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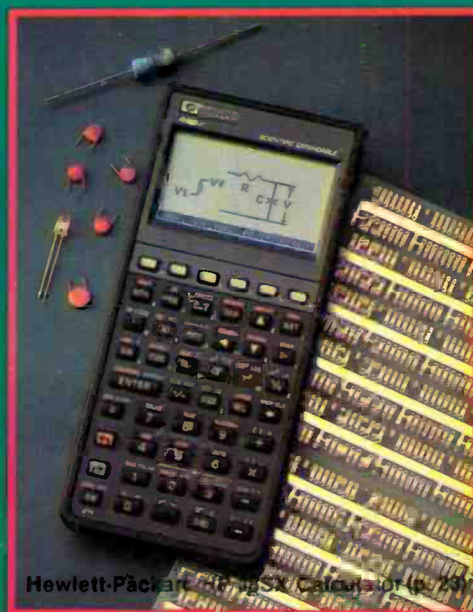
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

Special Focus On Math-Solving Products:

- MathCAD v2.5, Derive v1.60 & CPMCALC4 Math PC Software
- Hewlett-Packard's New HP 48SX Scientific Calculator

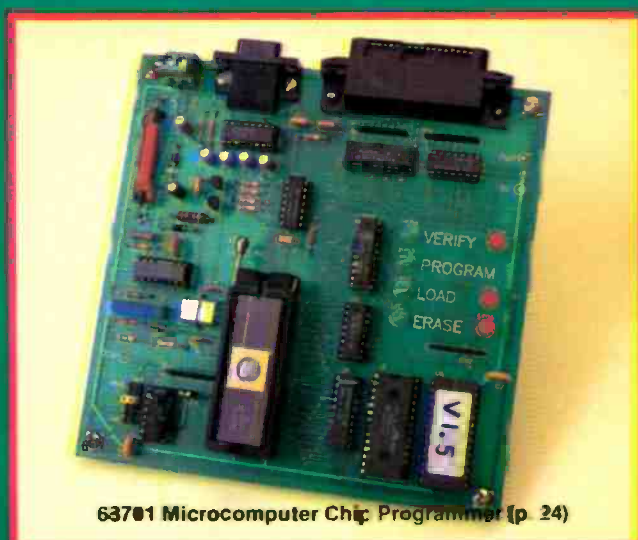


Hewlett-Packard HP 48SX Calculator (p. 23)

Also Featured:

- A Programmer for the 68701 Microcomputer Chip
- Electronic Control for Slide Projectors
- Interfacing 555 Timers To the Real World

Electronic Controller for Slide Projectors (p. 36)



68701 Microcomputer Chip Programmer (p. 24)

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Plus: Hands-On Look at the New "Loaded" Hewlett-Packard LaserJet III Laser Printer • Experimenting With Incandescent Lamps • Latest New Electronic and Computer Products . . . more.

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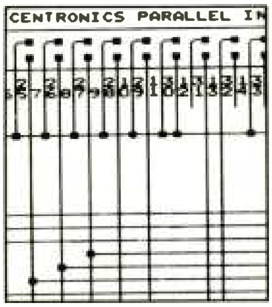
VOLUME 7, NUMBER 5



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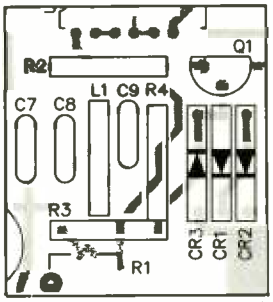

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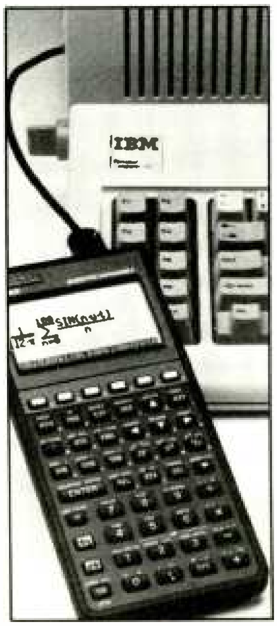

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Offices: 76 North Broadway, Hicksville, NY 11801. Telephone: (516) 681-2922. FAX (516) 681-2926. Modern Electronics (ISSN 0748-9889) is published monthly by CQ Communications, Inc. Subscription prices (payable in US Dollars only): Domestic—one year $17.97, two years $33.00, three years $48.00; Canada/Mexico—one year $20.00, two years $37.00, three years $54.00; Foreign—one year $22.00, two years $41.00, three years $60.00. Foreign Air Mail—one year $75.00, two years $147.00, three years $219.00.

Postmaster: Please send change of address notice to Modern Electronics, 76 North Broadway, Hicksville, NY 11801.

CQ Communications, Inc. is publisher of CQ The Radio Amateur's Journal, Popular Communications, Modern Electronics, CQ Radio Amateur (Spanish CQ), and the CQ Amateur Radio Buyer's Guides.

EDITORIAL

Thanks for the Memories

We worry about U.S. dependence on foreign oil; on foreign minerals such as chromium; and so on. There isn't too much one can do about materials that we don't have on our shores, of course. But production and quality of products that aren't dependent upon access to raw materials is another story. So we also worry about our declining automobile industry, our disappearing shoe industry, our withering clothing industry, and our beaten-down industrial machinery businesses. What to do?

Kawasaki, Yamaha and Honda, among others, caused much consternation a few years ago when their hold on the motorcycle industry appeared to be unbreakable. Harley-Davidson, a subsidiary of AMF, and the last bastion of U.S. motorcycle makers, was going down the drain. A group got together and bought the company, changed its production methods, and created a revitalized cycle maker that makes a profit and has moved into the forefront of the motorcycle industry—all in a very few years. The catalyst was the U.S. Government, by the way, which helped out for a few years with a declining import tax on foreign-made cycles over a certain size.

What has all this got to do with electronics? Well, it sort of parallels what happened in this industry. For example, from an $18 price to volume buyers in 1984, 256-Kbit DRAMs plummeted to only $1.80 in 1987—with immediate delivery. U.S. makers of dynamic random-access memories blithely dropped making these chips, accusing Japanese suppliers of dumping. One year later, with Texas Instruments and Micron Technology the only remaining major U.S. DRAM makers, the chips were being sold for $4.50 with delivery ranging up to 20 weeks!

To ensure a U.S. supply of DRAMs, a consortium—U.S. Memories Inc.—was formed in 1989 by seven computer and semiconductor makers. They anticipated support by other U.S. companies, of course, expecting some 25 or 30 more to kick in some money and commit to buying at least 20 percent of their DRAM needs from the consortium. But as the whole thing was revving up, the shortage of Japanese DRAMs began to subside by late 1989. From among some 60 U.S. computer companies, not a single one joined the consortium. No Apple Computer, Compaq or Sun Computer, among others who declined to join the founders, which included Digital Equipment Corp. and IBM. With the DRAM shortage gone, so was any interest. The U.S. Government looked the other way, too, as did other sources of financing. Finally, U.S. Memories called it quits as it entered the Nineties still-born.

It's really shameful, I think. Such shortsightedness will seriously hamstring future DRAM production—1-Mbit and 4-Mbit, onward to 16-Mbit and 64-Mbit. It seems that we have lost the will or the wherewithal to engage in large-scale semiconductor production battles, and will settle largely for niche production. Japan and Korea now own about 79 percent of the world's DRAM market. It's a market that will grow enormously in size due to expanding applications, from high-definition TV to computer workstations. Moreover, the technology of making DRAMs is akin to that of producing LCD screens, a product area that's expected to burgeon. It, too, requires lots of money to be invested in production equipment. Will the U.S. walk away from this opportunity, too? Probably.

All isn't lost in the memory world, say some industry sages. We've got the lead in flash memories, which some think might become a more important memory device. Specialty static and dynamic RAMs, too, are significant memory markets that are not scary commodity-like products. Moreover, some U.S. companies are even slinking back to producing DRAMs or leasing equipment for startup companies to do the same. But money is still tight; industry leaders aren't much interested in cooperating with others; the government is still hesitating about providing any industry assistance in whatever form.

Viewing the recent U.S. Memories debacle, it'll likely be a long time before a similar venture is attempted. So I'd guess that the DRAM market will remain a foreign-country commodity in the same way that oil is. And we'll just have to suffer the availability and price levels as economic times dictate.

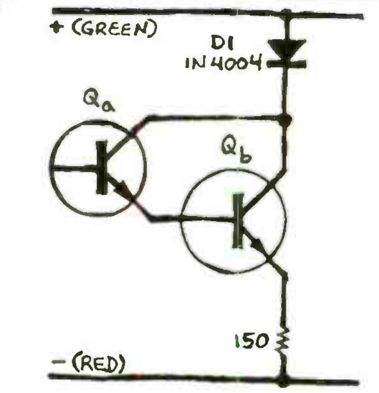
Art Salsberg

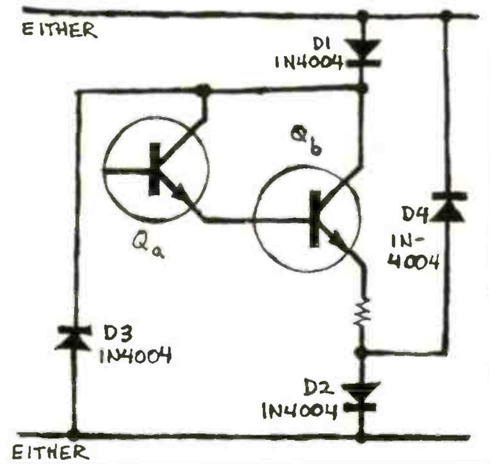
Reader Project Updates

• I enjoy the construction projects presented in *Modern Electronics* and sometimes see ways to improve on a published project. A case in point is the "Two-Line Telephone Answering-Machine Interface" that appeared in the February 1990 issue. In the article, the author noted that polarity of the phone lines is critical. I submit here a modification that creates a bridge circuit for seizing the line that is not in use. The original circuit equivalent is shown in Fig. 1. By adding three diodes per phone line, as shown in Fig. 2, the full-wave bridge circuit created makes polarity a non-issue.

If the top line in Fig. 2 is positive, as required in the original circuit, when Q_a and Q_b conduct, current flows through D1, Q_b and D2. Conversely, when the top line is negative (no current flows in the original circuit), current still flows through D3, Q_b and D4, thus seizing the phone line and causing a busy signal to be received by a caller on that line.

Thomas M. Kiehl
Largo, FL





• We have two telephone lines and one answering machine in my home. We've looked in the past for a device that would enable us to have the answering machine pick up either line, to no avail. I gave up looking for a solution long ago. Then the "Two-Line Telephone Answering-Machine Interface" that appeared in the February 1990 issue came along to solve the problem. However, while building the project I discovered two errors. One is that mention of C4 and R9 was omitted from the Parts List. The other is that J1 and P2 on the wiring guide were transposed. Unless this is corrected, phone line voltage from Line 2 will be fed into Line 1.

Thanks for an interesting solution to my problem. Keep the useful projects coming.

Kevin Fodor
Akron, OH

APPRECIATION DAYS. Everyone knows that there's a Mother's Day, Secretary's Day, and so on. But many people aren't so aware of special days that celebrate workers in the electronics industry. For example, Electronics Technicians are honored each year with a National Electronics Technicians Day in recognition of high performance standards maintained by these professionals. It's also a day (March 6) to commend the International Society of Certified Electronics Technicians (ISCET), which this year marks its 20th anniversary of certifying the professional capability of ETs. There were 27,578 certified techs at the end of 1989. (For info on the certification program, call 817-921-9101.)...Engineers celebrate their profession with a whole week (this year, February 18-24) with National Engineers Week. Activities revolve around Discover "E, a nationwide program that provides hands-on engineering experiences to students through schools, museums and libraries. The Week is co-sponsored by the Institute of Electrical and Electronic Engineers (IEEE) association.

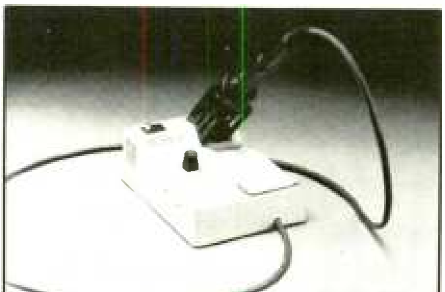
FCC PROPOSES CODELESS HAM LICENSE. With PR Docket 90-55, the Commission proposed to amend its rules by establishing a codeless amateur operator license, the Communicator Class. The FCC proposal also included modifying the licensing structure to Communicator, General, Advanced and Amateur Extra Classes. Present Technician and Novice licenses would be grand-fathered indefinitely, but they will no longer be issued if the cited proposal becomes official. But under the new structure, you'd need a General- or grand-fathered Technician-Class license to communicate on popular 2- and 6-meter VHF bands, where operators can reach a telephone number with a wireless portable or mobile rig and a relay-club membership.

PERSONAL COMPUTER TIDBITS. Maxell has introduced pre-formatted disks in the industry's four most popular formats....Ungar has a line of electrostatic dissipating (ESD) office and desk accessories, including various letter trays, desktop accessories, organizers, etc. The black-matte-finish products protect ESD-sensitive parts with Class 1, 2 and 3 sensitivity classifications (0-1,999 volts; 2,000-3,999 volts; and 4,000-15,000 volts, respectively)....Safeware, the microcomputer insurance specialists, announced a new repair insurance policy for computers. Called "Safeware Fix:It," the policy insures against breakdowns as well as external losses and theft. The company offers a 20% bonus coverage for licensed, registered software....Geller Software Labs (Montclair, NJ) has the first spell-checking software aimed at database and spreadsheet users, and programmers. It's said to work with languages such as C, Pascal, BASIC. and others.

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.

Soldering Station

The Model SA-570 soldering station from OK Industries has an operating range of 600° to 800° F. This provides high power for multiple applications, including soldering circuit boards with exceptional thermal demands. A 70-watt heating element with precise temperature control is



SA-571/572

claimed to provide excellent stability and repeatability and quick recovery on massive connections. In addition, the directly grounded tip meets MIL-STD-2000 resistance and voltage requirements.

This ergonomically designed soldering station has a low-profile, small-footprint housing that requires minimum bench space. The handpiece itself is light. A wide range of high-mass soldering tips are available for the Model SA-570. $86.90.

CIRCLE NO. 122 ON FREE INFORMATION CARD

80286-Based Laptop

Radio Shack's Tandy 2800 HD laptop computer is built around a low-power 80C286 microprocessor operating at a user-selectable 6 or 12 MHz. Housed in an "executive black" case, the 2800 HD features a 9⅛ × 8⅝-inch full-size electroluminescent back-lit EGA-compatible supertwist liquid-crystal display with 640 × 400-pixel resolution and 16 gray scales; an enhanced 84-key keyboard with true 101-key emulation mode and standard 3.5-mm keystroke; and the ability to exchange batteries without turning off the system. Storage capacity is 1 MB of user RAM (expandable to 2 MB), an internal 20-MB hard-disk drive with 29-ms access time; and one 1.44-MB 3.5-inch floppy-disk drive.

Ports available include EGA/CGA-compatible external video, bidirectional parallel and RS-232C serial. A socket is provided for an 80C287 numeric coprocessor. Bundled with the system and installed on the hard drive are Tandy's DeskMate® Version 3.3 productivity software, MS-DOS 3.3 and TEMM (LIM 4.0).

An internal replaceable rechargeable gel-type lead-acid battery is said to provide up to 2 hours operating time. This battery can be charged inside or external to the system, the latter with an included external battery charger. Additional batteries are available as options, as are an internal 2,400-bps modem, 1-MB memory upgrade and choice of protective carrying cases.

The computer measures 13.87 × 12.25 × 3.25 inches (when closed) and weighs less than 12.5 lbs. $3,499.

CIRCLE NO. 123 ON FREE INFORMATION CARD

Video Surround Sound

Panasonic's Model SY-DS1 digital signal sound processor is said to give surround sound style audio effects to home video systems without the need

to require or add rear speakers to the viewing area. The self-contained unit has a built-in amplifier, two speakers and digital sound processor. In use, the unit is placed atop or near the TV screen to obtain the surround-sound effect. It can be connected to any video source that has audio output jacks or to a stereo receiver if the TV receiver is connected to an external hi-fi system.

Internal circuitry sends a variably delayed audio signal throughout the listening environment. Effect inten-

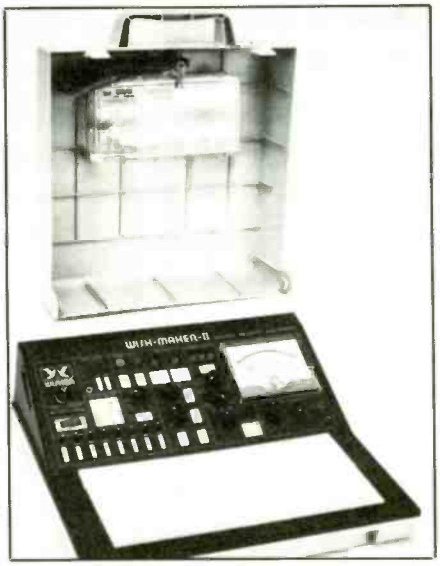
NEW PRODUCTS . . .

sity can be adjusted, depending on the source and according to taste. Most four-speaker arrangements have a small "hot spot" in which the surround-sound effect is at its best. According to Panasonic, the SY-DS1 is designed to expand this area to allow more people to experience the effect of surround sound. $250.

CIRCLE NO. 124 ON FREE INFORMATION CARD

Design Stations

Wishmaker 1 and Wishmaker 2 from Jameco Electronics are prototype design stations designed to meet the needs of electronics engineers, technicians and students. The two models

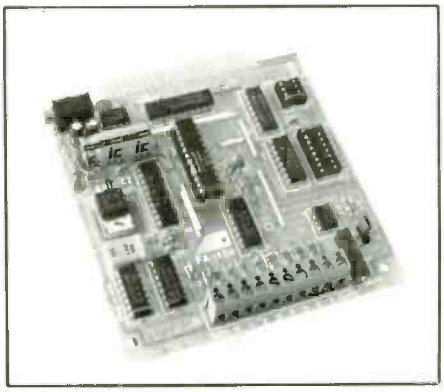


are said to simplify the building and testing of prototype analog (Wishmaker 1) and digital (Wishmaker 2) circuitry. Each includes a removable solderless breadboarding system, variable or fixed dc power supply, multiple-frequency signal generator, analog multimeter, fused overload protection, logic probe and more. $199.95, Wishmaker 1; $249.95, Wishmaker 2.

CIRCLE NO. 125 ON FREE INFORMATION CARD

A/D Converter

Alpha Products (Darien, CT) announced a high-speed 12-bit analog-to-digital converter board that expands its line of A-BUS devices for low-cost data-acquisition and con-



trol devices. The Model FA-154 board's conversion speed is rated at 10 microseconds, and each of its eight input channels accept a 0-to-5-volt signal. An on-board variable-gain amplifier permits reading of signals that are less than 1.2 mV (1 LSB). The board runs on most popular computers, including IBM PC-bus machines, Apple IIs, Commodores, etc. Furthermore, serial interfaces permit operation through any computer's RS-232 port. $179.

CIRCLE NO. 126 ON FREE INFORMATION CARD

Frequency Adapter

A new adapter designed to provide direct frequency readout on any multimeter is available from EXTECH Instruments Corp. (Waltham, MA). The converter provides frequency measurements over a range from 2 kHz to 20 MHz with a rated accuracy of 1% of reading. Minimum sensitiv-

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RICK BRUSH,
NRI PROGRAMMER/ANALYST

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ity is rated at 100 mV rms from 2 kHz to 10 MHz and 200 mV from 2 MHz to 20 MHz. Overload protection is to 500 volts ac and dc.

