifier over an op amp with four resistors is high input impedance and low bias current. A dual op-amp instrumentation amplifier configuration is a very economical means of achieving these performance goals with a minimum of components. A precision dual op amp combined with a trimmed resistor network produces a precision instrumentation amplifier at lowest cost and without external components.

With the single-IC approach, all resistors are formed on the same substrate. Therefore, resistor temperature coefficients match within 1ppm/°C, keeping the gain stable and the common-mode rejection ratio constant with changes in temperature. With discrete resistors, unless they are made from the same resistive material batch, there can be differences in the temperature coefficients of the resistors that can cause large errors (on the order of 100 ppm/°C) over a given temperature range.

Currently available single IC instrumentation amplifiers are relatively expensive ($10 or higher in 100-piece quantities) and are generally only used in those precision applications requiring either extremely low drift, very high performance or high input impedance not obtainable with simpler circuits. Designers have tended to design their own op-amp external resistor combinations for instrumentation amplifiers, except where they had no other choice.

Given the high performance and low cost of available op amps, it is not surprising that designers have neglected component level usage of instrumentation amplifier ICs. However, this may be changing because new high-performance instrumentation amplifiers at roughly half the cost of existing types are beginning to appear on the market. Now instrumentation amplifiers can be useful as components, rather than restricting them just to signal-amplifying applications because of price.

Low-cost instrumentation amplifiers will find wider application because of their performance and cost advantages. Although more expensive than the widely used op amp with resistors, new instrumentation amplifiers offer performance advantages. On-chip trimming reduces amplifier offset and increases resistor accuracy without increasing cost, making them an economical substitute even in many of the higher performance applications. Compared to current dedicated instrumentation amplifier devices, the new single IC resistor-amplifier combinations are both more versatile and much lower in cost.

A Chopper-Stabilized Instrumentation Amp

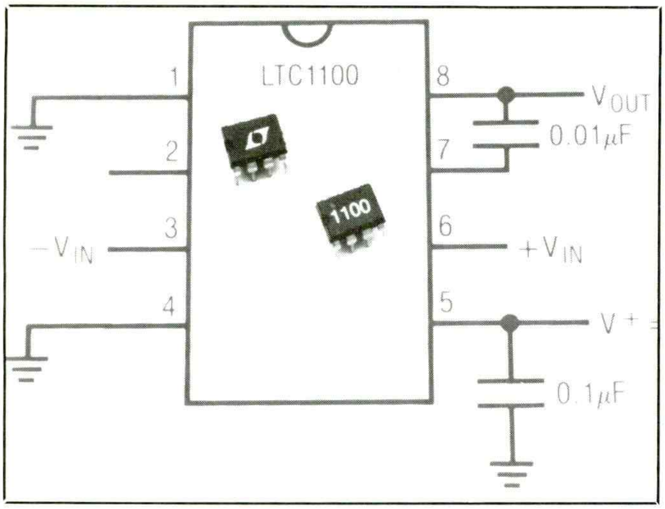
Linear Technology Corp. (1630 McCarthy Blvd., Milpitas, CA 95035) has introduced the LTC1100 instrumentation amplifier, a chopper-stabilized instrumentation amplifier. Chopper stabilization gives the device exceptional dc performance. Maximum input offset is 2 μV; maximum offset drift is only 100 nV/°C; 0.1 Hz to 10 Hz noise is 2 μV, to-peak.

The LTC1100 uses a dual op amp and resistors combination, which allows easy optimization of the instrumentation amplifier for a particular application. It can operate on a single 5V supply or supplies up to $\pm$8V. The new device is available in an 8-pin mini DIP package or a 16-pin small outline surface mount package.

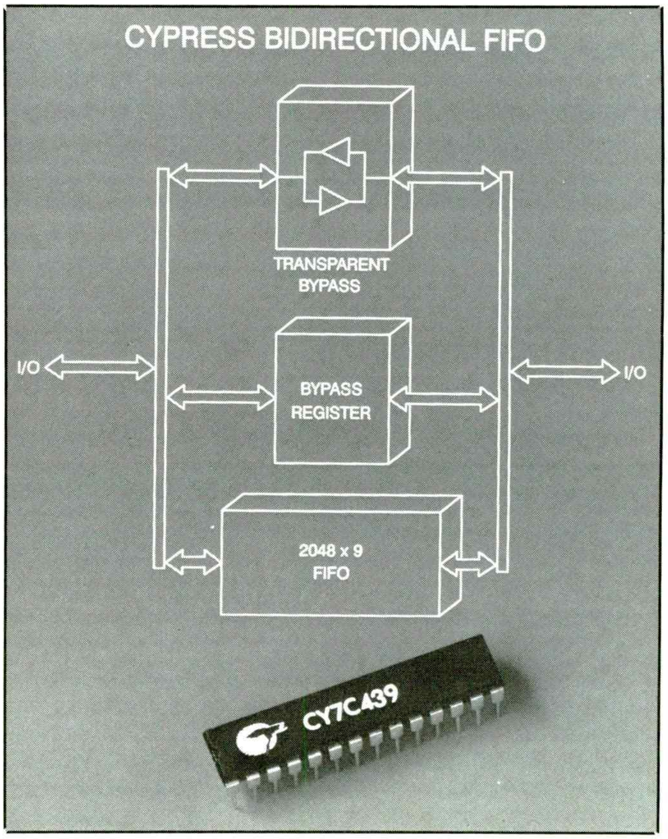
The LTC1100 has a fixed differential gain of 10 or 100 without requiring an external gain-setting resistor. Gain nonlinearity is 8 ppm maximum and gain error is +0.05% maximum. The output swings within 300 mV of its power supply rails with a 10,000-ohm load, and bias current is only 50 pA.

The LTC1100 overcomes many of the problems encountered in designing low-drift instrumentation circuits, including thermocouple effects. Thermocouple effects occur when any two dissimilar metals are in contact and can generate hundreds of microvolts of error.

Thermocouple effects can far exceed the offset of a low-drift instrumentation amplifier. Precision resistors, which by nature have a copper lead contacting a thin film or wire-wound resistive element, can generate errors of between two and hundreds of microvolts per degree, depending on the materials. The leads of most IC packages, when connected to a copper pc board, generate as much as 35 μV/°C in thermocouple errors. Even in well-designed systems, cumulative thermocouple errors make it very difficult to achieve low offsets in discrete chopper-stabilized instrumentation amplifiers



Linear Technology's LTC1100 chopper-stabilized instrumentation amplifier has less that 2 µV of error and less than 2 nV/° C offset drift.



Cypress Semiconductor's CY7C439 bidirectional FIFO comes in a 28-pin narrow package to provide a 2K × 9 FIFO, bypass register and transparent bypass circuitry on-chip.

that use resistors and op amps.