The adapter attaches to any multimeter via banana plugs. The user simply sets the multimeter to the 200-mV dc range and selects the frequency range to be measured via a rotary switch on the converter module. The supplied test leads then plug into banana jacks on the adapter and are used in the normal manner. The only other control on the converter is a HI/LO TRIG LEVEL slide switch. Separate POWER and LO BAT indicators are provided.

The converter measures 3.6″ × 2.8″ × 1.6″ and comes with a 9-volt battery and a pair of test leads. $49.

CIRCLE NO. 127 ON FREE INFORMATION CARD

Programmable Scanner

New from Cobra Electronics, the Model SR 901 desktop scanner offers programmable for up to 10 channels. It features Cobra's Express Tuning System that replaces the multi-button keypad with a three-button (up/down/fast) design that simplifies

tuning and programming operations. The uncluttered control area contains a large rotary volume/power control and nine-decade LCD display of tuned frequencies and operating status.

Features of the new scanner include: one-touch memory programming; automatic scanning and manual tuning; channel lockout; automatic squelch; telescopic antenna; and small 7½-inch square footprint. The scanner provides coverage in three frequency bands: Band 1—29 to 29.7 MHz 10-meter Amateur, 29.7 to 50 MHz vhf low and 50 to 54 MHz 6-meter Amateur; Band 2—136 to 144 MHz military land mobile, 144 to 148 MHz 2-meter Amateur, 162.4 to 162.55 MHz weather and 148 to 174 MHz high; and Band 3—400 to 406 MHz weather, 406 to 420 Federal Government, 420 to 450 70-cm Amateur, 450 to 470 uhf and 470 to 512 MHz uhf T.

A companion hand-held scanner, the Model SR-11, also features the Express Tuning System, 10-channel memory and same frequency coverage as the desktop unit. It uses four AA alkaline or rechargeable cells. $149.95, Model SR-901; $189.95, Model SR11

CIRCLE NO. 128 ON FREE INFORMATION CARD

IR Remote Controller For Amiga Computers

Edu-Vid Research's (Pembina, ND) IR Remote Controller is primarily a hardware package for use with Commodore Amiga personal computers. (A model for use with IBM and compatible computers is soon to be available.) It allows a VCR or any other infrared remote-controlled device to be operated by a user's program. The Controller can learn the IR pulse codes from the remotes of most devices. It can also detect when a VCR is actually sending a video signal and, with suitable monitors, can switch the screen from computer output to video output. In addition, "touch tones" can be placed on a video tape for the Controller to detect and its program do various things. These include mix the Amiga's sound or voice with the video sound or overlay computer output on the video output (if a separate Genlock is used) or simply stop the video while the computer outputs to the monitor screen.

Software provided with the package is intended to demonstrate the product's many uses. Meant mainly for people who program in BASIC,

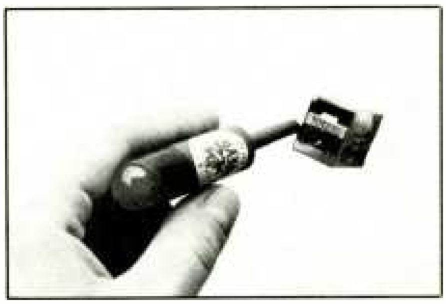
assembler or C to produce application programs, the IR Remote Controller comes with a cable to connect it to the parallel printer port of an Amiga 500 or 2000 (the Amiga 1000 requires an optional adapter), two cables for connection to a videocassette recorder, a 3.5-inch program disk and user's manual.

Power for the Controller is provided by four AAA cells. It draws less than 50 mA from the Amiga computer. $180 plus $5 shipping.

CIRCLE NO. 129 ON FREE INFORMATION CARD

Magnetic Sensing Probe

The Lil Devil™ Mag-Probe from HUB Material Co. (Canton, MA) detects residual magnetism and transient current pulses ("glitches") as fast as 10 milliseconds and identifies north and south poles in ac- and dc-powered solenoids, relays and any other electromagnetic device. There



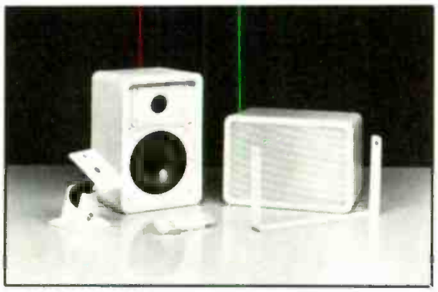
is no need to refer to a schematic diagram when troubleshooting a device under test with the Lil Devil. One just positions the probe tip close to the coil in the device. A LED in the handle of the Lil Devil lights if the device is energized. No electrical connection to the circuit or device under test is required.

Two models are available. The standard-sensitivity model tests large and standard-size solenoids and relays. The high-sensitivity model tests the full range of devices, down to subminiature reed relays.

CIRCLE NO. 130 ON FREE INFORMATION CARD

Indoor/Outdoor Speaker

Sonance's first box-type weather-resistant speaker system, available in two models, mounts in locations where an in-wall speaker system would be inconvenient or inappropriate. The Models SB30 and SB10 have the same 8½"H × 5½"W × 5⁵⁄₁₆"D enclosure dimensions. Both



are fully water-resistant as a result of their structural foam baffles and enclosure. The terminal connections provide waterproof electrical connections and permit single-handed cable insertion.

In addition to the key slot on the backs of the enclosures for direct wall hanging via a nail or screw, the speakers come with a pivot-type C bracket that mounts via a ball-joint bracket. The latter arrangement allows the user to position the speaker for best sound in a given area.

The Model SB30 is an enclosed two-way system that contains a 4" polypropylene woofer and 1" soft-dome tweeter. Crossover is at 3.5 kHz. Frequency response is rated at 75 Hz to 20 kHz ± 3 dB, impedance is 6 ohms, input power is 5 watts minimum and 50 watts maximum and efficiency is rated at 87 dB at 1 watt at a distance of 1 meter.

The Model SB10 offers an extended-range 4" polypropylene driver that provides a frequency response of 90 Hz to 15 kHz ± 5 dB. Nominal impedance is 8 ohms, input power is 5 watts minimum and 45 watts maximum and efficiency is rated at 85 dB at 1 watt at a distance of 1 meter.

Both speaker systems are available in black or white enclosures and hardware. $300, Model SB30; $150, Model SB10.

CIRCLE NO. 131 ON FREE INFORMATION CARD

60-MHz Oscilloscope

Beckman Industrial's new Model 9106 three-channel oscilloscope offers a 60-MHz bandwidth and the ability to display eight traces on-screen. Its third channel provides a

(Continued on page 82)

Enhance Your Math Prowess With Software & Hardware

Computer software and hand-held calculators ease the burden of complex calculations in different ways. Here are in-depth examinations of such products that reveal their strengths and weaknesses.

By Joseph Desposito

Mathematical Software For PCs

Anyone who designs electronic circuits invariably finds himself dealing with mathematical equations. Usually, these are solved with pen and pencil, scientific calculator or computer (or some combination of each). Those who use a personal computer have at their disposal a variety of ways to tackle mathematical equations. One way, and probably the most popular, is with a high-level programming language, such as BASIC, Pascal or FORTRAN. Another is with a spreadsheet program, such as Lotus 1-2-3. A third way is with mathematical software, which is the method we are concerned with in this article.

Mathematical software has certain advantages over other computerized methods of solving electronic design equations. For starters, this type of software eliminates the need for programming. Another advantage is that the formulas for problem-solving methods, such as matrix algebra, are built in. Also, some of these programs are capable of doing calculus, which is beyond the scope of programs like 1-2-3. Finally, mathematical software often can display formulas the way you are used to seeing them in textbooks and journals. This makes it possible to present design equations to others in a way that is easily understood.

The programs we review in the following pages are MathCAD v2.5 from MathSoft, Derive v1.60 and a brand new program called CMP-CALC4 from UDH Enterprises. There are many others, of course, but these are representative ones.

After we review the math software, we'll take a look at a new product from Hewlett-Packard, the HP 48SX scientific expandable calculator. Besides the regular features of a scientific calculator, it has graphics features that make it competitive with math software for the PC.

MathCAD version 2.5

Software for creating formulas that look good—calculate, too!

Of the many virtues of MathCAD v2.5 (MathSoft, 201 Broadway, Cambridge, MA 02139; 800-MATH-CAD), the one that is most enamoring is its ability to make the display on your computer resemble a page from an electronic design text or journal. MathCAD, which has a suggested retail price of $495, can integrate equations, graphs, text and figures on your computer display—and the equations and graphs are live! This means you can assign values to the variables of an equation to obtain results, graph those results automatically, and then, if desired, change the variable values to obtain new results and a new graph.

Besides the main program, MathSoft also sells applications packs for a variety of disciplines. The price of the Electrical Engineering Applications Pack (see sidebar) is $99.

MathCAD Operation

MathCAD for the IBM PC and compatibles (the program is also available for the Apple Macintosh) comes on two 5.25-inch disks or one 3.5-inch disk (both formats are included in the package). To install the program you simply copy the files to your hard disk.

MathCAD's opening screen displays its logo and the directive "Press F1 for help." Unfortunately, it's not immediately evident from the help screen how to access the program's main menu, or how to issue commands. If you use the documentation, you have to leaf through a few pages before it tells you to press F10 to access the main menu. Learning to use the program is rarely an intuitive, trial-and-error experience; it is mostly a "look it up in the documentation" one.

Everything you do in MathCAD—enter formulas, place text or sketches or produce graphs—you do free-form, on a display that emulates a scratchpad. To move around the scratchpad, you use the cursor keys or issue a "go to" command with the coordinates of the desired position. This is a cumbersome way to do things and is one of the least-appealing features of the program. Once you reach a desired position, you enter a formula, for example, by typing numbers, letters, mathematical operators or math symbols. The program requires that you define variables before you use them in a formula. This is done by typing the variable name followed by a colon and a number.

Math symbols are created with keyboard symbols or with Alt-key combinations. For example, an integral sign is created by typing an ampersand (&), and a "less-than or equal-to" symbol is created by typing Alt-(. To distinguish explanatory text from text used to represent variables, you alert the program by first typing quotes. You place a graph on the display by typing the sign.

MathCAD refers to each equation, plot or block of text you enter as a region. If, after you have created an equation, plot or block of text, you don't like its placement on the screen, you can move it (the region) by cutting it from one part of the screen and pasting it to another.

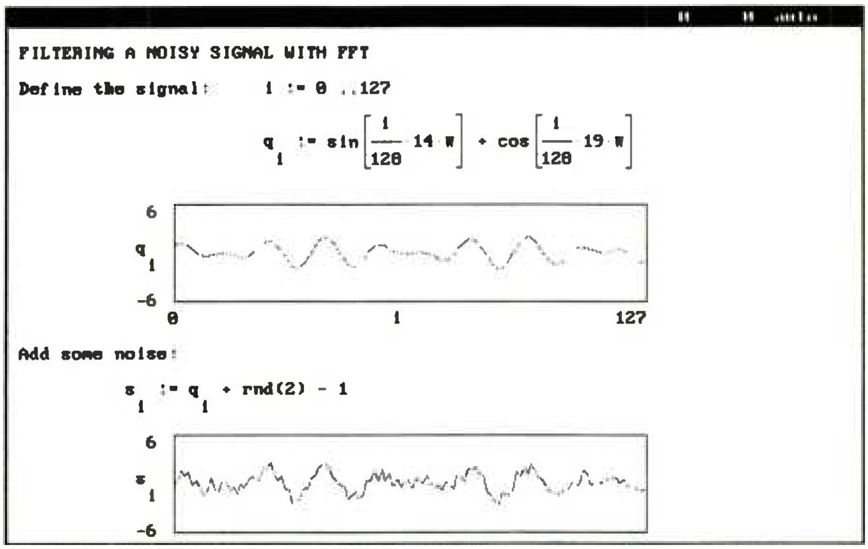


Fig. 1. In MathCAD, definition signs (: =) are often used instead of equal (=) signs.

If you press F10, a horizontal menu is displayed across the top of the screen. When you select a menu item, such as System, a drop-down menu appears with several choices. If you're working on an XT-class machine, the first thing you'll notice is how long it takes for the program to draw the menu box. This is the first indication of how incredibly slow the program can operate at times. Although you can use the program on a dual-disk IBM XT-type machine, you'll be much happier using it with the fastest machine and fastest hard disk you can lay your hands on. And throw in a math coprocessor for good measure.

If you press ESC, rather than F10, a command line appears instead of the horizontal menu. Anything you can do with the menu, you can do with the command line. Some commands can be issued from the keyboard, too, as Ctrl-key sequences.

MathCAD Features

The most striking feature of MathCAD is its ability to display an equation on the screen that essentially looks like an equation you would see in a textbook or professional journal. Whereas most spreadsheets or programming languages use an asterisk (*) for multiplication, a slash (/) for division, and a caret (^) for exponentiation, MathCAD uses traditional mathematics symbols. Additionally, MathCAD has symbols for integrals, derivatives, sums, products, square roots, subscripts, absolute value, Greek letters and others.

One symbol MathCAD uses is not a common math symbol. MathCAD distinguishes between an equals sign (=), which is the signal to calculate a result, and a definition sign (: =), which tells the program the value of a variable. The definition sign is entered by pressing a colon (:), but it is displayed on the screen as a colon plus an equals sign. If you want to enter an equation such as d = v*t, rather than v*t = 50, you normally use the definition sign. Thus, if you look closely at a MathCAD screen, such as the one shown in Fig. 1, definition signs predominate.

You can specify a range of values for a variable by entering an expression such as t: = 1..100 (an increment can also be entered). The program will calculate a set of answers and present them in a table, create a two-dimensional plot, or both. MathCAD can also create surface plots, such as the one shown in Fig. 2.

To create a surface plot you must specify a range of values for two variables. Once you create a plot, you can size, rotate or tilt it, hide lines and change the vertical scale. Besides entering a range of values from the keyboard, you can also enter values stored on-disk in an ASCII file. This is about as close as you can come in MathCAD to executing a program loop. Other programming-like features let you issue a set of commands stored in a text file, or use an IF function and relational operators to test a condition and change the behavior of an expression based on that condition.

MathCAD has built-in units for mass, length, time and charge. To attach a unit to a number, you simply multiply the two together. You can

MathCAD EE Applications

The MathCAD Electrical Engineering Applications Pack consists of a disk with 19 applications files, a file of units definitions, sample data files and a 120-page user's guide. The applications carry out common design calculations from several different branches of electrical engineering and employ MathCAD's complex arithmetic, matrix operators, equation solving and plotting capabilities. Topics covered in the applications pack include antennas and waveguides, circuit analysis, transmission lines, filters, coding and signal processing, and transfer functions for control theory.

You can load and run applications in the pack just as you would any other MathCAD documents. The applications implement common solution methods, and the documentation provides a brief background for the application.

To give you an idea of what one of the applications looks like, we've included part of the "Design of an IIR Filter" application here. The application designs a low-pass digital IIR filter of the Butterworth type. The user specifies the minimum stopband attenuations and defines the width and location of the transition band by specifying the passband and stopband edge frequencies.

MathCAD calculates the required filter order and constructs the transfer function. The routine provides coefficients for the transfer function and for its expansion in partial fractions, from which the impulse response can be calculated. The application also finds the filter output for some simple input sequences in two ways: by direct convolution with the truncated impulse response, and by using a difference equation based on the transfer function coefficients.

The coefficients of the numerator are: $e_i := M \cdot \dfrac{N!}{i! \cdot (N-i)!}$

To find the impulse response h for this filter, first find coefficients for the partial fraction expansion of the transfer function H:

$r := .001$

$$K_k := \frac{1}{2 \cdot \pi} \cdot \int_0^{2 \cdot \pi} H\left[r \cdot \exp(j \cdot \theta) + a_k\right] \cdot r \cdot \exp(j \cdot \theta)\, d\theta$$

[Ctrl][PgDn]

H expanded in partial fractions is:

$$H(z) := M + \sum_k \frac{K_k}{z - a_k}$$

The coefficients K are:

K_k
-0.215 - 0.091j
0.692 - 1.301j
4.03 + 2.56j
-6.164 + 8.384j
-12.936 - 10.819j
14.593 - 15.474j
14.593 + 15.474j
-12.936 + 10.819j
-6.164 - 8.384j
4.03 - 2.56j
0.692 + 1.301j
-0.215 + 0.091j

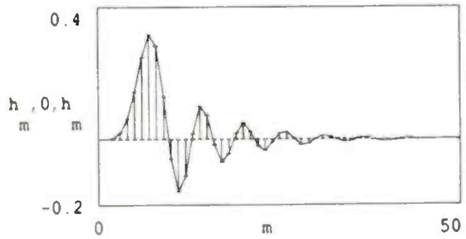
The beginning of the infinite impulse response h is given by:

$m := 0 \,..\, 80$

$h_0 := M \qquad h_m := \sum_k K_k \cdot a_k^{m-1}$

[Ctrl]]PgDn]

Plot of impulse response:



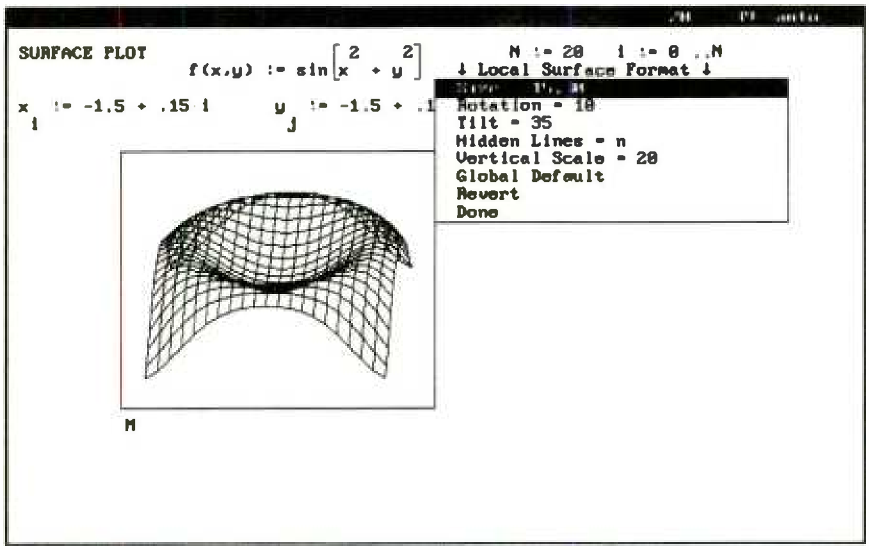


Fig. 2. A surface plot created with MathCAD.

also define your own units by using the definition sign.

MathCAD has 67 built-in math functions, including Bessel functions, fast Fourier transforms, vectors and matrices. Any calculation you can perform in MathCAD on single values, you can also perform with vectors or matrices of values.

Since you can insert figures on the MathCAD scratchpad, you might think that the program has built-in drawing functions. This is not the case. If you want to use a figure in a MathCAD document, you must create it in a drawing or CAD program that can create HPGL (Hewlett-Packard Graphics Language) files. You can then translate the file into MathCAD sketch format and import it into a document.

To enable you to print out your journal-like documents, MathCAD supports most popular printers and plotters, including postscript printers. And as if this weren't enough, MathSoft devotes 18 pages of the Reference manual to describing its printer and plotter drivers so that you can add your own, if necessary.

At this point, you may be wondering if MathCAD has any drawbacks other than its sluggish operation on PCs and XTs. It does. MathCAD cannot do symbolic math. Anytime you want MathCAD to solve an equation, it attempts to calculate a numerical answer. Thus, you usually need to provide values for all constants and all but one of the variables in an equation.

MathCAD's 262-page user manual is very nicely done, often including one or two screen shots on a page to explain operation of the program. Also included is a Reference manual and a Quick Reference manual. What is missing, however, is a Quick Start section in the manual.

Comments & Conclusions

With its beautiful displays as an inducement, MathCAD can easily lure you into giving up your old calculator, spreadsheet or self-written programs. And for some, the switch to MathCAD may prove very satisfying. MathCAD is a full-featured and powerful program that especially excels in its ability to display equations in mathematical notation and solve and graph those equations. What you may find distracting, though, is the speed at which it operates (especially if you do not have a math coprocessor installed in your computer) and the way it forces you to cursor around the screen to place equations, text, graphs and figures in a document. This program sorely needs a mouse for navigation. Other problems with MathCAD are its inability to perform symbolic math and its lack of a true programming language.

At a price of almost $500, MathCAD is for engineers or educators with high-powered PCs who not only need a program to solve problems, but also need one that can generate high-quality technical documents.

Derive v. 1.60

Getting an A + in symbolic math

It's hardly a surprise when a computer program spits out the answer to a math problem such as 2^{32} in a fraction of a second. It is a surprise, however, when a program can perform a relatively simple mathematical exercise such as finding the factors of $x^2 + 2x + 1$. In the first case, the solution depends on number crunching, something computers do exceedingly well. In the second case, the solution depends on something else, and only a program that performs symbolic math can give you the answer. Derive from Soft Warehouse (3615 Harding Ave., Suite 505, Honolulu, HI 96816; 808-734-5801) is a program that can do symbolic math, just as its predecessor MuMath did, and can crunch numbers, too. Derive is for the IBM PC and compatible computers, requires 512K RAM, and has a suggested retail price of $200.

Derive's Operation

Derive, which comes on a single 5.25-inch 360K floppy, is a menu-driven system. When you start the program, the opening screen is divided into two areas by a horizontal bar. The bottom portion (last four lines) of the

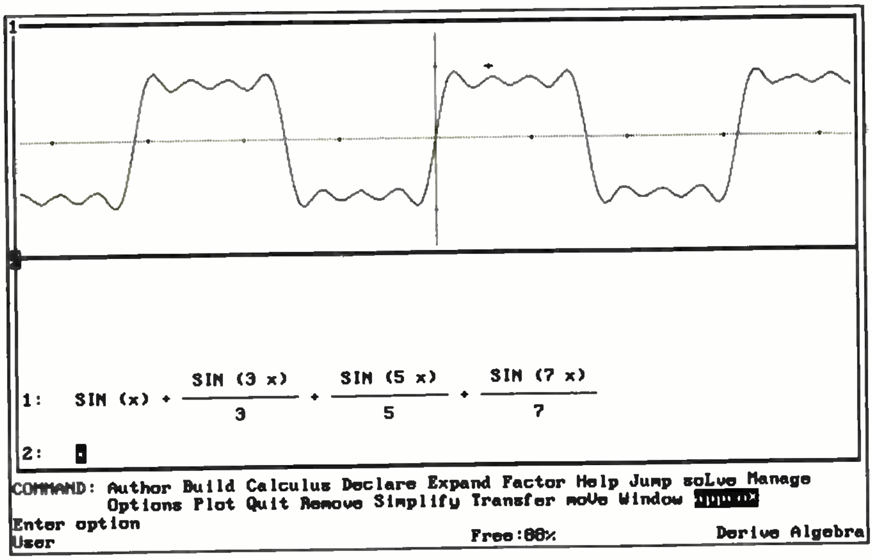


Fig. 3. Derive lets you mix algebra and plot windows.

screen contains the menu, a prompt line and a status line. The first menu you encounter contains 19 choices in two horizontal rows. You make a selection by typing a single letter (usually but not always the initial one) of the command, or by moving the highlight with the space bar or tab key (not the cursor keys) and pressing the Enter key.

The first choice on the menu, Author, lets you enter mathematical expressions or equations into Derive. When you choose Author, the menu disappears and a prompt appears. You can enter an expression, such as 53 * 12 or 2x + 3 or an equation, such as y = mx + b. A nice feature of the program is that it understands implicit multiplication. In other words, if you type two consecutive letters, the program assumes you want them multiplied together. After you type an expression, you press Enter, and the program moves it above the horizontal bar that divides the screen. This upper portion of the screen is known as the work area. Each expression in the work area is given a number, and the most recent entry is highlighted in reverse video.

The program's use of reverse video is interesting. When you first enter an expression, the entire entry is highlighted. You can change the highlight, however, with the cursor keys. You can highlight a portion of an entry, or you can move the highlight to another entry.

Eight of the menu choices directly affect entries in the work area. Some choices, such as Plot, operate on highlighted entries or parts of entries. For example, if the equation y = 2x + 3 is highlighted, and you choose Plot, the program draws the graph of the line y = 2x + 3. However, if you highlight only 2x, the program draws the graph of y = 2x. Other choices, such as Factor, prompt you for the number of the equation that you want to work on.

When the work area is first displayed, it is referred to as an algebra window. This means that equations or expressions entered in the menu area are transformed to look like equations or expressions from a textbook or journal. For example, when you enter an integral at the menu prompt, you do it by typing INT followed by a mathematical expression. However, when the program moves this entry to the work area, it displays a standard integral sign. Or if you want to enter a variable raised to a power, such as x^2, you enter it as x 2 at the menu prompt—the program displays the variable with a superscript in the algebra window. One thing the program does not do, however, is display subscripts.

The algebra window remains in effect until you choose Plot from the menu. Then the work area changes to a plot window. One of the slick features of the program is its ability to open several windows and mix algebra and plot windows on the screen at the same time, as shown in Fig. 3. To do this you choose Window from the main menu.

Though most operations are easily accessed from the main menu, some are inexplicably hidden away in sub-menus. For example, once you enter an expression, it's likely that you'll want to evaluate it at some point. To do this, however, you have to figure out that the Substitute command is in the sub-menu of the Manage command—not very intuitive. Or sometimes the program will give you an answer like $^1/_3$. If you want the decimal form of the answer, you have to scout through the menus to find Decimal as part of a sub-menu of Notation, which is part of a sub-menu of Options.

Although you can enter explanatory text and text expressions in formulas, it is not readily apparent how to do so. You must choose Word from a third-level menu after selecting Options and Input. Or, you can couch your text within quotes, but the quotes remain with the text. To access math symbols such as pi, theta and others, you enter alt-letter combinations.

Derive's Features

Derive is a crackerjack with symbolic math. The program makes it very easy to simplify, factor and expand expressions, and to solve equations for one variable in terms of another. The program also excels at plotting. Derive makes it a simple matter to plot two- and three-dimensional graphs, and to plot more than one graph on an x-y (two-dimensional) axis. There are also features that let you maneuver the plot after it is constructed, such as a zoom feature. One thing you can't do is print plots directly from the program.

Derive can do arithmetic, algebra and calculus, and it can work with vectors and matrices. To facilitate this, the program includes over 100 built-in functions that cover areas such as exponentials, logarithms, trigonometry, complex numbers, probability and statistics and others. If you need a function that the program doesn't address, it's easy enough to define it by selecting Declare from the main menu.

If you're interested in using units of measurement or physical constants in your equations, some are available in separate files supplied with the program. To use them, you merge the files into the current algebra window. If the units or constants you want aren't available, you can enter them by selecting Declare from the main menu.

Derive performs the majority of its math functions within a fraction of a second, without the help of a co-processor (which it will not use, even if you have one). Operations such as certain three-dimensional plots, however, can take several minutes to complete. Loading files from disk is also time-consuming, taking almost a minute to load a file with 40 entries.

Other features of the program include exact arithmetic to thousands of digits, approximate arithmetic to a desired degree of accuracy and integer factoring.

A major drawback of Derive is the lack of a programming language or any way to do recursive calculations. And there isn't any way to enter a range of values into an equation to get a range of results.

To get you up and running, Derive has a 126-page user manual, on-line help arranged by topic and nine demo files. The user manual is well-written and easy to understand, but it could use more sample problems.

Comments & Conclusions

Derive, which Soft Warehouse calls a mathematical assistant for your personal computer, is a well-rounded program that can perform many mathematical functions. The menu system, in general, is easy to learn and use, and the algebraic display is first rate, except for the omission of subscripts. Derive doesn't offer specific solutions for electronics, such as a file with electronics units or a file full of electronics equations, but these can be entered by the user.

Derive does many things, including symbolic math, and does them well. Although it lacks programming features, it's still an excellent program for general mathematical use and should be seriously considered for specific electronics work, too.

CMPCALC4

A calculator for complex computing

CMPCALC4 is a new program from UDH Enterprises (1000 E. William St., Suite 100, Carson City, NV 89701) that turns your PC into a complex number calculator. The program, which has a suggested retail price of $39.95, was written by an electronics engineer to assist in performing analysis of feedback circuits. A subset of the program, called CMPCALC3, is available free from the author for a $5 shipping and handling charge.

CMPCALC4 Operation

When you load CMPCALC4, a single prompt line appears on your screen. It says: Enter Cmplx no. or order ("H" for help). Entering a complex number, such as 4 + 2i, gives you an error message and returns you to the prompt; entering "H" gives you a help screen loaded with too much information. Fortunately, the user manual, which is 16 sheets of paper stapled together and printed on front and back does a better job of getting you started.

The manual explains that the program simulates an RPN (reverse Polish notation) calculator for complex numbers. To enter a complex number, you simply type in the real part, hit the space bar, type in the numerical value of the imaginary part, and press the Enter key. The program then puts the number on the top of the

```
ENTER CMPLX NO.OR ORDER ("H" FOR HELP)
 2.0000000000E+00 3.6700000000E+00
 6.0000000000E+00 6.0000000000E+00
 4.0000000000E+00 3.0000000000E+00




 2.0000000000E+00 3.6700000000E+00      A
```

Fig. 4. When you store a variable in CMPCALC4, it appears at the bottom of the screen with its name beside it.

A Guide to Selecting Math Software and Hardware

In the accompanying article, we reviewed three math programs that run on the IBM PC and compatibles, and in the follow-up article also reviewed a new scientific calculator from Hewlett-Packard. If you're in market for one of these or a competing product, it's likely that you're interested in some or all of the features listed in the Table presented here. The Table gives a "snapshot" of how each of the products reviewed here stack up against each other. Each feature is given a rating from 0 to 5, where 0 is the lowest rating and 5 is the highest.

To give you an example of how we rated each feature, take a look at "Programmability." The HP 48SX has a fine programming language; so it receives a 5. MathCAD and CMPCALC4 don't have a language but let you run commands automatically—this gets them a rating of 2. Derive has neither a programming language nor a way to execute commands automatically, so it receives a 0. If you're interested in the programming capabilities of the product, you could use this information to guide your choice of product. If, on the other hand, you're more interested in a program's ability to do symbolic math, you'll notice that Derive receives a 5, due to its excellent implementation of this feature. The HP 48SX receives a 3 because the feature is useful but has some drawbacks, as noted in the review. The other programs receive a 0 because they lack this feature. Again, if this is a feature you want to see in your program, the Table can help you in your decision.

The Table can also assist you in choosing products other than the ones reviewed here. Just use the features in the Table—along with others that may interest you—as a product selection checklist.

Comparing Product Features

Features	MathCAD	Derive	CMPCALC4	HP 48SX
Calculates range of values	5	0	0	0
Performs symbolic math	0	5	0	3
Factors equations	0	5	0	0
Finds roots of an equation	4	5	0	4
Handles complex numbers	5	4	5	5
Does matrix algebra	5	4	0	5
Does unit conversions	5	5	0	5
Programmability	2	0	2	5
2D plots	5	5	0	5
3D plots	4	4	0	0
Displays math symbols	5	4	0	4
Displays explanatory text	5	4	0	2
Prints a document	5	2	0	2
Electrical engineering modules	5	0	0	4
Price	$495	$200	$39	$350

stack, or storage area—the number appears on the screen just below the cursor prompt.

When a second number is entered, it replaces the first on the top of the stack, and the first is moved down one place. To perform a mathematical operation on the two numbers on the stack, you enter the operator at the prompt. The answer, which appears instantly, then moves to the top of the stack and the other numbers are erased. All numbers on the stack are displayed in scientific notation with 10 decimal places.

If you want to store a number, you enter it and then enter a command such as STO A (where *A* is a label). The number appears in a storage area at the bottom of the screen with the label name beside it, as shown in Fig. 4. You can store up to nine numbers in this area, and an additional 41 more that are not displayed.

If you want to automate procedures, you can do it by entering MEM at the prompt. CMPCALC4 lets you enter up to 500 steps and save them to a disk file. To re-run the sequence of steps, you load the file from disk with the LOAD command and then enter the RPT command.

CMPCALC4 Features

The obvious highlight of this program is its ability to perform mathematical operations on complex numbers. Besides the four main operations (+, −, * and /), the program performs complex exponential, logarithmic, trigonometric, hyperbolic and square-root operations. The program also has a few functions that it can perform, such as DUP (duplicate), SWAP and SWI (switch).

Automated procedures can use any command that can be entered at the prompt, plus a few others, which amounts to about 12 commands in all. There is also a way to call one file from another and to designate a file as a subroutine. Although the author states that CMPCALC4 has a programming language, there are no conditional, testing or looping commands available.

Included on the CMPCALC4 disk are three other useful programs: EDCALC4, QUINT, and POLSLV.

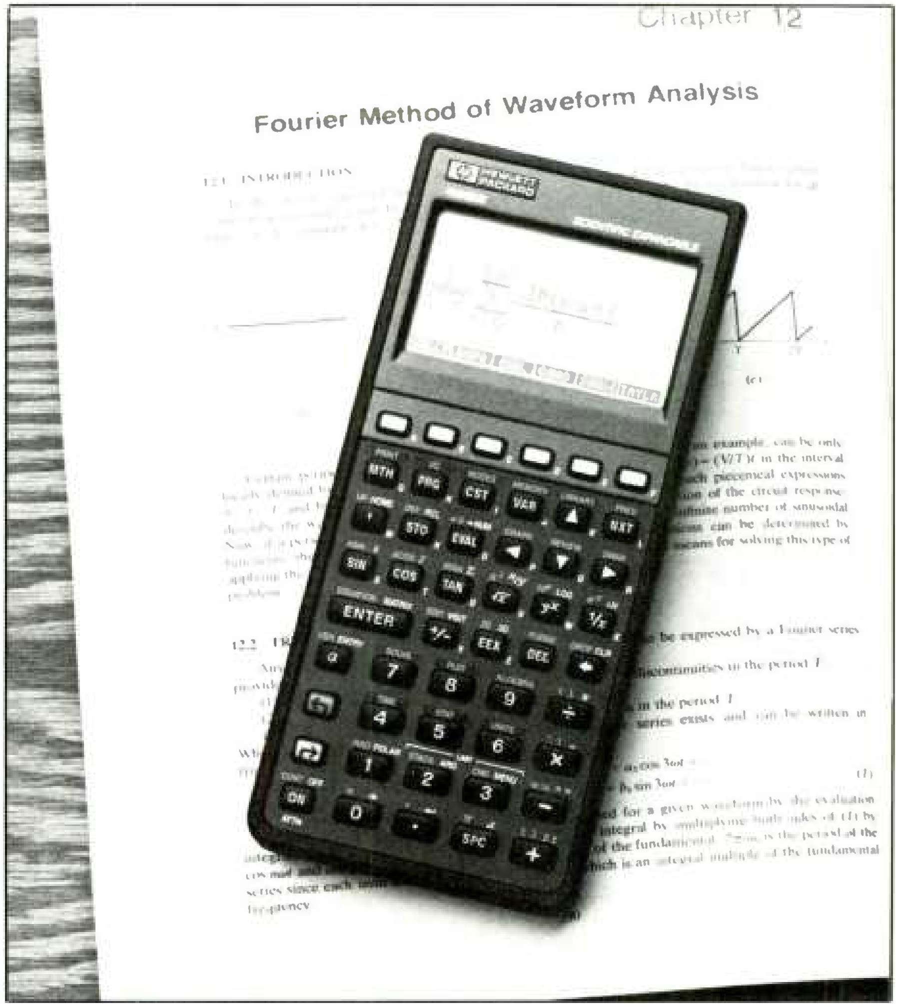
EDCALC4 is a text editor for the procedures you create with CMPCALC4. QUINT is a program that solves up to fifth-degree polynomials with real coefficients. POLSLV is a program that solves up to 20th-degree polynomials with real coefficients. The difference between QUINT and POLSLV is the approach used to solve the polynomials.

Although the user guide isn't professionally printed and contains some punctuation errors, it does a good job of explaining the program and gives some valuable examples from the author's engineering experience. In one example, he explains how the program can help you plot amplifier characteristics and Nyquist diagrams. However, the program itself doesn't permit the user to do any plotting or printing.

Comments & Conclusions

CMPCALC4 is a specialized tool that can help you deal effectively with complex numbers. The program has several limitations, it's true—namely, the user interface, an exclusive use of scientific notation and lack of printed output. But CMPCALC4 is easy enough to learn and use—with the help of the manual—and contains enough features to enable you to perform calculations and create automated procedures. Thus, if you work with complex numbers all the time and don't have a satisfactory tool to deal with them, CMPCALC4 is a good low-cost choice for the job.

H-P's Newest Scientific Calculator



For electronics engineers, technicians, educators and students involved in electronics, a scientific calculator is an indispensable tool for solving problems. These calculators have been around for many years, but it seems that each time a new model appears it has more features than any preceding it. This is just the case with the HP 48SX, the newest entry from Hewlett-Packard, a company known for its leadership position in this field. In fact, the HP 48SX combines the best features found in two earlier Hewlett-Packard products. It has the calculation and graphics capabilities of the HP 28S and the flexibility and expandability of the HP 41.

The HP 48SX, called a scientific expandable calculator, has advanced features that let you enter equations just as you would see them in a textbook or journal. It also allows you to manage unit conversions, such as changing feet to meters. These advanced features complement a long list of others, which are packaged in a unit that includes 256K ROM, 32K RAM, an 8-line by 22-character super-twisted liquid-crystal display

(Continued on page 70)

An MC68701 Microcomputer Chip Programmer

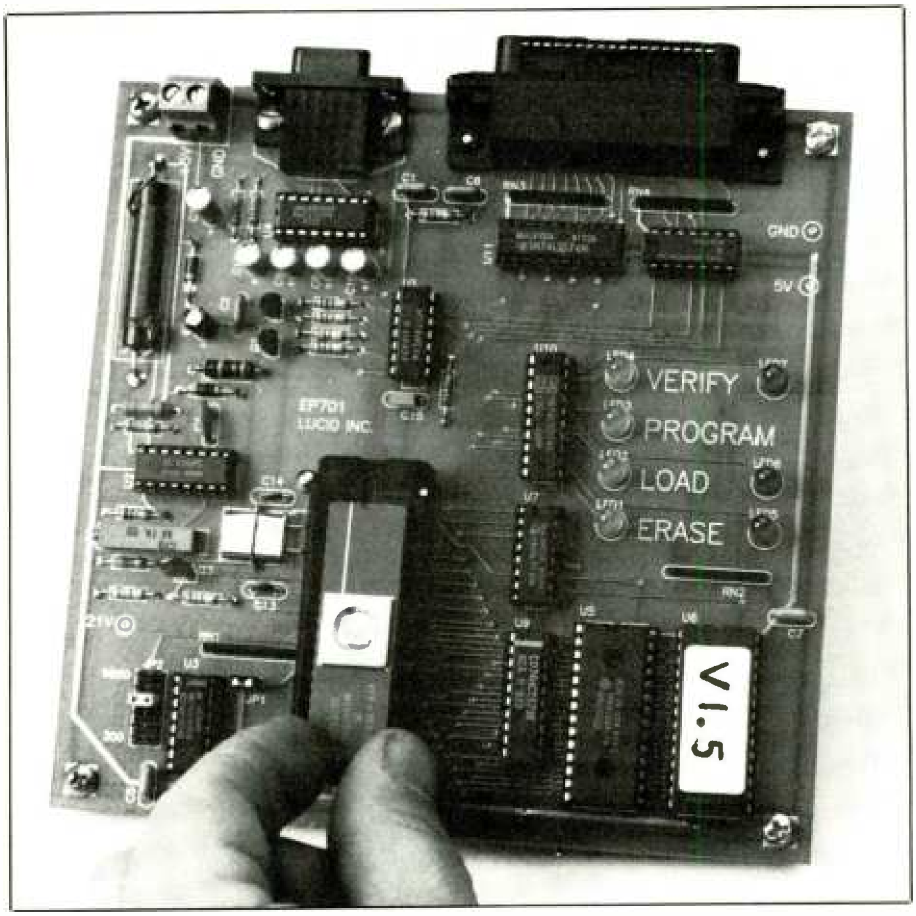
A computer-controlled device for programming the MC68701 to customize it for your application

By Brian B. Beard

In the past April issue, we familiarized you with the features and functions of the 68701 single-chip microcomputer IC in enough detail for you to utilize it in your own projects. This month, our discussion focuses on a programmer that permits you to program the on-chip ROM built into the 68701.