The LTC1100 chopper-stabilized instrumentation amplifier includes the resistors and chopper amplifiers in the same package. For commercial temperature range versions, this amplifier is packaged in a plastic DIP configuration on a copper-lead frame. Using a copper-lead frame and keeping the resistors and the amplifier chips at exactly the same temperature, the package eliminates thermocouple effects within the device. Offsets of under 5 µV for the completed amplifier can be achieved. If care is then taken with pc-board traces and connectors do not to generate additional thermocouple errors, this amplifier is usable for measuring very-low electrical levels.

Typical applications for the LTC1100 include strain-gauge amplifiers, thermocouple amplifiers, differential single-ended converters, and low-level signal amplification.

As mentioned, the LTC1100 instrumentation amplifier is available in 8-pin plastic and ceramic DIP in commercial and military temperature ranges. Pricing in 100-up quantities in mini DIP is $6.45.

Visible Light-Emitting Diode Lasers

Philips Components (Discrete Products Div., 2001 W. Blue Heron Blvd., Riviera Beach, FL 33404) has introduced two visible light-emitting diode lasers, the CQL80/D and CQL90/D, that can be used for such applications as bar-code readers, optical alignment systems, laser printers and target markers.

The CQL80/D visible laser diode is based on a ridge structure and is manufactured using a Metal Organic Vapor Phase Epitaxy (MOVPE) process on a InGaAlP or GaAs substrate. The laser emits a typical peak wavelength of 675 nm red light that is easily visible to the human eye, providing a maximum continuous-wave output of 5 mW. Its lifetime is anticipated at approximately 250,000 hours at 3 mW continuous-wave operation in ambient temperature.

At an optical power output level of 3 mW and an operating temperature of 25°C, the emitted laser light consists of a single-line spectrum, demonstrating the device's typical index-guided behavior.

Mounted in a standard 9.0-mm encapsulation, the device is equipped with a monitor diode that is optically coupled to the rear facet of the laser to control the optical output level. The device is specified for operation within a temperature range of − 10° to + 50° C.

The low-power CQL90/D visible light-emitting collimator pen contains a MOVPE grown GaAlInP laser and a collimator lens. This pen has a power output of 1 mW, emits visible light at a wavelength of 675 nm and a limited wavefront diffraction.

Encapsulated with circular, non-hermetic stainless steel, the pen is precision-manufactured to a diameter of 11 mm with an accuracy between +0 and −11 μm. Applications include bar-code reader and alignment systems.

Philips Components' new visible red laser diodes can be customized to suit customer requirements. Unit pricing for the CQL80/D is $48 in quantities of 5,000. Unit pricing for the CQL90/D is $135, also in quantities of 5,000.

A Bidirectional FIFO

An easy-to-use bidirectional 2K × 9 FIFO in a 28-pin slim DIP can simplify designs and save board space for designers creating new multiple-processor products. Cypress Semiconductor's (3901 N. First St., San Jose, CA 95134) new 30-ns CY7C439 operates in half-duplex, transparent bypass (transceiver) and registered bypass modes. Half-duplex mode provides the normal bidirectional operation that designers customarily implement with either single-direction chips and external control logic, or with pairs of single-direction chips.

Transparent bypass (transceiver) operation allows data to be sent "around" the FIFO in either direction at any time. While it provides a great deal of flexibility to designers, its most common use will be for programming "dumb" peripherals.

Registered bypass mode allows users to send single words in the reverse direction during normal FIFO operation. It enables peripherals to send status information to the control processor quickly, without turning the FIFO around.

Applications for Cypress' CY7C439 include processor-to-processor communications, intelligent disk controllers and communications channel controllers. The device is available in 28-pin, 300-mil plastic and ceramic DIPs and small outline, J-lead (SOJ) packages, and in 28-pin plastic and ceramic leadless chip carrier packages. The per-unit price for quantities of 100 of the 30-ns PDIP CY7C439-30PC is $33.15. **ME**

The Real Windows Finally Arrives

By Ted Needleman

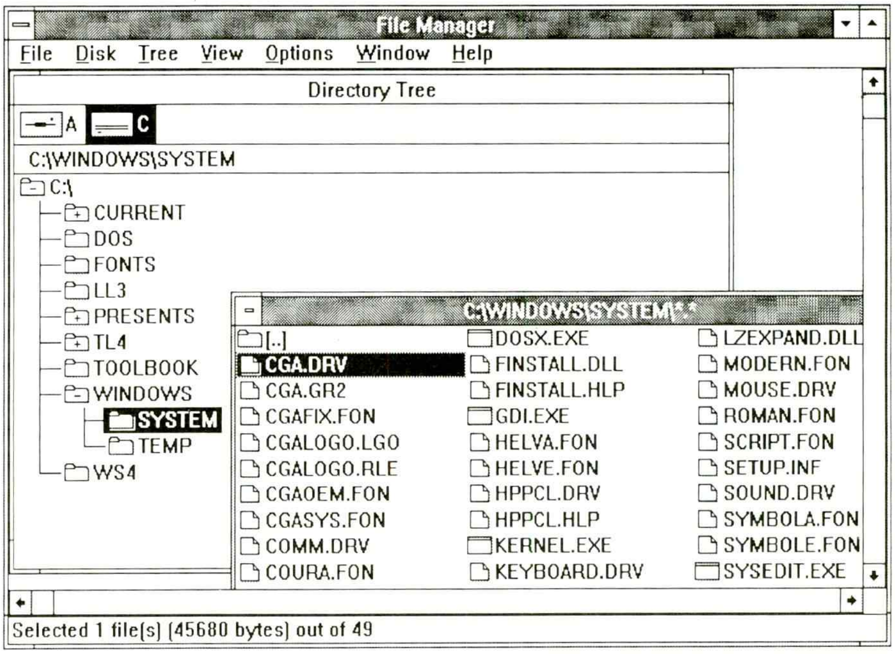
On May 22nd, after months of delays and postponements, Microsoft finally announced the newest version of Windows—Windows 3.0. In a lavish introduction, satellite telecast from New York City, an elaborate multi-media presentation loudly proclaimed "It's Cool!"

"Cool" or not, this newest version of Windows redefines the state-of-the-art in GUI (Graphical User Interfaces) for Intel-processor-based PCs, finally bringing it up to the level of Apple's Macintosh and even exceeding the Mac's GUI in some respects.

With all the hoopla surrounding the introduction of Windows 3.0, it's easy to forget that windows-based interfaces have been around for quite a while. In the late 1970s, when the first CP/M-based microcomputers were becoming popular, Xerox's PARC (Palo Alto Research Center) facility was experimenting with an icon-based windowing environment for its STAR systems. And while Xerox never introduced this environment into commercial computing, the concept was picked up by Apple for its $10,000 Lisa system and its much more successful follow-up, the Macintosh.

While the Lisa was an outright flop, and the Macintosh's popularity started off slowly, several companies working on the IBM-PC side of the street were impressed with the idea of an interface that let you work on a visual level. The first to get a product out the door was the now-defunct VisiCorp. The VisiOn operaing environment was introduced slightly before Microsoft's Windows 1.0 and went abslutely nowhere.