Programming single-chip microcomputers can present major problems because the unusual pinouts used make them incompatible with standard EPROM programmers. Low-cost programmers often require the additional steps of first programming a 27XX series EPROM first. This EPROM is then used to transfer on-board data to the single-chip microcomputer chip. The two-step process can be annoyingly slow and requires the use of two programmers.

In contrast, the Programmer to be described is the *only* one needed to program the 68701 chip. It is flexible, fast and easy to use as well. Operated from a single 5-volt dc supply, it features its own dc-to-dc converter that provides the 21 volts required for successful programming. Light-emitting diodes indicate the status of the programming process, and a parallel printer port permits connection to virtually any personal computer.



About the Circuit

Figure 1 is a block diagram of the various elements that make up the Programmer. As you can see, at the heart of the six basic blocks is the one labeled CPU. The heavy lines routed from the CPU to the LED INDICATORS and PRINTER PORT blocks indicate an eight-line bus. All other lines indicate single-conductor lines between the various elements that make up the Programmer.

Figure 2 is the schematic diagram of the Processor and Memory circuits. Microcomputer chip *U8* runs the programming process. When power is applied to the Programmer, *U8* begins in mode zero, the only mode that allows the EPROM to be programmed. Instead of fetching the reset vector at $FFFE, *U8* fetches the starting address from $BFFE in mode zero.

Table 1 shows the memory map of the Programmer. The operating program and interrupt vectors are programmed into 2764 EPROM *U6*. This program determines the 68701 type in use (standard or U4 version)

Table 1. Memory Map for Programmer

68701	68701U4	
$0000-$001F	*	MPU Registers (68701)
$0020-$007F	$0020-$003F	Unused
$0080-$00FF	$0040-$00FF	Internal RAM (68701)
$0100-$5FFF	*	Unused
$6000-$7FFF	*	Printer Port Input
$8000-$9FFF	*	External RAM (6264)
$A000-$BFEF	*	External EPROM (2764)
$BFF0-$BFFF	*	External Interrupt Vectors (2764)
$C000-$DFFF	*	LED Output
$E000-$F7FF	$E000-$EFFF	Unused
$F800-$FFFF	$F000-$FFFF	Internal EPROM (68701)

and adjusts the size of the buffers in 6264 RAM *U5* accordingly.

The status of the programming process is indicated by light-emitting diodes *LED1* through *LED7* in Fig. 3(A). Each pair of LEDs is assigned a different function to monitor and report upon, whether the process was a success OKAY or a failure FAIL, with green indicating success and red indicating failure. For *LED1* and *LED5*, the function is ERASED; *LED2* and *LED6*, LOAD; *LED3*, PROGRAM; and *LED4* and *LED7*, VERIFY.

In this Programmer, the Serial Port, shown schematically in Fig. 3(B), is RS-232-compatible, which makes it usable with just about every personal computer now in use. MAX232 serial chip *U4* contains two RS-232 drivers, two RS-232 receivers and an on-chip charge pump. The charge pump uses the 5-volt dc supply line to generate the bipolar voltages required by the RS-232 drivers.

Listed in Table 2 are the pinouts for the serial connector on the Programmer. No handshaking controls are actively controlled by the Programmer, and DTR is not connected (and is, thus, ignored) by the Programmer. DSR and DCD are wired to the "on" condition, or +V, at all times. RTS is received, buffered and looped back to the host at CTS, which makes CTS track RTS.

Baud rate of the Programmer is selected with jumper network *JP2*, while jumper *JP1* permits selection of either modem (0) or printer (1). All standard rates from 300 to 9,600 baud are selectable with appropriate position of *JP2*.

Shown schematically in Fig. 3(C) is the circuitry for the Parallel Printer Port. Each data byte sent to the printer or, in this case, the Programmer, is signaled by DST strobing low, which sets the flip-flop made up of *U12C* and *U12D*. This sets the BUSY line and latches the new data byte into *U11*. The 68701 microcomputer chip in Fig. 2 monitors the BUSY line (P17). When it detects activity on this line, it reads the new data byte from *U11* in Fig. 3(C).

After processing the new data byte, *U8* strobes ACK (acknowledge) at *P16* low. The rising edge of ACK clears the *U12C/U12D* flip-flop, which clears the BUSY line to allow the host computer to send the next data byte.

The only power required by the Programmer is 5 volts dc at 500 milliamperes. The +21 volts (V_{pp}) needed to program the EPROM is supplied by the Dc-to-Dc Converter circuit shown schematically in Fig. 4(A). Trimmer potentiometer *R10* permits

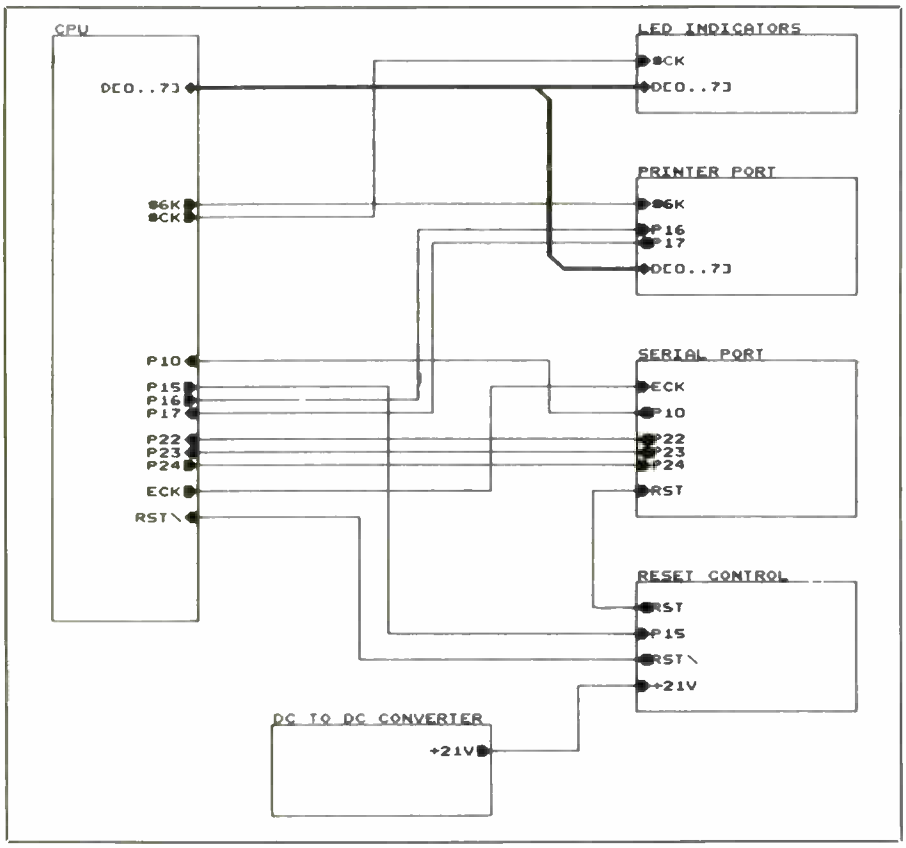


Fig. 1. Overall block diagram of the elements that make up the Programmer.

adjustment of V_{pp} to the required +12-volt level needed for programming. This +21 volts is applied to RESET pin 6 of *U8* only when the internal EPROM is being programmed. Power is distributed to the various ICs that make up the programmer as specified in the Table that accompanies Fig. 4(A). Switching of V_{pp} is accomplished with the circuit shown schematically in Fig 4(B).

The Programmer does not feature its own ac-operated 5-volt dc power supply. While it is a valuable tool, the Programmer is not the type of project that you will use every day or even fairly often. Therefore, since most hobbyists and experimenters will already have on hand a suitable regulated 5-volt dc bench supply, this can be used when needed. If you do not already have such a supply, or wish to make the project self-contained, you can build any of a number of such supplies from the projects presented in *Modern Electronics* and other periodicals and books. You can even use a plug-in wall-type 5-volt supply that is capable of delivering 500 milliamperes or more of current.

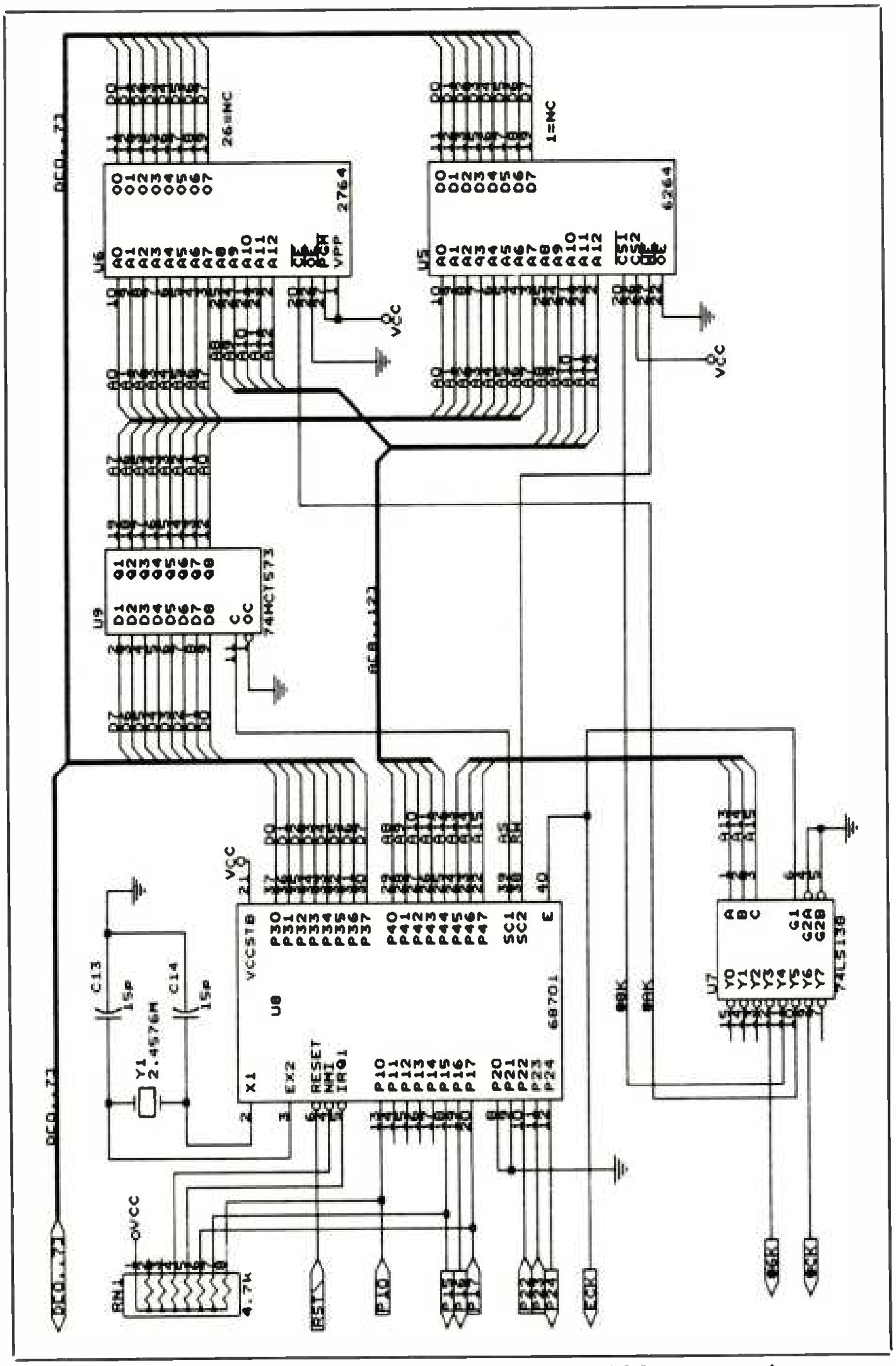


Fig. 2. Schematic diagram of the Processor and Memory sections.

Construction

As you can see from the fairly large number of schematic diagrams presented here, the Programmer is a fairly complex piece of hardware. The large number of interconnections makes point-to-point wiring a task that should be performed only if you are an experienced project builder who is comfortable with the Wire Wrap technique. Otherwise, it is strongly recommended that you purchase a ready-to-wire printed-circuit board from the source given in the Note at the end of the Parts List.

If you are an experienced project builder and have confidence in your abilities to successfully wire together such a complex circuit, you can do so using perforated board that has holes on 0.1-inch centers and suitable Wire Wrap hardware. But work very carefully, and strike off each conductor run as you make it.

Whichever method of construction you use, it is a good idea to use sockets for all DIP ICs and a ZIF (zero-insertion-force) socket for *U8*.

Home fabrication of the double-sided printed-circuit board for the project is not recommended as practical because of the need for plating-through the holes that interconnect conductors located on both sides of the board. The ready-to-wire pc board from the kit supplier has plated-through holes and is silk-screened on the component side for

Table 2. Serial Port Connector Pinouts

Pin	Circuit	Description	Direction
1	CF	Carrier Detect (DCD)	From Programmer
2	BB	Receive Data (RD)	From Programmer
3	BA	Transmit Data (TD)	To Programmer
4	CD	Data Terminal Ready (DTR)	No Connection
5	AB	Signal Ground (SG)	N.A.
6	CC	Data Set Ready (DSR)	From Programmer
7	CA	Request To Send (RTS)	To Programmer
8	CB	Clear To Send (CTS)	From Programmer
9	CE	Ring Indicator (RI)	No Connection

easy component installation.

Assuming you are using the pc board, start wiring it by installing the sockets for the ICs. If you go the Wire Wrap route, arrange and orient the components as near to the layout shown in the photo at the beginning of this article. Whichever method of construction you use, however, do *not* plug the ICs into the sockets until after you have conducted preliminary voltage checks and are satisfied that the project has been properly wired.

Once the sockets are mounted in place, proceed with installation of the resistors, capacitors, crystal and jumper pins. Make certain that the electrolytic capacitors are properly polarized before soldering their leads into place. Continue wiring the board with installation of the LEDs and transistors. Again, make certain that the LEDs are properly oriented and the leads of the transistors go into the proper holes before soldering any pins into place.

Mount power terminal strip *J1*, DB-9S serial connector *J2* and parallel printer connector *J3* in their respective locations. Then mount and solder into place trimmer potentiometer *R10*. Finally, mount sufficiently long "legs" at the four corners of the circuit-board assembly for the components mounted on it to clear whatever surface upon which the project sits. Use suitable length spacers and machine screws for the legs. Alternatively, you can build a wooden frame of sufficient depth in which to mount the Programmer to accomplish the same ends.

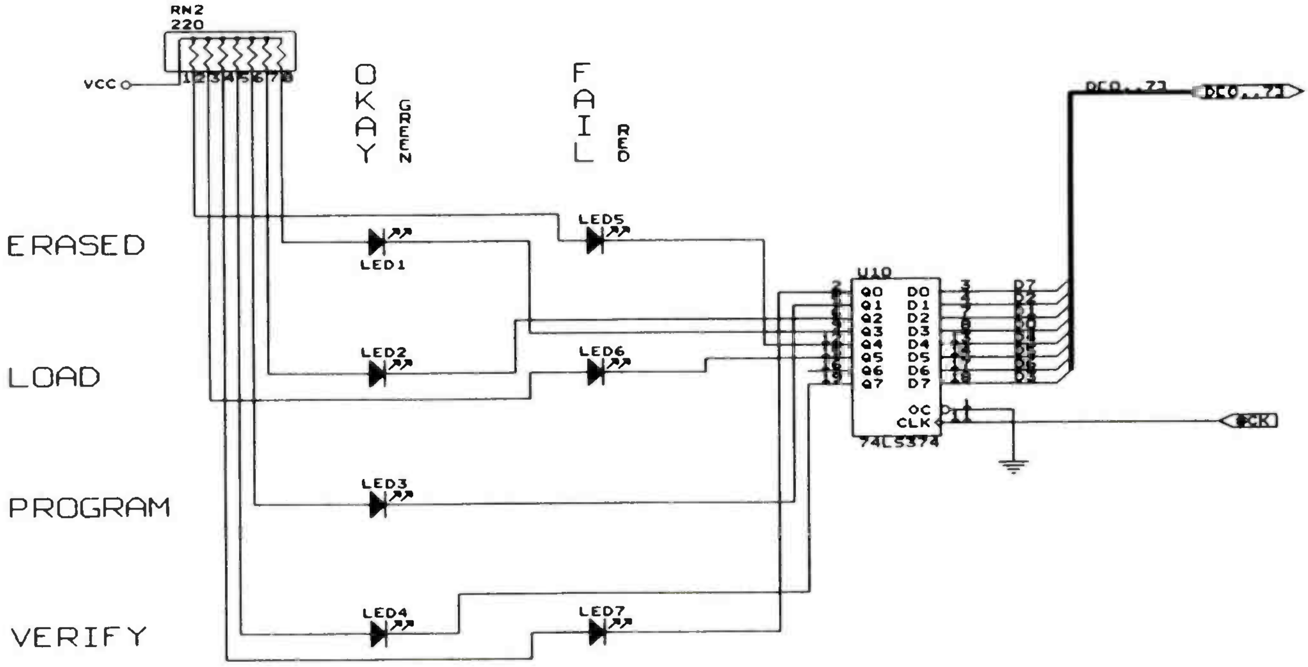
Initial Checkout

The only instrument you need to check out the Programmer is a dc voltmeter or a multimeter set to the dc-volts function. Clip the common lead of the meter to a suitable circuit ground point, such as pin 2 of *J1*. With no ICs installed in the sockets, apply +5 volts dc to the Programmer