But then, again, neither did Windows 1.0. MS-DOS users were slow to see the benefits of Windows, and its strange amalgamation of a graphical approach (icons and pull-down menus) mixed with text-based commands did little to convince potential users that it was as easy to use as the Mac's point-click-drag operating system. It wouldn't be until almosty three years later, in 1986, that Windows would start to have some impact.



Printout of Windows 3.0's File Manager screen.

There are several factors that contributed to the slow acceptance of MS-Windows, one of which also influenced its eventual popularity. Windows Version 2 looked and worked better than the first version, but it was still a mixed bag. You selected a program to run or an operation to be performed with the mouse, but somewhere along the way you would have to return your hands to the keyboard for some typing. Version 2 was just not perceived to be as easy to use as a Mac.

Even with this limitation, vendors started to write applications that would take advantage of Windows' features. Aldus ported its popular PageMaker desktop-publishing package over to Windows, and many other vendors soon joined the ranks of Windows supporters. By this time, IBM's AT and other 80286-based PCs had become popular, which was the second factor in the eventual acceptance of Windows.

Because Windows ran on top of MS-DOS, it added substantial processing overhead to the PC, even before any application was run. And while it was *possible* to run Windows on an 8088-based machine, everything ran so slowly that an 8088-based Windows system was an annoyance, rather than a benefit.

Windows 2, even on an AT, could be frustratingly slow. It wasn't until the acceptance of "turbo" ATs, running at 12 MHz (twice the clock speed of IBM's original AT), that Windows applications began to show acceptable performance. Even with this roadblock, an increasing number of vendors have supported their applications in this environment. There are two major reasons for this. Windows is visually attractive, and it provides one of the simplest means to write a hardware-independent, graphically-oriented application.

Operating Environment vs. Operating System

In order to understand Windows' attraction to vendors, you first have to understand what Windows actually is. It is not an operating system, nor is it a DOS shell (though it does have many features of a shell). An operating system, such as MS-DOS, is a software system composed of several parts, each of which has a different function.

The major part of DOS is its BIOS, or Basic Input/Output System. The operating system's BIOS mediates between the processor, applications software and all of the computer's peripherals, including keyboard, video adapter, RAM and disk memory and serial and parallel I/O ports.

Some of the "direction" instructions of the operating system are contained in ROM (read-only memory) chips. These are the BIOS ROMs located on your PC's motherboard. More instructions are contained in two hidden files that are stored on the boot track of your disk drive (either hard disk or floppy disks that have been made into "system" disks when you formatted them).

When you boot up your system, additional hidden parts of the BIOS are read into your PCs RAM memory, along with the second part of the operating system needed to run your PC, a visible file called COMMAND.COM.

COMMAND.COM is DOS's command processor. It interprets those instructions that you type at the keyboard and tries to decide what it is that you're asking the PC to do. The first thing it asks is whether the keyboard input is requesting a function that is an integral part of DOS, such as DIRectory, MODE, REName, COPY or the like, and is, therefore, already loaded.

If the input isn't a function that is already loaded in memory, COMMAND.COM assumes that it is a request to run a program or utility and attempts to find it in the current disk directory or through whatever subdirectories have been specified by a PATH command. If it does find it, it loads and runs the requested program; if not, it returns a "Bad Command or File Not Found" message on the screen.

An operating environment, such as Windows, is actually an extension to DOS. It sits on top of the operating system and takes over many of the supervisory functions that DOS performs. Instead of DOS presenting the familiar C prompt, it tells Windows that it is ready to accept keyboard input. In the meantime, Windows has presented a completely different set of screens to the user based on little illustrations called icons. When you, as a user, click on an icon, Windows figures out what operation you want to perform and conveys this information to DOS.

Windows also acts like a "middleman" to your software applications. For example, when PageMaker (or any other application running under Windows) wants to print, Windows handles the software's request, calling up routines called drivers that tailor the output to the particular print device you have specified. If you're using a laser printer, Windows will make sure that the correct soft-fonts have been downloaded and that whatever Escape Codes the printer needs have been placed into the print stream.

This makes Windows a very attractive choice for developers of applications. They write the applications to one set of operating conditions—Windows—without having to take into consideration all the other variables of hardware, such as multiple choices of printers and video displays. The same application code can run on a wide range of systems.

Windows 3.0

Because Windows buffers the application against the hardware and memory-management details, the installation of Windows onto your system has always been a bit involved (but never very difficult). With Windows 3.0, as with previous versions, installation is an automatic process that consists of answering questions about your system's configuration and inserting numerous disks as requested. Windows can tell pretty accurately what your system contains in the way of memory, keyboard, video adapter and mouse. But it always gives you the chance to correct it if you made a wrong choice.

One area where Windows doesn't even try to guess is the type (or types) of printer(s) you will be using and where they're attached. You will have to specify these during the installation process (or at a later time) so that Windows can load the correct printer drivers.

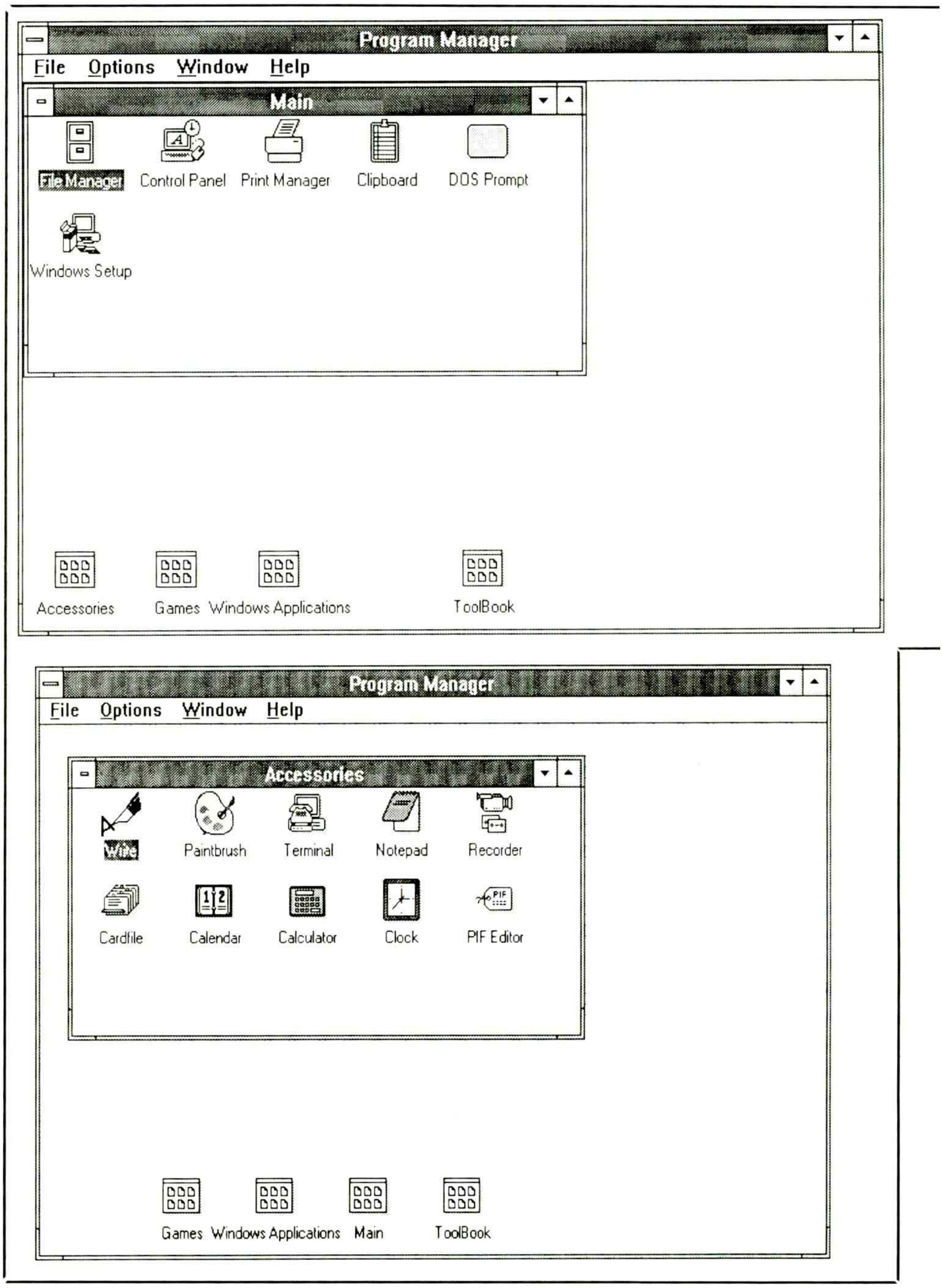
Windows 3.0 has a considerably improved ability to modify the setup at a later date. Earlier versions allowed you to add or delete printer drivers as your needs changed. But if your other equipment changed, if you upgraded to VGA from EGA after Windows was installed, you would have to reinstall Windows from scratch. This was more of a pain than it might first appear because each application that is installed into Windows puts information Windows needs into a special Windows file named WIN.INI. Likewise, any additional fonts that were installed also placed information into this file so that Windows would know that they are available and where they were located on your hard disk.

Reinstalling Windows replaced this WIN.INI file with the very basic version that was built during the installation process. Savvy Windows users always renamed this file before reinstalling Windows and cut-and-pasted the relevant parts of the new WIN.INI created by the configuration change into the old information file. Then you would delete the new WIN.INI file and rename the old file (containing all of your applications and font information) back to WIN.INI.

Windows 3.0 changes all of that. If your PC's configuration changes, the new version has a setup menu that lets you change the video or mouse that you originally specified. It asks for the relevant Windows disks and updates the WIN.INI file with the new configuration without disturbing anything else.

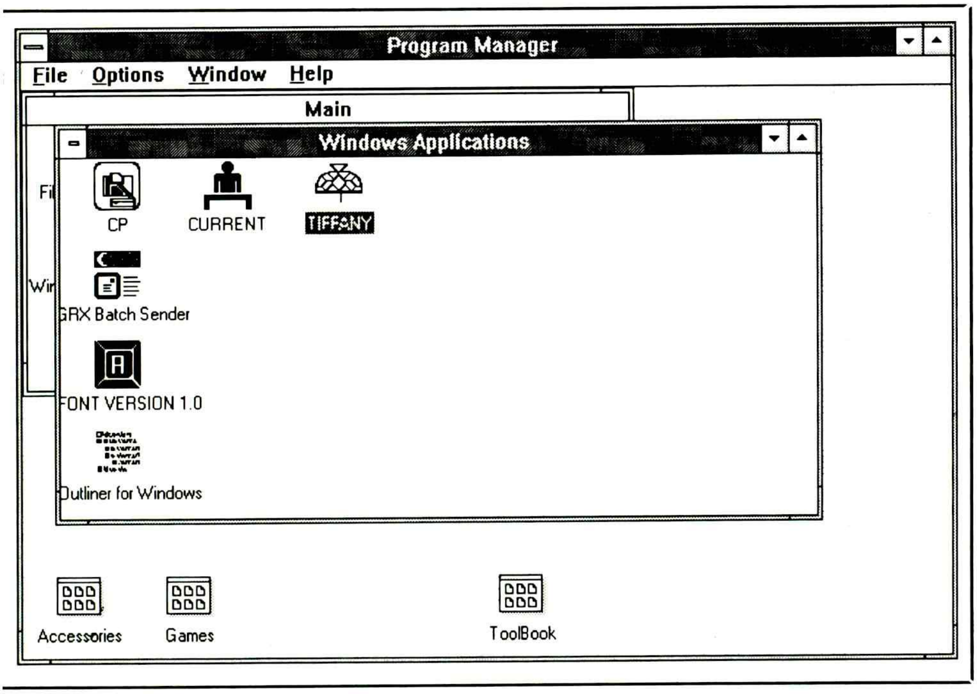
Unfortunately, if you're using a "nonstandard" video display device, such as a dual-page desktop-publishing monitor or a mouse that can't use one of the standard drivers included with Windows (Microsoft, Mouse Systems or Logitek), you'll still have to rerun SETUP.

Once Windows 3.0 has been installed, there are quite a number of differences you'll notice in running and using it.



First off, the new Windows has three modes of operation, depending upon what type of processor and memory configuration the system you're running it on has. These modes are called "standard," "real" and 386 enhanced." For 80286-based PCs with less than 1MB of RAM you'll need to run Windows 3.0 in "real" mode. In this mode, Windows uses only 640K of RAM, and it's the mode that you'll need to start Windows in to use most older Windows-based applications that haven't been certified for compatibility with Version 3.0. Even then they may or may not work correctly.

I've tried a few Windows applications



Windows 3.0's (A) Main, (B) Accessories and (C) Windows Applications screens.

(not upgraded for 3.0 compatibility), and most worked fine. Word for Windows, Excel and IBM's Current personal-information manager seemed to run fine. Computer Associates' Cricket Presents didn't. It came up, but without the toolbox necessary to construct or edit applications.

Next is "standard" mode, which works like "real" mode but allows access to extended memory and lets you switch to non-Windows applications. To run in "standard" mode, you must have an 80286 PC with 1MB or more of RAM.

Finally, "386 enhanced" mode, which requires an 80386 with at least 2MB of RAM, is the environment for which Windows 3.0 is really designed. In this mode, applications written for 3.0 can ignore the 640K DOS RAM limitation and run in virtual memory. Virtual memory is a technique developed for minis and mainframes that allows an application to use more RAM memory than is physically available. Portions of the program are swapped to and from disk as needed. This mode also lets you perform actual multitasking. You can have several applications actually running at the same time in different Windows.

Not only does Windows 3.0 look different, with screen "buttons" that actually appear to "press" when you click on them, but it also contains some significant enhancements in the utilities it provides.