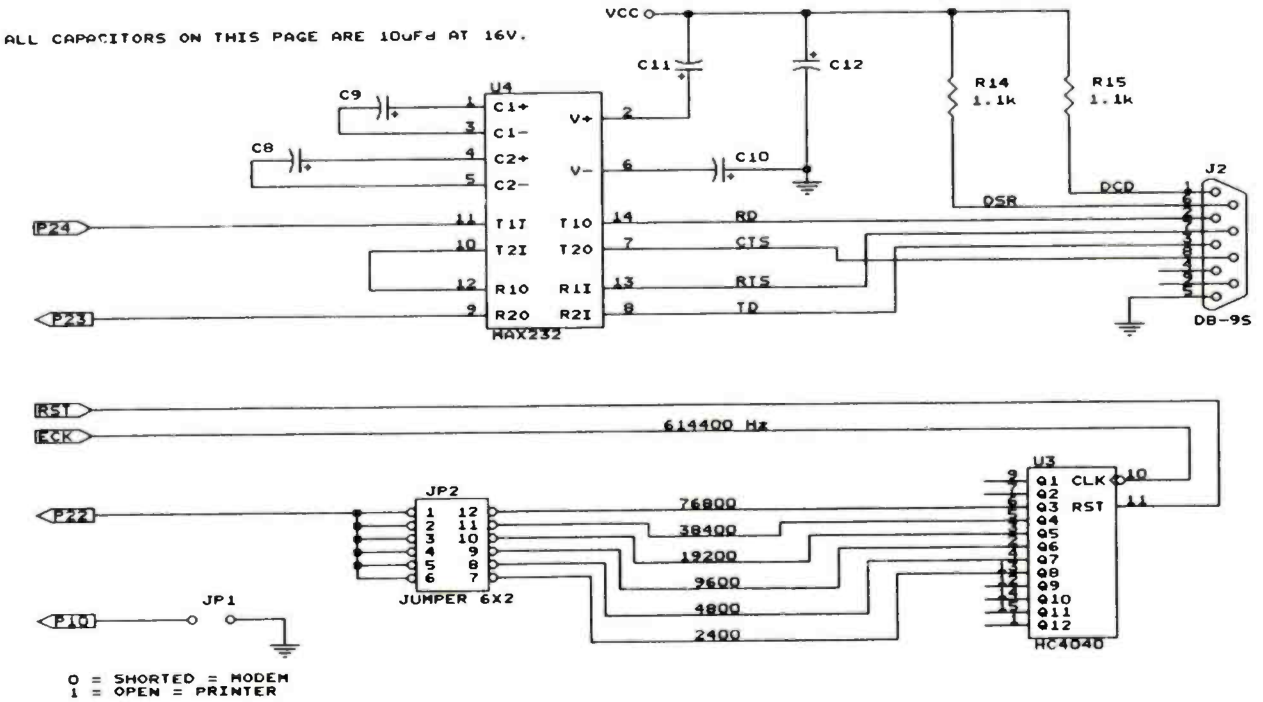
PARTS LIST

Semiconductors
D1,D2—1N5819 diode
LED1 thru LED4—Green light-emitting diode
LED5 thru LED7—Red light-emitting diode
Q1,Q2—2N3904 silicon npn transistor
Q3—2N3906 silicon pnp transistor
U1—74HC14
U2—78S40
U3—HC4040
U4—MAX232
U5—6264
U6—2764 64K EPROM
U7—74LS138
U8—MC68701 single-chip micro computer
U9—74HCT573
U10,U11—74LS374
U12—74LS00
Capacitors
C1,C2,C5,C6,C7—0.1-μF ceramic disc
C3—22μF, 50-volt radial-lead electrolytic
C4—680-pF ceramic disc
C8 thru C12—10-μF, 16-volt radial-ead electrolytic
C13,C14—20-pF ceramic disc
C15—0.01-μF ceramic disc
Resistors (¼-watt, 5% tolerance)
R1 thru R4—1,500 ohms
R5,R6—6,800 ohms
R7,R11—100,000 ohms
R9—130 ohms
R12—4,700 ohms
R13—0.62 ohm
R14,R15—1,100 ohms
R16—100 ohms
R8—270 ohms, ½-watt
R10—1,000-ohm, ¾-inch pc-mount trimmer potentiometer
RN1,RN3,RN4—4,700-ohm eight-pin SIP resistor network with pin 1 common
RN2—220-ohm eight-pin SIP resistor network with pin 1 common
Miscellaneous
J1—Two-position power terminal strip
J2—Pc-mount DB-9S serial D-type connector
J3—Pc-mount 36-pin parallel printer connector
JP1—Single jumper assembly
JP2—6 × 2 jumper assembly
Y1—2.4576-MHz solder-mount crystal in HC-18 case
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap hardware (see text); sockets for all ICs except ZIF socket for U8 (see text); 5-volt, 500-mA dc power supply (see text); solder; etc.

Note: A minimal EP701 Programmer kit containing a silk-screened double-sided pc board with plated-through holes and solder mask; programmed 2764 EPROM; and documentation diskette in 360K IBM format is available for $35 from Lucid Inc., P.O. Box 292, Mary Esther, FL 32569. Florida residents, please add state sales tax. All other components are available from local suppliers and mail-order houses.

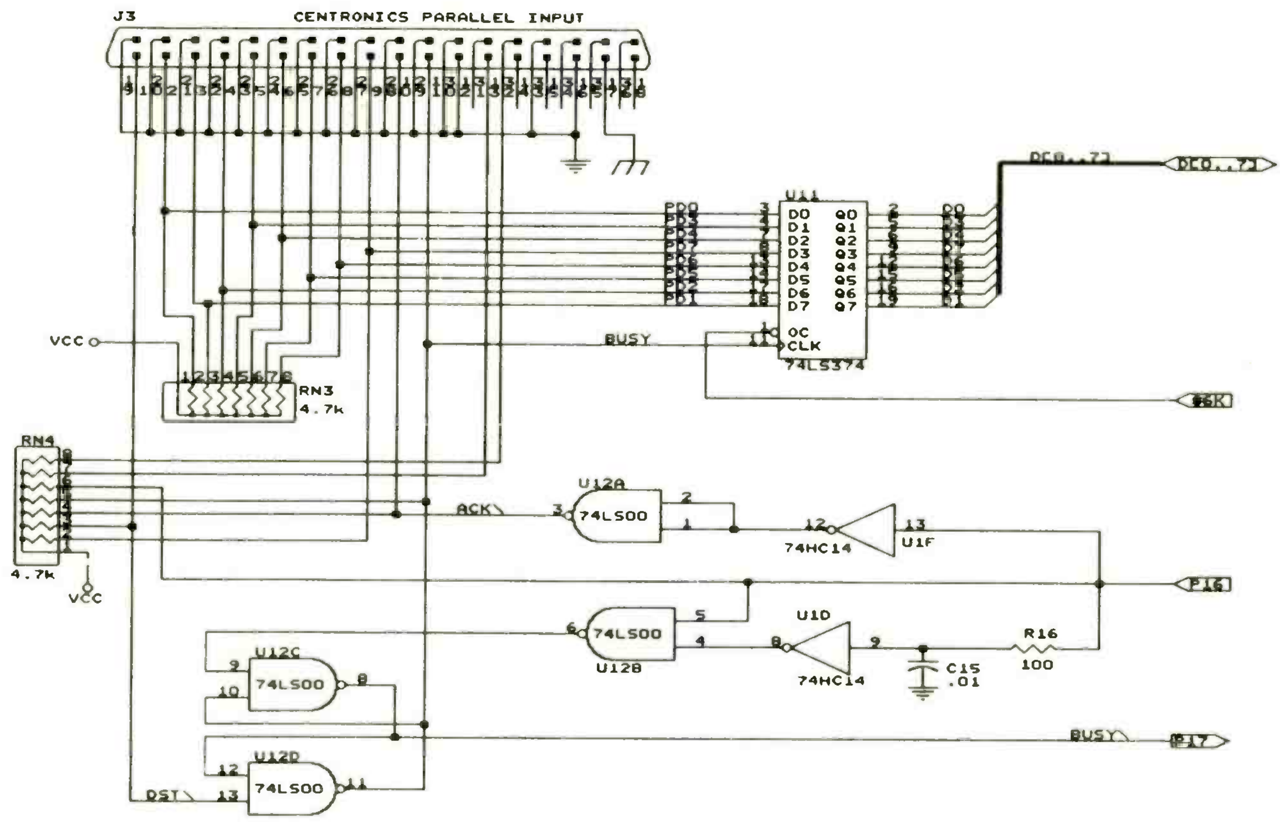


(A)



68701 Baud Clock pin P22	Baudrate
76800	9600
38400	4800
19200	2400
9600	1200
4800	600
2400	300

(B)



(C)

Fig. 3. Schematic details of the Programmer's (A) LED indicator, (B) Serial Port and (C) Parallel Port circuits.

via *J1*, making certain that the power source is properly polarized.

With power applied to the project, touch the "hot" probe of the meter to each of the V_{cc} socket pins indicated for *U1* through *U12* in the table accompanying Fig. 4(A). In all cases, you should obtain a reading of approximately +5 volts.

If you fail to obtain the proper reading at any one or more points in the circuit, power down the Programmer and rectify the problem. Check to make sure that all components are in the correct locations and that all are properly oriented and based. Check to make sure that all components are soldered into place. Solder any connection you might have missed and reflow the solder on any suspicious connection. If you locate any solder bridges, particularly between the closely spaced pads for the IC sockets, clear it with desoldering braid or a vacuum-type desoldering tool. Do not proceed until you have rectified the problem.

Once you are certain that the project is properly wired, plug the 78S40 into the *U2* socket. Make certain that the chip is properly oriented and that no pins overhang the socket or fold under between IC and socket. (This applies for *all* IC installations.) Reapply 5 volts dc to the project.

With the common lead of the meter still connected to circuit ground, touch the "hot" probe to pin 1 of *U2*, and adjust the setting of trimmer control *R10* for a reading of +21 volts. If you are using a digital meter, you may notice that the reading jumps between 20.8 and 21.2 volts. This is caused by the slow switching speed of *U2*. When the 68701 that will be plugged into the *U8* socket is not programming its EPROM, there is very little current drawn; so the slow switching speed will effortlessly keep up with the demand.

Now use the "hot" probe to measure the potential at RESET pin 6 of the *U8* socket. Your reading should be about +4.9 volts. If it is 21 volts or so, there is a problem with the circuitry around *Q1* and *D3*; if near ground potential, the problem is in the *Q2* circuitry. Whatever the case, if a problem exists, power down the project and rectify the problem.

Once you obtain the proper readings at all specified points in the circuit, power down the Programmer, remove the meter from the circuit-board assembly and allow the charges to bleed off the electrolytic capacitors. Then plug the ICs into their respective sockets. Install an erased 68701 in the *U8* ZIF socket. *Note:* Whenever you install or remove the 68701, make absolutely certain that you first disable power to the circuit! Otherwise, you run the risk of permanently damaging the microcomputer chip.

Place a jumper on the JP1 pins. Then place another jumper on the JP2 pins for the baud rate you wish to use. Turn on power to the Programmer and note that all LEDs, except the OKAY one for the ERASE function, come on for about a second and then extinguish.

Using the Programmer

Your Programmer is now ready to be put into operation. To operate it, connect the Programmer to your computer via either its Serial or Parallel Port, using the appropriate cable. In the case of the Parallel Port connection, you simply unplug the cable from your printer and plug it into Parallel Port connector *J3*.

If you are using the Serial Port arrangement, bear in mind that the Programmer is designed to operate as a DCE device. It uses a nine-pin female-type D connector that is directly compatible with nine-pin COMM ports on most IBM PCs and compatibles. The pin assignments and signal directions for Serial Port connector *J2* are enumerated in Table 2. If your modem or serial printer uses a 25-pin D connector, you must make an adapter cable to use the Programmer with it. Be sure when making this cable that you check the definitions of the lines on your computer and match them with the correct lines of the Programmer.

You can operate your Programmer in either of two modes. If jumper *JP1* in Fig. 3(B) is not bridging (shorting together) the two contacts

A 68701 Assembly-Language Programming Example

A good way to show you how to use the Programmer described in the main article is to step you through a sample assembly-language program. Such a program is that provided in Listing 1. Comments, like the first line of the program, begin with an asterisk (*). The next eight lines in the program are examples of the EQU, or "equate," directive, which allows you to assign a name to a numerical value. After this, you can use the name instead of the value, which makes the program easier to read. For example, consider the following two lines of code:

```
P1DDR  EQU  00
       CLR  P1DDR
```

The first line assigns the name "P1DDR" (Port 1 Data Direction Register) to the value zero. The second line clears the data at address P1DDR—in this case, address 00. The same thing can be done with CLR 00, but using the name P1DDR gives clearer meaning to the intent of the code.

Equate directives are valuable programming tools in that they help you to create an environment that uses familiar names. However, equate directives generate no executable code.

The next directive you come to in Listing 1 is ORG, or "originate." This directive tells the assembler where code should be placed in memory. In Listing 1, the code would be assembled to start at location F800, which is the bottom of the internal EPROM for a standard 68701 microcomputer chip.

Executable code is divided into two parts. These are an initialization section that begins at the label RESET and a main program that begins with the label LOOP.

Initialization begins by disabling all maskable interrupts. It then sets the stack pointer to address 00FF, which is the top of the RAM internal to the 68701. Next, it clears the Port 1 Data Direction Register at address 00. Accumulator A is loaded with the value FF. Note that this instruction uses immediate addressing (#); so the Accumulator is loaded with the literal value FF, not the data stored at address FF. Finally, Accumulator A is stored at Port 3

Listing 1. Assembly Language Source Code

```
*EXAMPLE ASSEMBLY LANGUAGE PROGRAM FOR THE 68701
P1DDR    EQU     $00      *PORT 1 DATA DIRECTION REGISTER
P2DDR    EQU     $01      *PORT 2 DATA DIRECTION REGISTER
P1DAT    EQU     $02      *PORT 1 DATA REGISTER
P2DAT    EQU     $03      *PORT 2 DATA REGISTER
P3DDR    EQU     $04      *PORT 3 DATA DIRECTION REGISTER
P4DDR    EQU     $05      *PORT 4 DATA DIRECTION REGISTER
P3DAT    EQU     $06      *PORT 3 DATA REGISTER
P4DAT    EQU     $07      *PORT 4 DATA REGISTER
*
         ORG     $F800    *START OF INTERNAL EPROM
RESET    SEI              *DISABLE MASKABLE INTERRUPTS
         LDS     #$00FF   *INITIALIZE STACK POINTER
         CLR     P1DDR    *MAKE PORT 1 LINES ALL INPUT
         LDAA    #$FF
         STAA    P3DDR    *MAKE PORT 3 LINES ALL OUTPUT
         STAA    P4DDR    *MAKE PORT 4 LINES ALL OUTPUT
LOOP     LDAA    P1DAT    *READ THE DATA AT PORT 1
         STAA    P3DAT    *SEND IT OUT ON PORT 3
         COMA             *COMPLEMENT IT
         STAA    P4DAT    *PUT THE COMPLEMENT OUT ON PORT 4
         JMP     LOOP     *GO BACK AND DO IT AGAIN
*INTERRUPT VECTORS
         ORG     $FFF0
         FDB     RESET    *SERIAL COMM
         FDB     RESET    *TIMER OVERFLOW
         FDB     RESET    *OUTPUT COMPARE
         FDB     RESET    *INPUT CAPTURE
         FDB     RESET    *EXTERNAL INTERRUPT
         FDB     RESET    *SOFTWARE INTERRUPT
         FDB     RESET    *NONMASKABLE INTERRUPT
         FDB     RESET    *RESET
*
```

Listing 2. Assembler Listing

```
                      *EXAMPLE ASSEMBLY LANGUAGE PROGRAM FOR THE 68701
0000                  P1DDR   EQU    $00    *PORT 1 DATA DIRECTION REGISTER
0001                  P2DDR   EQU    $01    *PORT 2 DATA DIRECTION REGISTER
0002                  P1DAT   EQU    $02    *PORT 1 DATA REGISTER
0003                  P2DAT   EQU    $03    *PORT 2 DATA REGISTER
0004                  P3DDR   EQU    $04    *PORT 3 DATA DIRECTION REGISTER
0005                  P4DDR   EQU    $05    *PORT 4 DATA DIRECTION REGISTER
0006                  P3DAT   EQU    $06    *PORT 3 DATA REGISTER
0007                  P4DAT   EQU    $07    *PORT 4 DATA REGISTER
                      *
f800                          ORG $F800     *START OF INTERNAL EPROM
f800 0f               RESET   SEI           *DISABLE MASKABLE INTERRUPTS
f801 8e 00 ff                 LDS #$00FF    *INITIALIZE STACK POINTER
f804 7f 00 00                 CLR   P1DDR   *MAKE PORT 1 LINES ALL INPUT
f807 86 ff                    LDAA   #$FF
f809 97 04                    STAA P3DDR    *MAKE PORT 3 LINES ALL OUTPUT
f80b 97 05                    STAA P4DDR    *MAKE PORT 4 LINES ALL OUTPUT
f80d 96 02            LOOP    LDAA P1DAT    *READ THE DATA AT PORT 1
f80f 97 06                    STAA P3DAT    *SEND IT OUT ON PORT 3
f811 43                       COMA          *COMLPEMENT IT
f812 97 07                    STAA P4DAT    *PUT THE COMPLEMENT OUT ON PORT 4
f814 7e f8 0d                 JMP   LOOP    *GO BACK AND DO IT AGAIN
                      *INTERRUPT VECTORS
fff0                          ORG $0FFF0
fff0 f8 00                    FDB   RESET     *SERIAL COMM
fff2 f8 00                    FDB   RESET     *TIMER OVERFLOW
fff4 f8 00                    FDB   RESET     *OUTPUT COMPARE
fff6 f8 00                    FDB   RESET     *INPUT CAPTURE
fff8 f8 00                    FDB   RESET     *EXTERNAL INTERRUPT
fffa f8 00                    FDB   RESET     *SOFTWARE INTERRUPT
fffc f8 00                    FDB   RESET     *NONMASKABLE INTERRUPT
fffe f8 00                    FDB   RESET     *RESET
                      *
```

and Port 4 Data Direction Registers, which sets all bits of both ports to output status.

The main program begins by loading Accumulator A with the data from Port 1 and storing it at the Port 3 data register. Since Port 3 is all outputs, data written to its Data Register immediately appears on the Port 3 pins of the 68701. Next, Accumulator A is complemented and stored at the Port 4 Data Register. Finally, the program jumps back to LOOP—the top of an infinite loop.

The interrupt vectors are the last part of the listing. There are eight vectors, and each one is a 16-bit address. The processor requires the vectors to be at the very top of the internal EPROM for all modes of operation, except mode zero. An FDB (Form Double Byte) directive places a 16-bit value at the next two bytes in memory. For the example in Listing 1, all vectors are set to the label RESET, which is address F800.

When power is applied to the 68701, a reset interrupt is generated and the vector at FFFE is fetched. In this case, address F800 will be fetched and the program will begin to execute there. The initialization code will run, followed by the main loop. The processor will continuously read the data on Port 1, output it on Port 3 and output its complement on Port 4.

When the source code is assembled, using the freeware cross-assembler from Motorola, two files are created. These are the Listing File given in Listing 2 and the S19 Output File given in Listing 3. The Listing File contains the address and bytes assembled for each line of input, followed by the original source code. The S19 Output File is an ASCII representation of the binary file that will be programmed into the EPROM on-board the 68701.

Listing 3. Assembler S19 Output File

```
S11AF8000F8E00FF7F000086FF97049705960297064397077EF80D7D
S113FFF0F800F800F800F800F800F800F800F8003D      S9030000FC
```

shown, the Programmer acts as a printer. On the other hand, if the jumper is present, the Programmer operates as a modem.

In Printer mode, the Programmer monitors the Parallel and Serial Ports and accepts data from whichever is active. The S19 output of an assembler can be sent to the Programmer just as though it is a printer. For example, on an MS-DOS system, you would simply connect the Programmer in place of your printer and type the normal print command: PRINT (FILENAME).S19.

In printer mode, the Programmer performs all operations automatically. The result of each step in the programming process is indicated by the appropriate LED on the circuit-board assembly. If any step fails, the appropriate red LED lights and the process ceases at that point. When programming is successfully completed, all four green LEDs will be lit.

When power is first applied to the Programmer, all LEDs come on for a second to check their operation. The program then checks the on-board EPROM of the 68701 to determine if it is completely erased. If so, the chip is ready to be programmed, and the green ERASE LED turns on.

The programmer now waits for you to send it an object file via either the Parallel or the Serial Port. The object file must be in the Motorola standard S19 format. Any assembler for the 6801/03 microprocessor will generate this type of output.

As the object file is sent to the Programmer, it is converted to binary format on the fly and is stored in the RAM buffer. If an error occurs during conversion, such as a non-hex character or bad checksum, the red LOAD FAIL LED turns on.

Once the object file is loaded, the internal EPROM can be programmed. Successful completion of the programming step is indicated by an on green PROGRAM OKAY LED.