Program Manager is new to Windows 3.0 and is usually the first window you'll see when you start Windows 3.0. Program Manager is one of a group of icons that contain utilities and applications. Others that you'll see include Accessories, Games, Windows Applications (if you install any) and Non-Windows Applications (again, if you install any).

Within the main group of Program Manager utilities are the File Manager, Control Panel, Print Manager, Clipboard, Windows Setup Utility and the DOS prompt (which lets you exit Windows to run a DOS application). Program Manager can also be used to run a non-Windows application by just pulling down a menu and typing in the application you wish to use.

File Manager provides a visual representation of your directories' structure and contents. It looks a lot like the shell provided with MS-DOS Version 4.0, but unlike DOS, you can click and drag a file (or a whole set of files) from one director to another. This is one of the features I've liked most about the Macintosh, and it's a pleasure to finally find it in Windows. File Manager also lets you create and change directories. In fact, it replaces the MS-DOS Executive found in earlier versions of Windows.

The Control Panel and Clipboard are similar to Windows 2.0 versions (though the features in each have been extended and enhanced) and let you choose output devices and cut-and-paste between respective applications.

Print Manager replaces Version 2.0's Spooler. It's very similar but adds a Medium Priority setting between high and low. This priority setting determines how much of the PC's time will be spent on the application and how much processor time will be delegated to spooled print tasks. Print Manager also allows you to set the level of urgency for display of messages from the spooler and has network-level print spooling.

In addition to the utilities contained within Program Manager, Windows 3.0 also contains a set of "accessories." These include Windows Write, a word processor similar to that included with Microsoft Works; Paintbrush, a full-color paint program; a terminal-emulation program; a calculator; a calendar; a clock; a notepad; a cardfile; and a recorder. The recorder is particularly useful, allowing you to construct a macro simply by turning it on and recording a sequence of keystrokes. Additionally, there is a Games group that has two video games: Solitaire and Reverse.

Windows 3.0 also comes with a run-time version of Asymetrix' ToolBox and a DayBook application programmed with ToolBox ready to use. ToolBox is an object-orinted application development system with features similar to Apple's

PC CAPERS . . .

HyperCard for the Macintosh, but with additional features that aren't particularly obvious from the DynaBook application included with Windows. DynaBook, however, is a useful feature for keeping track of appointments and things to do.

The Bottom Line

Microsoft is really pushing Windows 3.0. The company has budgeted $10-million for its introduction, the largest product-introduction budget ever for a microcomputer software product. Microsoft intends to bring a Windows road show to 20 cities nationwide and send out more than 400,000 demo disks that show what Windows 3.0 can do. In addition, the company has made it easy and inexpensive to upgrade to 3.0. You can upgrade any registered prior version of Windows, including the run-time version many vendors included with their applications, for only $50. Bought outright, the list price of Windows 3.0 is $149.

The rub, however, is that while it costs only $50 to upgrade (and almost everyone has at least a run-time version of Windows laying around somewhere), to make full use of Windows 3.0's capabilities takes a fairly hefty PC. In addition, the upgrade fees for many of the Windows application software you may already be using are probably not quite this reasonable. And if you have to upgrade three or more applications packages at a couple of hundred dollars each, the true cost of moving to Windows 3.0 can be considerably more than Microsoft's $50 for the Windows 3.0 upgrade.

If you make extensive use of a Windows application like PageMaker, Excel, Arts & Letters or others, you'll probably want to make the switch. Windows 3.0 is a lot closer to what a GUI should be than its predecessor, it has some nice accessories, and it's easier to change if this should be needed.

If you don't use a Windows application much of the time, there isn't much reason to get a copy of Windows 3.0 to run DOS (Version 3.0 or later is required) applications. The processing overhead slows down your PC considerably, and you'll see many of its advantages only with applications that have been written to make use of them.

Microsoft predicts that it will ship a million copies of Windows 3.0 over the next year. While I have little reason to doubt this prediction, I do doubt whether this means that there will be a million users of Windows 3.0.

If you're not already running Windows, I'd advise you to wait. When you buy a copy of an application that requires Windows 3.0, chances are good that the software will come with it (Microsoft is no longer producing a run-time version). Furthermore, some computer makers say they'll be installing Windows 3.0 on 386 computers they sell; so check this out if you're planning to buy a 386 computer soon. Until then, you can satisfy your curiosity with a trip to a local retail computer store. ME

Manufacturer Address

Windows 3.9
Microsoft Corp.
One Microsoft Way
Redmond, WA 98052
Tel.: 206-882-8080

LETTERS . . . *(from page 7)*

of values. For example, Vector([x, sin x], x, −2, 2, 0.1) produces a table in which the first column ranges from −2 through 2 in steps of 0.1 and the second column has the corresponding values of sin x.

You can define functions in terms of other functions and operations. The files for exact and series solutions of differential equations provide sophisticated examples of such programming.

David R. Stoutemyer
Chairman of the Board
Software Warehouse

• Just read the articles on Math Software and the HP-48SX calculator in the May issue. It is very good to have articles like these that show the reader a lot more than simply a review of the advertising materials put out by the product manufacturers. Now I would like to see *Modern Electronics* publish an evaluation of the Sharp PC-E500 pocket unit along the same lines, giving a solid and objective review of its strong and weak points.

I had not realized that *Modern Electronics* is a CQ [Communications Inc.] publication. Congratulations on a very good job. ME is probably one of the very best and positive means to extend a much-needed helping hand to those people interested in electronic projects.

Ralph Marler, KC1JG
Portsmouth, NH

Numbers Mix-Up

• In the "Modern Electronics News" section in the August issue, the telephone number to use to contact Tom Selgas at Cyrix Corp. is 214-234-8388. The last two digits were incorrectly noted as zeros.

Bernard Shaw
Odessa, NY

Parts Availability

• I imagine that most of your readers like to build the projects featured in *Modern Electronics*. However, in order to purchase most electronic parts—such as transistors, ICs, etc.—one must be prepared to buy in 100-piece quantities. Can you tell me of any electronics retail outlet that sells in small quantity? Local retail stores usually have a very limited choice.

A.J. Hollenbeck
Harrisville, NH

The great majority of the components needed to build any of the projects featured in Modern Electronics *are available from a host of mail-order houses that advertise in electronics magazines such as* Modern Electronics, *unlike the OEM electronics distributors that sell largely in high-volume quantities. Occasionally, one or more items in a Parts List may not be available from any of these sources and will have to be purchased from the author.—Ed.*

BOOKS

Using Quattro Pro. *By Stephen Cobb. (Published by Osborne/McGraw-Hill. Soft cover. 845 pages. $22.95).*

Here is a cleanly written book about using Borland's impressive "Quattro Pro" integrated electronic spreadsheet/database/graph software (see the review in this issue's "Software Focus" column).

After an introduction about the background of this type of software and a brief overview of the software's workings, the author moves deftly into practical ways to work with the powerful software. He covers spreadsheets, databases, formulas, building, viewing, printing, graphing, macros and the like.

This fine guide moves through each focused section by starting with fundamental applications, segueing to advanced techniques. The book is well illustrated with video screen black-and-white shots that support the practical steps described in the text. An appendix includes support and printer tables.

Overall, this is an information-packed book that serves well for hands-on guidance in learning the basics and more sophisticated uses of Quattro Pro. Although not enhanced with color printing or attractive illustrations, it is packed with meaty facts for beginner and knowledgeable user alike.

NEW LITERATURE

Components/Products Catalog. A comprehensive 192-page catalog from Mouser Electronics lists more than 22,000 components from more than 80 manufacturers and products for the electronics field. Products new to this edition are listed at the beginning. Thereafter, products are listed according to category, starting with semiconductors, progressing through lamps/LEDs, connectors and cables, resistors, capacitors, etc., and finishing with equipment/tools/meters, propotyping kits and books, and surface-mount equipment. For a free copy of Catalog No. 564, write to: Mouser Electronics, 2401 Hwy. 287 North, Dept. ME, Mansfield, TX 76063.

SBC and Controllers Catalog. Micromint's 1990 catalog focuses on compact computer/controllers and introduces a number of new hardware and software tools and solutions for engineers and system designers. This full-color, 32-page pocket-size catalog fully describes (including technical specifications and prices) a line of miniature single-board computers, multi-function expansion boards, computer/controllers, interface boards, video digitizers and software, accessories and ROMs. For a free copy, write to: Micromint Inc., 4 Park St., Vernon, CT 06066.

Catalog Supplement. A full-color supplement to the Contact East General Catalog is now available. It lists and describes a wide range of brand-name products for testing, repairing and assembling electronic equipment. Product areas in this supplement include: linear power supplies, analog/digital oscilloscopes, inspection devices, soldering/desoldering equipment, temperature/humidity chart recorders, static-protection devices, test equipment, adhesives, precision hand tools and Contact East's exclusive line of tool kits. For a free copy, write to: Contact East, 335 Willow St., Dept. ME, N. Andover, MA 01845.

Test/Design Equipment Catalog. A new 36-page catalog that covers high-performance and affordably priced electronic testing and prototyping equipment is available from Global Specialties. It features a full line of breadboarding products, logic test equipment, power supplies, frequency counters, function generators, a logic analyzer system and PC troubleshooting products, including extenders and expansion boards. Among the offerings new to this catalog are a portable protocol analyzer, data-acquisition board for PCs and compatibles and a hand-held logic analyzer. Prices are included. For a free copy, write to: Global Specialties, 70 Fulton Terr., Dept. ME, New Haven, CT 06512.

Applications Literature. "AN8: Power Conditioning Techniques for Batteries" is the title of an application note available from Linear Technology. It contains a variety of voltage-regulation circuits for battery-powered applications. Given are a variety of approaches for power conditioning for both switching and linear regulators, with attention paid to efficiency and low-power operation. Included are 14 circuit schematics with performance data and discussion of component selection criteria. For a free copy, write to: Gary Evans, Adv. Mgr., Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7487.

PC Paintbrush IV Plus: In Pursuit of the Perfect Paint Program

By Joseph Desposito

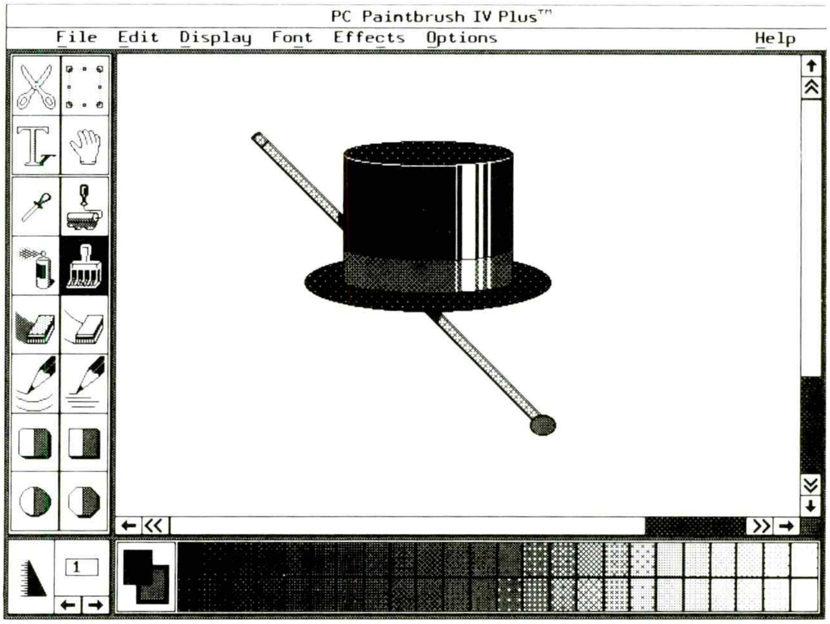


Fig. 1: The opening screen of PC Paintbrush IV Plus has a menu bar, paint tools, colors and a work area.

Whenever I get my hands on a new paint program, I'm curious to find out if it can compensate for my admittedly poor artistic skills. With this attitude, I popped the shrink-wrap of a new product from ZSoft (450 Franklin Rd., Suite 100, Marietta, GA 30067) called PC Paintbrush IV Plus. Designed for the IBM PC and compatibles, this new software package is the successor to PC Paintbrush IV. Since the two products were released within 6 months of each other, I'll be covering the new features of IV Plus, as well as those that first appeared in PC Paintbrush IV. These programs allow you to create and retouch images on a PC.

A word about ZSoft is appropriate, since it is the developer of the .PCX graphics file format, one of the standards of the industry. The company has roots as far back as 1982, when its founder, Mark Zachmann, created a screen-capture program called Frieze, which incidentally is still the core of every ZSoft product. In 1983, ZSoft began selling PC Paintbrush 1.0 and made agreements to bundle it with such products as Tecmar video boards and the Microsoft Mouse. With this kind of distribution, the .PCX file format used by PC Paintbrush quickly became the *de facto* industry standard for communicating bit-map information among computer software and peripherals.

All "paint" programs let you do free-hand drawing on a computer screen using an input device, such as a mouse or graphics tablet, and sometimes the keyboard, if a pointing device is not available. Where they differ is in the peripherals they support, such as printers, video adapters and scanners, and in the features they offer.

For someone like myself, who lacks artistic ability, a paint program must provide as much support as possible, both through peripherals and innovative features. Many of these programs, however, are fraught with limitations and, therefore, frustrating to use. PC Paintbrush IV Plus, which has a suggested retail price of $199, has some interesting new features, but like other programs of this type, has its limitations, too.

About the Program

PC Paintbrush IV Plus is a stand-alone paint program for the PC that resembles a Microsoft Windows application. The program uses what ZSoft refers to as a CUA (common user access) interface, an interface very similar to that of Windows. The opening screen (see Fig. 1) has a menu bar along the top, 16 tools are displayed in two columns along the left-hand side, a selection of colors or shades of gray appear along the bottom of the screen and a window is shown in the middle.