The last step in the procedure is to verify that the programmed EPROM

IC	+V	GND
U1	14	7
U2	13	3
U3	16	8
U4	16	15
U5	28	14
U6	28	14
U7	16	8
U8	7,21	1
U9	20	10
U10	20	10
U11	20	10
U12	14	7

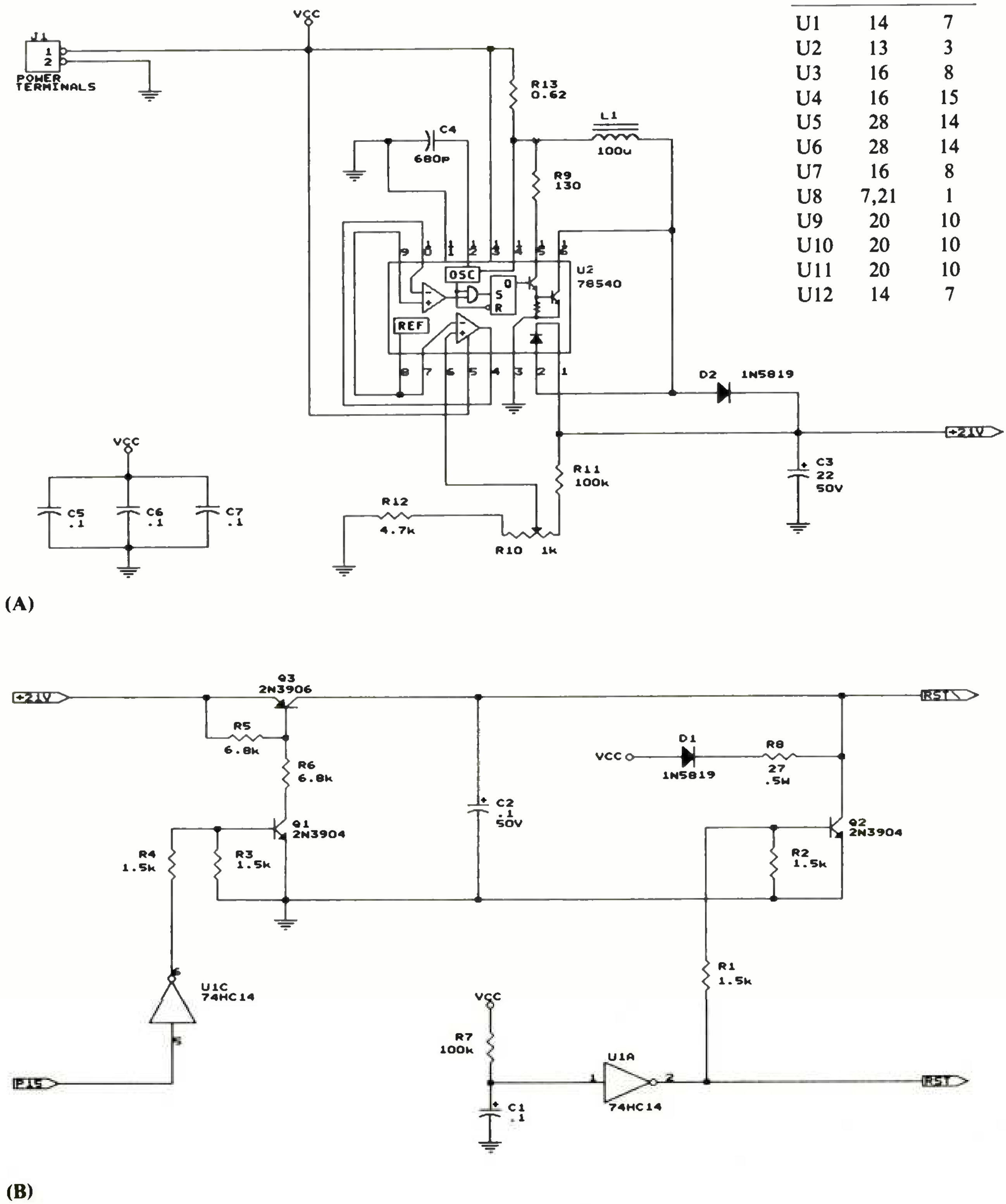


Fig. 4. Schematic details of the Programmer's (A) Dc-to-DC Converter and (B) Reset Control circuits.

Table 3. Modem Mode Menu Screen

```
(U)pload ASCII S1/S9 file to buffer
(P)rogram EPROM from buffer
(V)erify EPROM against buffer
(X) Buffer display, ASCII hex
(Y) EPROM display, ASCII hex
? _
```

is the same as the object file loaded into the RAM buffer. If verification is successful, the green VERIFY OKAY LED turns on. If the verify step fails, the red VERIFY FAIL LED turns on.

In Modem mode, the jumper is present on *JP1* and uses only the Serial Port. To use this option, your computer must be loaded with a communications program capable of handling ASCII file transfers.

Modem mode allows you to interact with the Programmer via the menu shown in Table 3. Bear in mind that this is not an automatic mode. You must tell the Programmer to perform each step of the procedure. These steps normally are:

(1) Upload the ASCII S1/S9 file to the buffer;

(2) Program the on-chip EPROM from the buffer;

(3) Verify the data contents of the EPROM by comparing them with the data file stored in the buffer.

Though Modem mode is not automatic in its operation, it does give you more interactive flexibility than is possible in Printer mode. For example, in Modem mode, if you programmed the 68701 and you cannot remember what program it contains, the Programmer lets you determine what the contents are. With the Programmer, you can upload an object file and verify it against the programmed data in the EPROM to see if both contain the same data.

In Modem mode, the program will not automatically terminate if a step fails. Therefore, you can upload and verify again and again until you locate the correct file. **ME**

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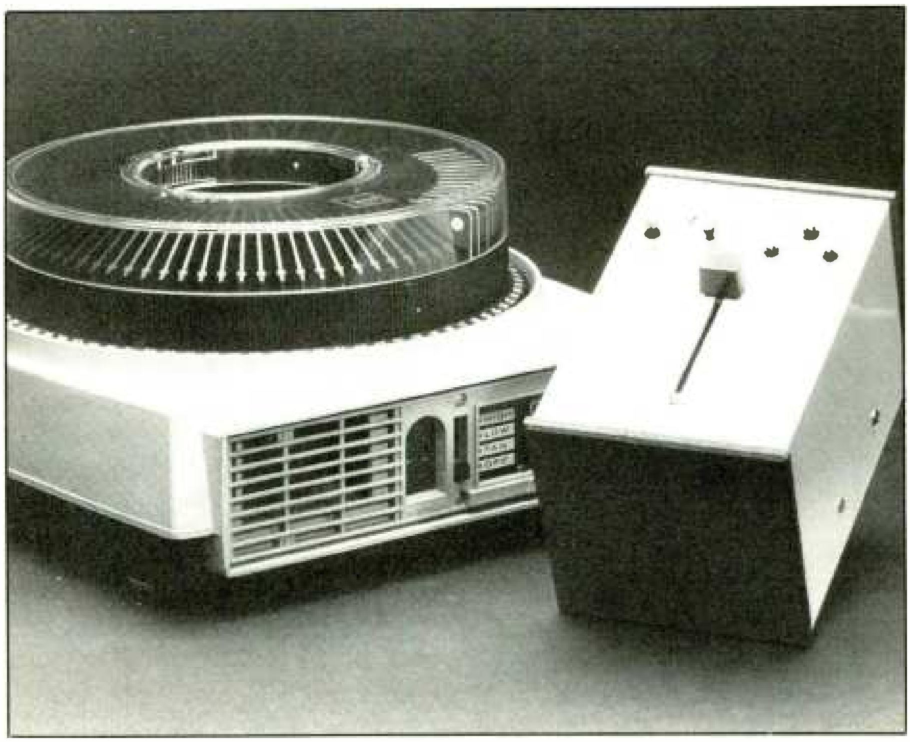
An Electronic Controller For Slide Projectors

Controls on and off of a projector only when a slide is needed and provides a fade-in/fade-out feature for smoother presentations

By David Ponting



The constant whine of the fan motor of a projector can be an irritating distraction to both narrator and audience during a slide presentation. The Electronic Controller project described here will alleviate this problem.

Our Electronic Controller for Slide Projectors is a small device that turns on the projector only when a slide is needed and changes to the next slide before it switches itself off. Additionally, it permits each slide to be faded in and out for a smoother, less jarring visual presentation. The project actually consists of two basic elements—a phase-controlled dimmer circuit for the fade-in/fade-out function and a switch-on/change-slide/switch-off control circuit. The project does not require any modification of the projector itself and is relatively easy to build using readily available components and materials.

About the Circuit

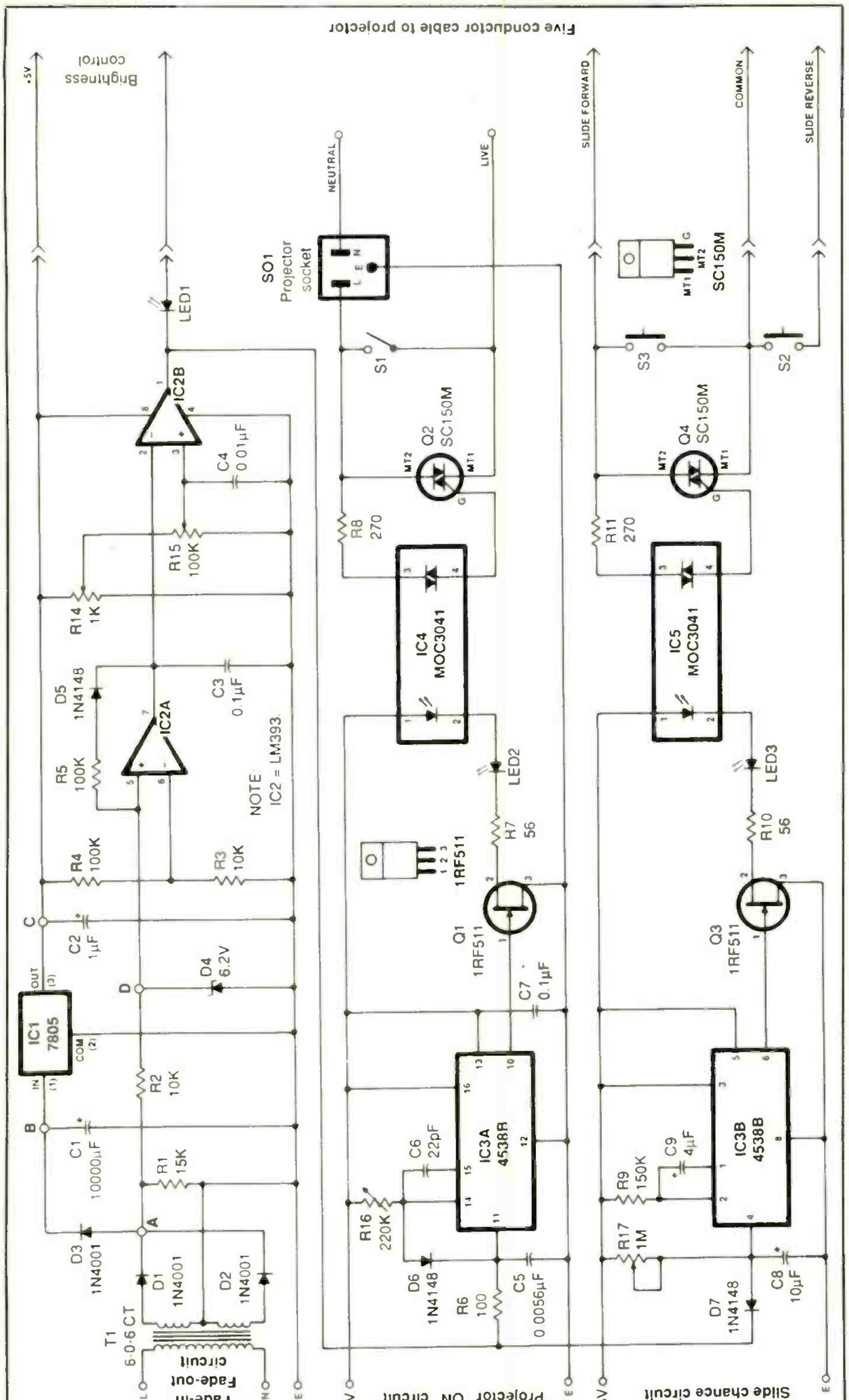
Shown in Fig. 1 is the schematic diagram for the entire Controller circuitry. The fade-in/fade-out dimmer portion of the circuit is composed of both comparators in *IC2*, optical isolator *IC6*, the last stage shown in Fig. 2(A), and each stage's associated components. Note also that the 117-volt ac-line-driven dc power supply for the entire project precedes the dimmer circuit.

The fader circuit was designed around the LM393 dual voltage comparator specified for *IC2*. This particular chip is designed to operate from a single-ended dc power supply.

In Fig. 1, operation of the dimmer circuit is as follows. The low-voltage ac output from power transformer *T1* is passed through rectifier diodes *D1* and *D2*, to emerge as half-wave pulsating dc. Resistor *R1* is included in the circuit to assure that enough current flows to switch the diodes fully on.

Diode *D3* isolates point A, the junction of the three diodes, from the smoothed dc produced by the filtering action of *C1*, at point B, so that the potential at the IN terminal of regulator *IC1* is approximately +8 volts. At the OUT terminal of *IC1*, point C, the potential is a regulated +5 volts, which is further filtered by *C2* and distributed throughout the circuit as needed.

Resistor *R2* and zener diode *D4*



PARTS LIST

Semiconductors

D1,D2,D3—1N4001 or similar 50-PIV, 1-ampere rectifier diode

D4—6.2-volt, 0.4-watt zener diode

D5,D6,D7—1N4148 or similar switching diode

LED1,LED2,LED3—T-1 ¾ light-emitting diode (one each red, yellow, green)

IC1—7805 fixed +5-volt regulator

IC2—LM393 dual comparator

IC3—CD4538B dual CMOS multivibrator

IC4,IC5,IC6—MOC3041 optical isolator

Q1,Q3—IRF511 (or any) n-channel power MOSFET

Q2,Q4,Q5—SC150M or similar triac

Capacitors

C1—1,000-µF, 10-volt electrolytic

C2—1-µF, 50-volt tantalum

C3,C7—0.1-µF polyester

C4—0.01-µF polyester

C5—0.0056-µF polyester

C6—22-µF, 10-volt tantalum

C8—10-µF, 16-volt tantalum

C9—4-µF, 16-volt tantalum

Resistors (¼-watt, 5% tolerance)

R1—15,000 ohms

R2,R3—10,000 ohms

R4,R5—100,000 ohms

R6—100 ohms

R7,R10,R12—56 ohms

R8,R11,R13—270 ohms

R9—150,000 ohms

R14—1,000-ohm multi-turn trimmer potentiometer

R15—100,000-ohm linear-taper slide- or rotary-type potentiometer (see text)

R16—1-megohm trimmer potentiometer

Miscellaneous

S1—Spst lever or slide switch

S2,S3—Normally-open, momentary-action spst pushbutton switch

SO1—Chassis-mount three-contact ac receptacle

T1—6.3-volt center-tapped, 100-mA minimum power transformer

Printed-circuit boards or perforated board with holes on 0.1" and suitable Wire Wrap or soldering hardware (see text); sockets for all DIP ICs and optical isolators; remote cable assembly (see Note below); suitable enclosure(s); ac line cord with plug; rubber grommets; small-diameter heat-shrinkable or other insulating tubing; heat sink (see text); spacers; machine hardware; hookup wire; solder; etc.

Note: The special seven-pin molded plug and 36" of five-conductor cable required for the remote cable assembly can be ordered as Part No. 215420 from Kodak Parts Service Dept. (716-724-7278) for $15. Alternatively, see text for details. One source for SC150M triacs is All Electronics (800-826-5432), which also sources many of the other components specified here.

Fig. 1. Schematic diagram of basic Controller circuit.

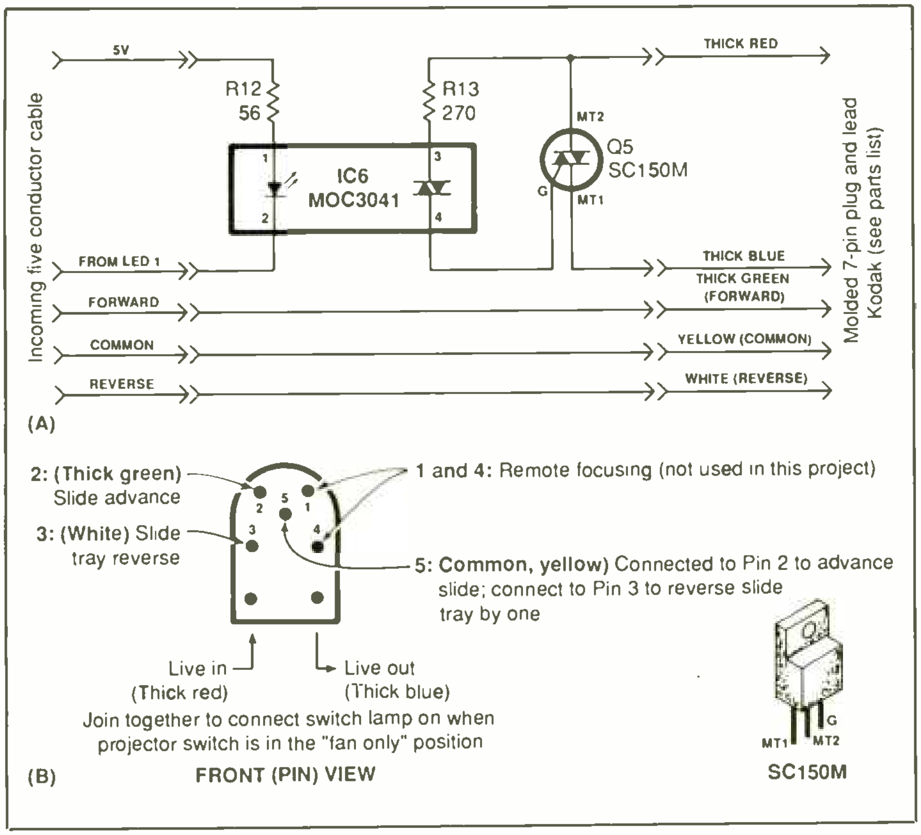


Fig. 2. Schematic diagram and wiring instructions for small junction box.

regulate the pulsating dc from point A and make it independent of any but very large variations in the ac input to the circuit.

Shown in Fig. 3(A) is the waveform that appears at noninverting (+) input pin 5 of *IC2A*. This comparator stage has an open-collector output, which means that until the inputs at pins 5 and 6 are the same, the output at pin 7 of *IC2A* is effectively an open switch.

Initially, *C3* is charged through *R5* and *D5* by the waveform at point D, shown in Fig. 3(B). This is clearly a very nonlinear charging current, but it does produce an almost ideal waveform at pin 7 of *IC2A*.

The voltage divider made up of *R3* and *R4* ensures that the inverting (−) input at pin 6 of *IC2A* is held just above 0 volt. When the pulsating dc input at pin 5 returns almost to 0 volt at the end of each half cycle, both inputs of *IC2A* become equal. At this point, the internal transistor in the output stage of this comparator switches into conduction and discharges *C3*, with the resulting waveform shown in Fig. 3(C).

The straight vertical portions of the waveform shown in Fig. 3(C) are the result of the output transistor inside *IC2A* switching on and discharging *C3*. The curved portions have the almost ideal waveshape cited above to allow the lamp in the projector to begin lighting without wasting the low end of main FADER control *R15* and to speed toward full brightness at the high end of the control, while being linear in the middle of the control's range.

Potentiometer controls *R14* and *R15* make up a pair of voltage dividers. Adjusting *R14* assures that at one end of this main FADER control *R15*, the lamp in the projector is fully off. Hence, the inputs going to pins 2 and 3 of *IC2B* are, respectively, a set potential that can be varied from about 2 volts to 0 volt by *R15*, and a sawtooth voltage of the same amplitude. With *R15* set at mid-position, the superimposed inputs are as shown in Fig. 4.

When the voltage set by *R15* rises to an amplitude that is just slightly greater than that of the sawtooth amplitude, the pulses disappear and the output at pin 1 of *IC2B* is always high. Conversely, when the voltage set by *R15* has an amplitude that is less than that of the sawtooth, the pulses again disappear but, this time, leave the output continuously low.

When the output at pin 1 of *IC2B* is zero, both *LED1*, which is in the circuit to give an indication of the lamp brightness in the projector, and the LED inside optical isolator *IC6* (see Fig. 2) will always be lit. With the LED inside *IC6* on, the internal triac is triggered into conduction and, in turn, drives external triac *Q5* into full conduction.

As *R15* is adjusted toward its alternate stop position, pulses synchronized with the 60-Hz ac line will be generated. Both *LED1* and the LED internal to *IC6* are briefly switched off during each half cycle, as are the internal and external triacs. As a result, the projector lamp will not be receive full 117-volt ac line voltage all the time. The lamp will be dimmed progressively as *R15* is adjusted toward its far end of travel.

Capacitor *C4* filters out any noise that might be picked up by the leads from *R15* from entering *IC2B* via + input pin 3. This capacitor should be placed as close as possible to the pin 3 input during assembly of the circuit.

All of the above assumes that the 117-volt ac line power to the projector is on but, at the beginning of the process, the projector is off and waiting for the command to show the first slide in the cannister or tray.

It would be an easy procedure for you to turn on the projector and then fade in the lamp. However, it is more convenient if starting to move the fade up is the way to switch on the projector. This is accomplished in this Controller by the Fig. 1 circuitry made up of *IC3A*, *Q1*, *IC4* and *Q2* and their associated components.

One-half of a CD4538B dual monostable multivibrator, shown as *IC3A*, is used here as the controlling element of the circuit for switching on the projector. Assume that the projector is off and FADER control *R15* is set so that the lamp would be off if the projector were switched on. Under these conditions, the output from pin 1 of *IC2B* would be high.

As soon as the fader starts to move up, however, a series of initially narrow pulses are initiated, the first of which can be used to trigger *IC3A*. When this stage is triggered, its output at pin 10 goes high. This causes *Q1* to switch into conduction, in turn causing the LED inside optical isolator *IC4* to light. When this occurs, the triac internal to *IC4* switches on and drives external triac *Q2* into conduction. The result is that 117-volt ac line power is applied to the projector through ac receptacle *SO1*.

Of course, at this stage, you do not want the timer to time out and switch off the projector until the projection lamp has been faded up, the first slide has been viewed, the lamp has fully faded down and the change mechanism has advanced to the next slide. Early timing out is prevented by *D6*. The first pulse comes in, triggers the onset of the output pulse and *C6* starts to charge through trimmer potentiometer *R16*. However, each succeeding incoming pulse short-circuits *C6* via *D6*, and so discharges the capacitor.

When the lamp is fully on, pin 1 of *IC2B* is low. Hence, *C6* will not charge at all. This capacitor will be permitted to charge fully only when *R15* has been returned to its fully faded-out position and all incoming pulses have ceased. Only then can the timed output pulse really begin. Provided this pulse is long enough in duration to permit a third part of the circuit to change the slide (this time interval can be adjusted by setting *R16*), the desired purpose is achieved.

The remainder of the circuit, built around the second multivibrator stage inside the CD4538 and shown as *IC3B* in Fig. 1, is used to change the slide before the projector finally switches off. Initially, with the projector off, the output at pin 6 of *IC3B* is low while the input at *D7* is high.

With the first negative-going pulse from pin 1 of *IC2B* at pin 4 of *IC3B* through *D7*, *C8* immediately discharges through *D7*. Further pulses keep the capacitor discharged. With *IC3B* configured so that it will trigger only on a rising input, the output at pin 6 remains low and will not trigger to a high state until *C8* is again permitted to fully recharge.

Full recharging of *C8* does not occur until the projector lamp fader has been returned to its fully faded-out position. Only then will *C8* recharge through *R16*. As the potential across *C8* rises through the input threshold of *IC3B*, the output pulse begins. The slight delay before the output pulse goes high allows the projector lamp to be completely out so that changing of the slide will not be seen on-screen.

Use of optical isolator *IC5* and triac *Q4* permits the slide-forward/reverse connections in the projector to be made without having to use a relay. The slide-change mechanism advances the slide tray by one.

In summary, as the fader is first operated, the projector switches on and the lamp is brightened to full. When the slide is no longer required, the fader completely fades out the lamp in the projector, at which time the slide changes and the projector switches itself off.

Spurious spikes are prevented from falsely triggering *IC3A* by *R6* and *C5* in the projector switch-on circuit. Decoupling by *C7* helps in preventing similar false triggering. This latter capacitor should be placed as near as possible to pins 8 and 16 of *IC3A* during construction.

Slide or toggle switch *S1* and pushbutton switches *S2* and *S3* permit you to manually set up and operate the system. As mentioned above, *LED1* gives an indication of the brightness of the lamp in the projector. Power to the projector is visually indicated by *LED2* lighting, while a slide change is indicated by *LED3*.

A lightweight five-conductor cable of reasonable length (up to 100 yards is possible with this Controller) operates the projector from a remote point. By including optical isolator *IC6*, as shown in Fig. 2, close to the projector, this control cable does not have to carry 117-volt ac line power. Inserted in the cable close to the projector, a small box serves as the junction that allows three of the cable's five conductors to join directly to the common conductor (yellow insulation), forward thick conductor (green insulation) and reverse conductor

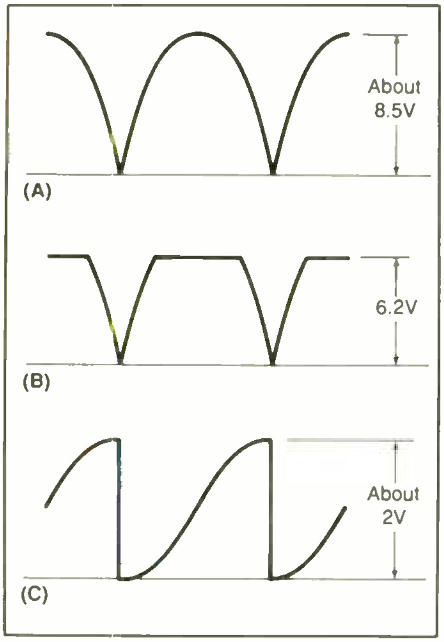


Fig. 3. Waveforms that appear at various points in fade-in/fade-out circuitry: (A) pulsating dc with an amplitude of about 8.5 volts at point A; (B) truncated pulsating dc with an amplitude of 6.2 volts at point D; and (C) waveform at pin 7 of IC2 of about 2 volts.

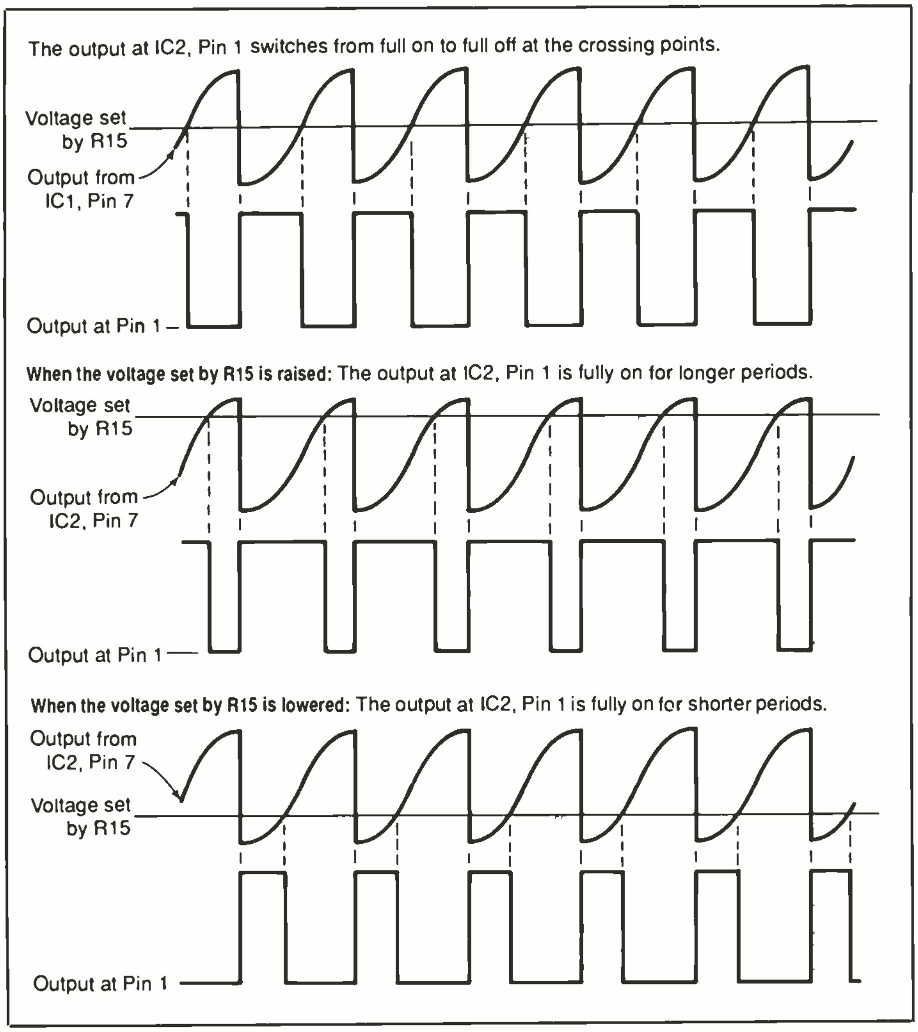


Fig. 4. Pulse waveforms at pin 1 of IC2 for various settings of fader control R15: (top) at mid-position; (center) near top of control; and (bottom) near bottom of control.

(white insulation) of the projector's molded plug and cable.

The timing sequences for the complete Controller circuit are shown in Fig. 5. Figure 5(A) details the timing for switching on the projector and fading the projector lamp to full brightness. Figure 5(B) details the timing for fading the projector lamp to full off, changing the slide and switching off the projector.

Construction

There is nothing critical about assembling the Controller circuitry, other than to observe the normal precautions about isolating the 117-volt ac from the low-voltage dc portions. Therefore, you can use printed-circuit boards on which to mount and wire together the circuitry or perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Whichever way you go, be sure to use sockets for all DIP ICs and optical isolators.

If you wish to wire your circuitry on printed-circuit board, use the actual-size etching-and-drilling guides shown in Fig. 6. Then wire first the main and then the smaller boards exactly as shown in Fig. 7. (If you opt for point-to-point wiring on perforated board, use the wiring guides shown in Fig. 7 as rough layouts for the components.)

When wiring the board, install and solder into place first the sockets for the ICs and optical isolators. Do *not* plug the ICs into their respective sockets until you have conducted preliminary voltage checks and are certain that everything is okay. If you cannot locate six-pin sockets for the optical isolators, carefully cut down sockets with more pins or substitute Molex Soldercon® socket strips.

With the sockets in place, install and solder into place the resistors and trimmer controls, then the diodes and capacitors. Note that most resistors and diodes mount vertically on the board. Make certain that you properly orient any electrolytic capacitors and all diodes before soldering their leads into place.

Next, install and solder into place regulator *IC1* and then the power MOSFETs, followed by the triacs. Again, make absolutely certain that each of these devices is properly based before soldering any leads into place.

Note that a number of components associated with the large main circuit-board assembly mount off the board. These include the power transformer, all three switches, the three LEDs and slide potentiometer *R15*. To make connections to these components, you must install suitable length wires at the indicated locations. Make these wires about 4 inches long. Strip ¼ inch of insulation from both ends of each. If you are using stranded hookup wire, tightly twist together the fine wires at both ends of all wires and sparingly tin with solder. Then plug one end of each wire into the indicated hole and solder into place.

Keep in mind that two copper conductors on the smaller junction-box pc board, both associated with triac *Q5*, carry about 3 amperes of 117-volt ac line power. These are indicated by extra-heavy traces in the smaller guide in Fig. 6. Strengthen these traces by soldering along their lengths thick pieces of heavy-duty bare copper wire before installing and soldering triac *Q5* into place.

You can use any enclosure you wish to house the large circuit-board assembly. It must be large enough to accommodate the assembly and power transformer and have enough panel space on which to mount the switches, control and LEDs. Machine the enclosure as needed (see lead photo for a suggested panel layout), including drilling the hole for entry of the five-conductor control cable. If you do not have the proper tool to make the long, narrow slot for the slide control, substitute a rotary control. Of course, doing this sacrifices some of the "feel" for smooth fades in and out.

After machining the enclosure, deburr any holes drilled through metal to remove sharp edges. Line the ac line cord and control-cable entry holes with rubber grommets and mount the switches, slide (or rotary) control and five-pin connector in their respective locations. Mount the power transformer with suitable hardware. Solder the transformer's secondary leads in the appropriate holes in the circuit-board assembly.

Trim 1½ inches of outer plastic jacket from the five-conductor cable and strip ¼ inch of insulation from all conductors. Tightly twist together the exposed wires of each conductor and sparingly tin with solder.

Pass this end of the cable through its rubber-grommet-lined entry hole and secure a large plastic cable tie tightly around it about 4 inches from the end inside the enclosure to serve as a strain relief. Plug the conductors into the holes labeled +5V, FROM LED1, SLIDE FORWARD, COMMON and SLIDE REVERSE. Make a note on a slip of paper of the color coding used for each conductor connection. then mount the circuit-board assembly with ½-inch spacers and 4-40 × ¾-inch machine screws, lockwashers and nuts.

Note: Instead of making direct cable connections to the circuit-board assembly, you can mount a female DIN-type five-pin connector in a suitable hole in the enclosure and wire from it to the circuit-board assembly. Then terminate one end of the control cable in a matching five-pin male DIN-type connector, as illustrated in the cover photo.

Tightly twist together the wires in each conductor of the ac line cord and sparingly tin with solder. Pass this end of the line cord through its rubber-grommet-lined hole and tie a strain-relieving knot in it about 4 inches from the end inside the enclosure. Separate the conductors a distance of about 1½ inch and slip over each a 1-inch length of small-diameter heat-shrinkable tubing. Twist together one line-cord conductor and one power transformer primary lead and solder the connection. Do the same for the other line-cord conductor and transformer primary lead. Then slide the tubing over the connections to completely insulate them

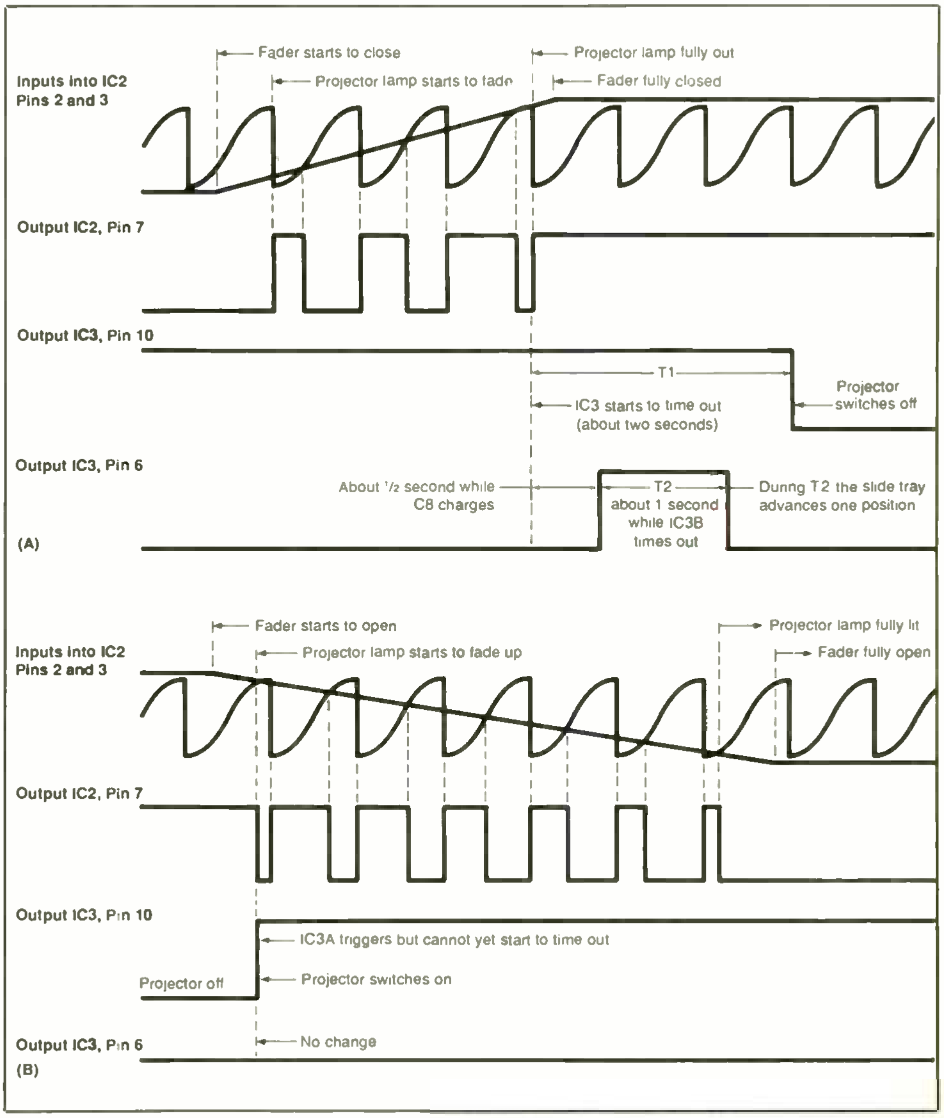


Fig. 5. Timing diagrams for (A) fading out lamp, changing slide and switching off projector and (B) switching on projector and fading up lamp. Waveforms are not to scale.

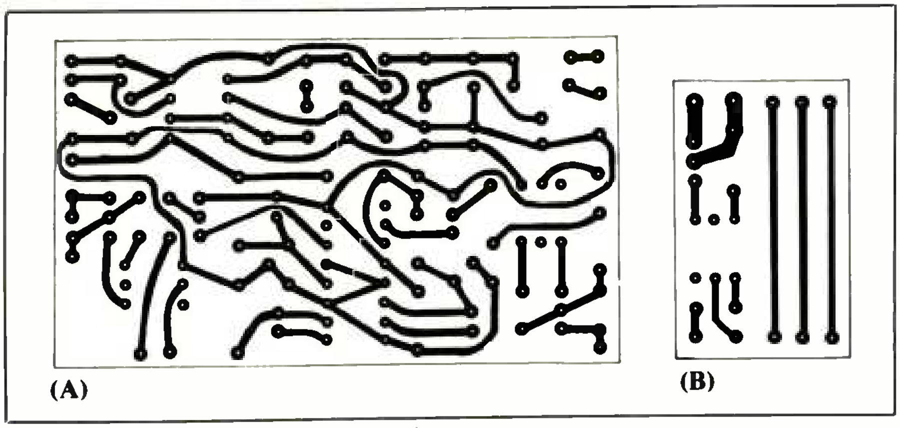


Fig. 6. Actual-size etching guides for (A) main and (B) junction-box circuits.

and shrink it into place.

Next, wire the LEDs into the circuit, making certain that you make the correct connections to the anode and cathode leads. Insulate all connections with heat-shrinkable or other plastic tubing. Then wire the switches and slide (or rotary) control into the circuit.

Plug the LEDs into their respective holes in the top panel of the enclosure. If the LEDs do not remain in place by friction, secure each with a small daub of silicone adhesive or fast-setting epoxy cement.

Machining of the smaller junction box in which the smaller circuit-board assembly is to mount requires drilling of only three holes. One hole is needed for mounting the circuit-board assembly inside the smaller enclosure. Then one hole is required for entry of the control-cable from the main unit and another for exit of the cable that goes to the projector. After all holes are drilled, deburr them to remove sharp edges and line the cable holes with rubber grommets.