The menu bar along the top of the screen has seven choices: File, Edit, Display, Font, Effects, Options and Help. When you click on one of these choices with the mouse, a menu drops down and reveals another list of as many as 12 choices. For example, if you wanted to zoom in on a portion of the drawing, you click on Display, and then, when the menu drops down, you click on Zoom In.

The drawing commands are along the left side of the screen and are presented with icons, rather than words. To draw free-hand, you click on the paintbrush, move the pointer over to the window, hold down the left mouse button and move the mouse. When you want to move to another part of the drawing, you release the button and move the mouse. If you want to draw straight lines, curved lines, polygons and ellipses, you pick the appropriate icon, move the mouse to the window, hold down the left mouse button and move the mouse. When you are finished drawing, you release the mouse button. Any time you are uncertain about what to do, you can click on Help, and select the information you need.

Most of the painting functions are performed the same as the operations above. You select the icon, move to the drawing window, hold down the left mouse button and move the mouse. If you want to erase part of your drawing, you select the eraser. If you want to fill in parts of your drawing with a solid color, you select the paint roller. If you want to fill in parts of your drawing with a speckled color, you

Fig. 2: Drawings of Alexander Hamilton show before and after using special effects, such as Smudge and Blend.

select the spray can.

To add text to a drawing you must first select a font from the Font menu. There are 20 fonts and eight different type styles, such as plain, outline and shadow. Once you pick a font and a style, you then select the text icon. After you do this, an Enter Text window appears. You type your text into this window, rather than onto the drawing window. When you're finished entering the text, you click on OK to return to the drawing window. To place your text into this window, you must hold the mouse button down to move the mouse. This action draws a box on the screen. When you release the button, the text you entered fills the box. If you make the box long but not wide, your text will be vertical; if you make the box wide but not long, it will be horizontal. A long and wide box will place your text on several lines.

The remaining icons are the eyedropper, hand, gadget box and scissors. The eyedropper tells you the exact color you are pointing at in the drawing window, a very useful feature when you are trying to match one of 256 VGA colors. The hand moves the drawing around the window. The gadget box lets you select a rectangular piece of the drawing and move, copy, stretch, shrink, tilt, rotate, cut or save it. You do this by clicking on different parts of the gadget box. The scissors lets you outline an irregular shape and then perform the same operations as was done in the gadget box.

You select colors or shades of gray along the bottom of the screen. A click of the right mouse button selects the primary color or shade; a click of the left mouse button selects the secondary; a click of the right button while holding down the shift key selects the background.

One of the new features of PCPaintbrush IV Plus is support for large-scale images. If your image is much larger than the screen size, scroll bars along the bottom and right-hand side of the window let you move to different parts of the image. The program deals with large images through a disk-based virtual memory technique and through support of expanded and extended memory.

Another of the program's new features is built-in scanner control. You can select a menu choice called Scan Image from the File menu and directly control your scanner. For example, you can set brightness and contrast, resolution and other parameters associated with a scanner. An option called Prescan lets you scan a full page at low resolution and then select only the portion you desire to scan at high resolution. Flawed images can be improved by image-processing features such as Remove Spots, Sharpen and others.

PC Paintbrush IV Plus also includes the new features of its predecessor, PC Paintbrush IV. Chief among these is a set of special effects. There are seven of them: Blend, Brightness, Contrast, Gradient, Tile Pattern and Tint. Six let you alter the colors or shades of a drawing in various ways. One of them, Tile Pattern, lets you create a 3-D pattern with one of the tiles that come with the program. (A tile is a pattern you use to create things like borders—very similar to the way you use ceramic tiles. The tiles are stored in tile files.)

Another important new feature is a split-screen multi-level zoom that lets you do precise editing of an image with superior control, regardless of image size. Other new features are an eyedropper tool to ensure precise editing of colors; the gadget box and hand for maneuvering images; support of TIFF as well as the PCX file format; support of color, black-and-white, and gray-scale; and support for either outline or bit-map fonts.

Installation & Use

PC Paintbrush IV Plus comes with two sets of disks—three 3.5″ and six 5.25″ disks. DOS 3.0 or later is required. You install the program much the same way as you do a Microsoft Windows program; that is, you type "pbsetup" at the DOS prompt. The installation program supports 35 different input devices including graphics pads or tablets, 366 video adapters including the high-resolution modes (1,024 × 768 with 16 colors and higher) for some of them, and 170 printers including laser, inkjet, and color models.

Oddly enough, installation of the scanner must be done manually, by adding the scanner driver to your CONFIG.SYS file. This procedure is explained in the manual. The program supports 47 scanners (including three-color scanners) and two video frame grabbers. The scanner we tried to install is The Complete Page Scanner from The Complete PC. Although the program supports other scanners from this company, it does not yet support The Complete Page Scanner (at the time this article was written, a ZSoft spokesperson told us the driver was in the beta stage of development). To use scanned images from The Complete Page Scanner with PC Paintbrush IV Plus, we had to use the software that came with the scanner to create a .PCX file.

To get a feel for the program, we followed a tutorial for creating a top hat and cane. One of the nice features of PC Paintbrush IV Plus is a position display. It tells you exactly which pixel you occupy on the screen. This is very helpful when trying to keep ovals (or circles) aligned, as we needed to do when creating the top hat. Another convenience is the ability to constrain a line vertically, horizontally or at a 45-degree angle. This lets you connect pieces of an image with impeccable control. The top hat, which we drew in black and white, was relatively easy to create, thanks to the position display and line constraints.

The next part of the tutorial concerned image enhancement. The program includes an image with two pictures of Alexander Hamilton (see Fig. 2). The image on the left is the original, while the image on the right is the result of using special effects, such as blend and smudge.

The tutorial task is to make the "before" picture look like the "after" picture. The Effects menu includes such menu choices such as Blend, Brightness, Contrast, Gradient, Tile Pattern and Tint. When you pick one of these—Smudge for example—the tools on the left-hand side of the screen change. There are just two tools available for smudging—a spraycan and a filled box. If you choose the spraycan, you can smudge an area of the image manually. If you choose the filled box, you outline the area of the image you want smudged and the program does it automatically.

The problem with Smudge and some of the other special effects is that the tutorial advises you to "continue using the Spraycan (or filled box) until you are satisfied with the results." This advice essentially means that using a special effect is a trial-and-error procedure, one that will take much practice before it can be done well. This tutorial, like the other, is printed in black and white.

The fact that both tutorials are in black and white led me to wonder about the purpose of a paint program. I installed PC Paintbrush IV Plus on an ALR 486 PowerFlex computer with 4MB of RAM and Super VGA. With this kind of system, I expect to work in color. The program does provide a few color images, but how does one go about creating one of these images?

When I looked at the color images with the Zoom feature, I realized they were beyond the scope of my abilities; so I called the company to ask how they were created. One, a picture of an astronaut, superimposed on the skyline of New York City, was done by overlapping two images scanned with a Sharp color scanner. The other, a picture of a red sports car, was the winner of a contest sponsored by ZSoft. I quickly realized why I couldn't create a sophisticated looking color image.

Although I was able to scan color photos, the scanner I used provided me with a halftone image (grayscale) of the photo. When you open a file of this type, the program asks if you want to convert to color. Answering "yes" to this query simply gives you blue, rather than grayscale. The other difference is that a color palette, rather than a grayscale palette, appears along the bottom of the screen. Unfortunately, the program does not let you automatically substitute one color for another in a given area of the image.

PC Paintbrush IV Plus comes with a 218-page manual in a three-ring binder. The manual includes two tutorials, explanations of each of the menu choices, explanations of each of the drawing tools, installation instructions and other relevant information. The manual is well written and illustrated and has a table of contents and index. My only complaint with regard to the manual is that it is not printed in color.

ZSoft has a technical support line, which you can reach by calling the company (rather than an 800 number). We called and received satisfactory answers to our questions.

ZSoft, as well as third-party vendors, sell products that work with PC Paintbrush IV Plus. There are also many clip-art packages and scanned images available from other vendors and from public-domain distributors and bulletin boards.

Conclusions

From my experience with PC Paintbrush IV Plus, it seems obvious to me that there are a couple of ways to create sophisticated color images with the program. The first is to install either a color scanner or video frame grabber in your system. The second is to hire a very artistic computer person (unless you are one yourself).

It is possible, however, to create sophisticated color graphs (of the type you might see in *USA Today*) with the program. It's also possible to use the text capabilities of the program to create professional-looking color slides for business presentations. A brochure included with the program explains how you can produce 35-mm slides from PC Paintbrush IV Plus files and even includes an 800 number to call for this service.

In my view, it's not even feasible to perform much modification of a color image once you have it on file. To produce decent-looking halftone images, you'll need a monochrome scanner. Black-and-white line drawings and color charts are easiest for the non-artist to create with the program. To correctly use any of the special features, such as blending and smudging, takes a lot of practice.

At $199, PC Paintbrush IV Plus is a program meant for people whose PC systems include expensive peripherals. The program certainly has the power you need to create professional-looking color and grayscale images, but you need either the special equipment or expertise to tap that power. If this is the case, then I recommend that you purchase PC Paintbrush IV Plus. If not, you may be happier with the $99.95 PC Paintbrush IV or another paint program. **ME**

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boost obtained was due to the transformer's deviation from a flat response. As the plot shows, loss is minimal above about 3 kHz. Best response was obtained at 7 kHz, making this frequency ideal for Morse code transmission.

Noise picked up by the receiving stake in the test setup was at a −63-dB level with a transformer and at a −93-dB level without the transformer. This yielded a S/N of 40 dB at 7 kHz, which would increase with distance but could also be increased with judicial use of tone controls or an equalizer.

Microphone Preamplifier

Twenty and more years ago, almost every audio amplifier and tape recorder used for high-fidelity reproduction came equipped with a built-in microphone preamplifier. This is no longer the case. If you have a fairly recent amplifier that you want to use for communicating through the earth, chances are that it does not have the requisite microphone inputs built into it. If this is the case, you must use an external preamplifier circuit between your microphone and the input to your amplifier.

You can, of course, purchase a commercial mike preamp and use it with this system. However, since this is a hobby pursuit (and perhaps you want to make a minimal monetary investment in materials), you can build a very good mike preamp using the schematic diagram shown in Fig. 7. As you can see, this circuit is built around two popular 741 operational amplifiers (actually, any other op amp will do if you have it on hand). The support components are also very low in cost.

Component layout for the Fig. 7 circuit is not critical, but it is a good idea to locate the input and output at opposite ends of the layout and to use a shielded enclosure for the circuit. The latter is because you want to minimize the effects of induced hum to an absolute minimum.

If you wish, you can design and fabricate a printed-circuit board on which to mount and wire together the mike preamp ccomponents. Otherwise, simply mount the components on perforated board that has holes on 0.1-inch centers with the aid of Wire Wrap or soldering hardware and use a point-to-point wiring technique to interconnect them. Whichever way you go, though, be sure to use sockets for the ICs.

When you are finished assembling the circuit-board assembly, house it inside a small metal enclosure that can accommodate it and a 9-volt battery. Machine the enclosure to provide mounting holes for the circuit-board assembly, input and output jacks and the GAIN control.

When you are finished building the mike preamp, use shielded cable to connect its LINE LEVEL OUTPUT to the AUX input of the channel you are going to use for receiving on your amplifier and connect the shielded cable from your microphone to the MIC INPUT jack on the preamp. Then make all other connections to complete setting up your station.

When you are up and running, try experimenting with other people in your locality to see just how far you can communicate. As a network of communicators is set up, you just might find that "rag chewing" through the earth can be every bit as enjoyable and demanding a hobby as amateur radio through the airwaves.

arate listening zones that independently and simultaneously play different programs. Each zone can have as many different rooms as the user desires, with the r-f remote transmitter providing full control over both zones. There is no limit to the number of rooms and remote controllers the system can accommodate, and additional speakers can be added to an established zone at any time. $2,400 for basic one-room system (Music Center, remote controller and Powered Acoustimass Speakers).

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According to Alden, the new printer is well-suited for such applications as medical scanning, electron microscopy, undersea research (such as sub-bottom profiling), aerial reconnaissance and satellite photos. Images are printed in less than a minute. Additionally, a high-speed black/white mode can be used for printing line art from CAD systems, with a complete 10″ × 18″ drawing ready in less than 30 seconds.

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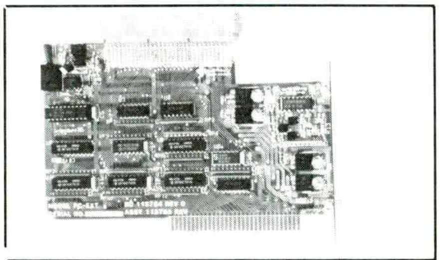

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(Continued on page 81)

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NEW PRODUCTS

(from page 77)

Inc. (Broomfield, CO) solves this problem by directing the call to its proper destination. It allows telephone devices that normally answer all incoming calls to answer only those calls directed at them.

RingRite simply plugs into any modular telephone jack and the answering device into RingRite. It separates the telephone line from the device to be controlled and passes the selected custom ringing pattern through to the answering device

plugged into it. This allows the additional ringing patterns to act as separate telephone lines for incoming calls without affecting outgoing calls. The controlled device can be a fax machine, answering machine, modem, telephone instrument, etc.

When a call comes in, RingRite determines what number was dialed from ring pattern generated. A slide switch on the unit can be set for any of three ring patterns. It passes only the selected pattern on to the device connected to it.

With RingRite, you can have two separate answering machines, each with a separate message on it, on the same line. You can also have a dedicated fax or modem number so that an incoming call can be directed exclusively to the fax machine or your computer. RingRite is said to be compatible with all fax machines, answering machines, modems, telephone instruments and other telephone devices and phone company services like Call Waiting, Speed Dialing, etc. $79.95.

CIRCLE NO. 43 ON FREE INFORMATION CARD

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