Prepare the unfinished end of the control cable as detailed above. Pass the cable through its hole in the enclosure and, again, use a large plastic cable tie to provide strain relief. Plug the conductors into the appropriate holes in the small circuit-board assembly (observe the same color coding used for the connections to the main circuit-board assembly) and solder each into place.

The seven-pin molded plug and 36 inches of seven-conductor cable required for connection from the small branching box to the slide projector can be obtained from Kodak (see Note at end of Parts List). All you need do to wire this into the circuit is to prepare its unfinished end as described above for the control cable. Pass this end into the enclosure through its grommet-lined hole, use a large plastic cable-tie strain relief and wire it to the small circuit-board assembly as detailed in Fig. 2.

A less-expensive solution is to use two plugs, both available from your local Radio Shack store. Cat. No. 270-041A is a round five-pin plug that fits into the top section of the socket on the projector, and Cat. No. 270-017 is a multiple-pin plug that can be machined to fit a number of formats, including the two-pin format on the projector.

If you go the less-expensive route, you must fabricate the cable assembly yourself. This is simple enough to accomplish, using the details given in Fig. 2 for wiring the cable to both the circuit-board assembly and the connectors.

Exercise care when fitting the small circuit-board assembly into its enclosure. If you use a plastic box for the enclosure, make sure that no entry/exit conductors on either side of the board can touch any others. Also, fit a small heat sink onto the triac on this board. Secure the board to the enclosure via the hardware that secures the heat sink into place.

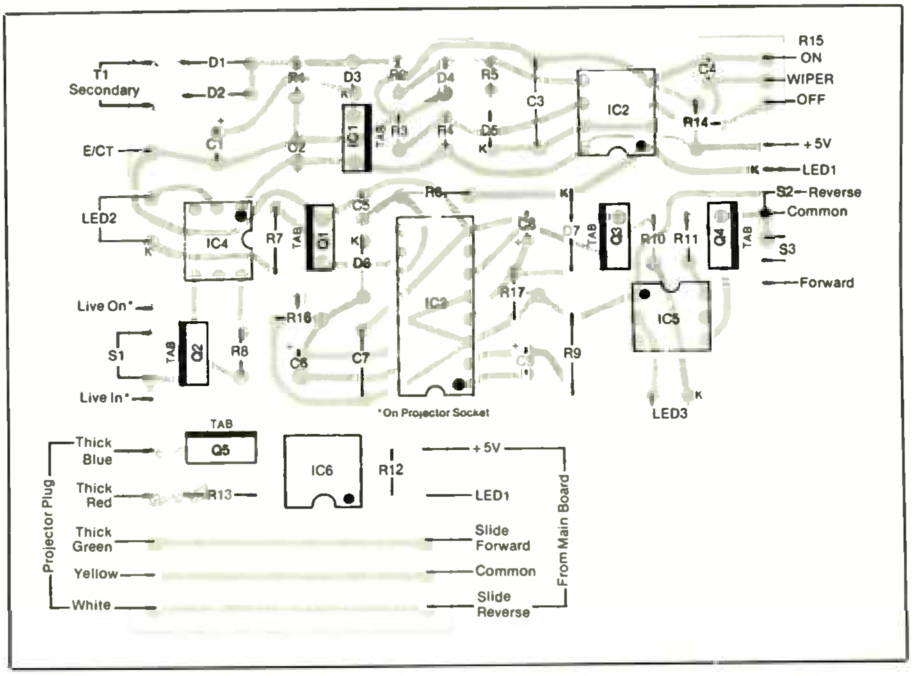


Fig. 7. Wiring diagrams for (A) main and (B) junction-box circuit boards.

If you use a metal enclosure for the junction-box assembly, make certain that the inside of the box is well-insulated from any part of the circuit-board assembly. The recommended triac on this board has an isolated metal tab that can be used to secure the circuit-board assembly into place. Additionally, the metal box will provide the required heat-sinking.

Checkout & Use

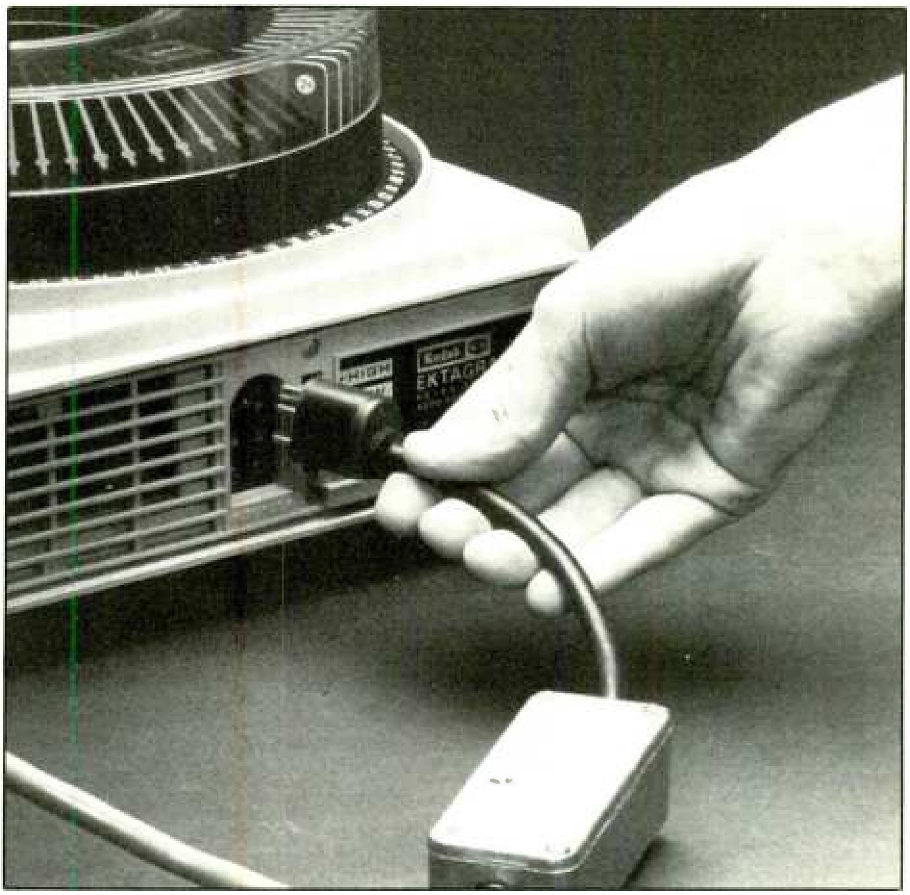
Make sure no DIP IC or optical isolator is plugged into any socket on either board. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to circuit ground. Plug the line cord of the Controller into a convenient ac outlet and touch the "hot" probe of the meter to pin 8 of the *IC1* socket and note the reading obtained. It should be +5 volts. If it is not, touch the "hot" probe to OUT pin 3 of *IC1* and note if the reading is +5 volts. If you still do not obtain a reading of +5 volts, touch the "hot" probe to IN pin 1 of *IC1*. Now the reading should be approximately +8 volts.

Switch your multimeter to the ac-volts function. Touch the "hot" probe to the junction between *R2* and *D4*. The meter should give a reading of approximately 6 volts ac.

If you fail to obtain the correct reading at any of the points cited, unplug the project from the ac outlet and correct the problem. Do not proceed until you do obtain the correct reading at each point.

Using the "hot" probe of the meter, check the voltages at pins 3 and 16 of the *IC3* socket and pin 1 of the *IC4*, *IC5* and *IC6* sockets. In all cases, the correct reading is +5 volts. Failure to obtain the proper reading at any socket pin requires remedial work to rectify any wiring or component-installation error.

Once you obtain the proper readings at all points cited, unplug the project from the ac line and disconnect the meter from it. Carefully plug



Small junction box plugs into connector on slide projector via a multiple-conductor cable. This box must be located as near as possible to the projector but can be tethered to main control unit via a cable up to 100 yards long.

the ICs and optical isolators into their respective sockets. Make sure each is in its proper socket and is properly oriented and that no pins overhang the sockets or fold under between devices and sockets.

Set *R16* and *R17* to about mid-position. Plug the projector into an ac outlet, plug the cable coming from the small branching box into the projector and plug the control cable into the main unit. Plug the main unit into an ac outlet. The projector fan may start operating and the lamp light (though not at full brightness) in the projector at this point.

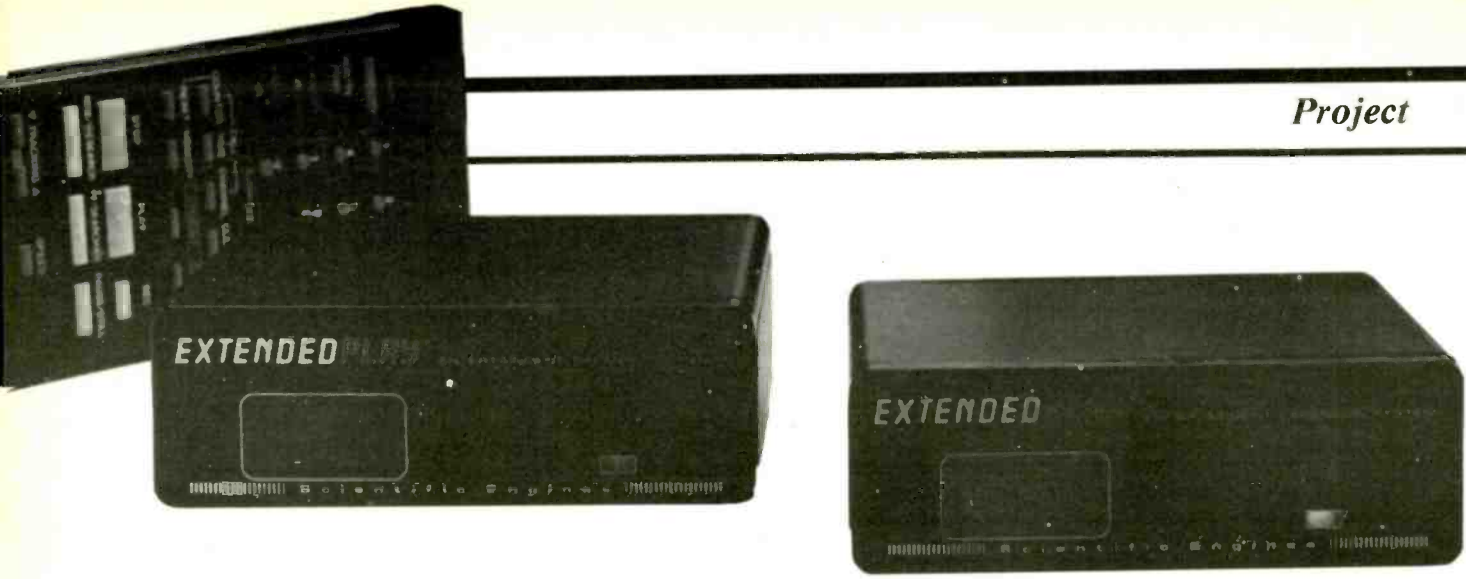
Operate the slide control up and down to see if this action dims and brightens the projector lamp. If it allows the lamp to go out completely, the projector mechanism should advance to the next slide and switch off.

Adjust the setting of *R16* until the slide-advance process is completed before the projector switches off. Leave the slide control in a position that leaves the projector lamp just glowing dimly.

Adjust the setting of *R14* to brighten the projector lamp, and move the slide control until the lamp just glows again. Repeat the process as many times as necessary until the slide control is at the "out" end of its travel. Now adjust the setting of *R14* to completely fade out the lamp, at which time, the slide should change and then the projector switch off.

If *R14* is set too critically, switching on an electrical appliance close to

(Continued on page 82)



The Extended Play Remote-Control System

(Conclusion)

Operating and construction details for the receiver module, system checkout and installation and use

By Crady M. VonPawlak

Last month in Part 1 of this article, we discussed the theory of operation, construction and initial checkout of the transmitter portion of the Extended Play Remote-Control System. This month we conclude with the receiver module, system checkout and installation and use of the full system. The system enables one to control a VCR or stereo music system with his infrared hand-held remote controls from another location without running connecting wire or cables. Thus, one can watch or listen on a set in another room while maintaining full control of the device in the main room.

About the Circuit

The complete schematic diagram of the receiver circuitry is shown in Fig. 7. Capacitor *C6* and resistor *R9* provide capacitive coupling of the signal impressed on the ac line by the transmitter to coupling transformer *T2*. This RC network plays a secondary role, attenuation of large power-line spikes and transients that can enter *T2* or power transformer *T1*.

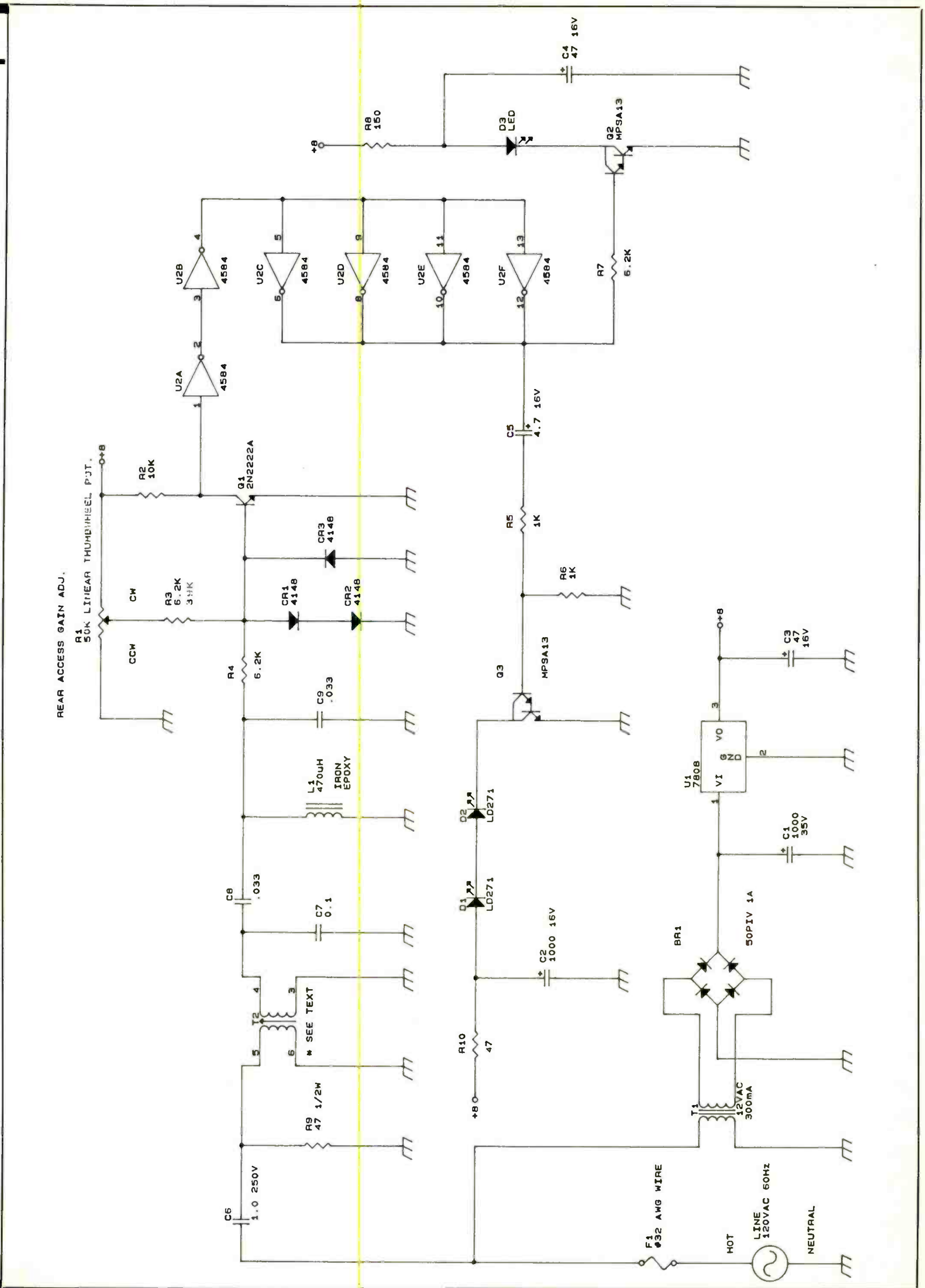
The receive side of *T2* (pins 5 and 6) is impedance-matched to the ac power line. This impedance can vary from 3 to 14 ohms. To accommodate these variations, the receiver circuit has been optimized for a 3-ohm worst-case operation.

As the incoming signal is passed to the secondary of *T2* (pins 3 and 4), it is stepped up by a turns-ratio of approximately 10:1. Capacitor *C7* across this winding forms a high-Q LC resonant tank circuit that is designed for optimum operation in the frequency range of 30 kHz to 60 kHz, which is the anticipated frequency range of the received signal.

This signal is then passed to the series-parallel bandpass filter made up of *C8*, *C9* and *L1*. The circuits thus far described extract and passively amplify only those signals impressed onto the ac power lines by the Extended Play carrier-current transmitter while rejecting the majority of transients, noise and signals produced by non-related, carrier-current devices.

After filtering and amplification, the received signal is passed to current-limiting resistor *R4* and clipping diodes *CR1* and *CR2*. The two diodes limit signal amplitude to a normalized level of approximately 1.4 volts, as seen by transistor *Q1*. Reverse-biased switching diode *CR3* across *CR1* and *CR2* clamps against nega-

Fig. 8. Complete schematic diagram of receiver module circuitry.



REAR ACCESS GAIN ADJ.
R1 50K LINEAR THUMBWHEEL POT.
CW
CCW
+8
R2 10K
Q1 2N2222A
R3 6.2K 3.9K
R4 6.2K
CR1 4148
CR2 4148
CR3 4148
C9 .033
L1 470uH IRON EPOXY
C8 .033
C7 0.1
T2
* SEE TEXT
R9 47 1/2W
C6 1.0 250V
U2A 4584
U2B 4584
U2C 4584
U2D 4584
U2E 4584
U2F 4584
R8 150
D3 LED
Q2 MPSA13
C4 47 16V
R7 6.2K
C5 4.7 16V
R5 1K
R6 1K
Q3 MPSA13
D2 LD271
D1 LD271
C2 1000 16V
R10 47
+8
C3 47 16V
U1 7808
VI
GND
VO
C1 1000 35V
BR1
50PIV 1A
T1 12VAC 300mA
F1 #32 AWG WIRE
HOT
LINE 120VAC 60HZ
NEUTRAL

tive-going transients that may enter through the bandpass filter stages.

A variable-level voltage divider bias is provided for *Q1* by *R3* and trimmer potentiometer *R1*. This circuit provides a simple method of adjusting overall receiver gain (sensitivity) for setting optimum performance for a given location within your home. Resistor *R2* sets the collector current for transistor *Q1*.

When the received control signal is passed to the base of *Q1*, a current flows through the emitter-collector junction of *Q1*, which causes the collector voltage to appear as a ground (low) potential to the input of *U2*. Resistor *R2* holds the input to one gate of *U2* in a normally high state until a control signal is received.

CMOS hex Schmitt-trigger inverter *U2* cleans up the amplified signal that appears at the collector of *Q1*. It also provides additional drive current to accommodate both the LED visual indicator and the IR driver final output stage.

Visual indication of a received signal is provided by light-emitting diode *D3*. The output signal from *U2* is passed to current-limiting resistor *R7* to drive the base of switching transistor *Q2*. This causes a current to flow through the emitter-collector junction of *Q2* and forward-biases the LED. Current for *D3* is provided by *R8/C4*. Capacitor *C4* maintains a high current at the anode of *D3* while preventing excessive dropouts and spikes from appearing on the 8-volt dc power supply during the LED turn-on and turn-off cycles.

These on/off cycles appear at the same rate and frequency as that of the received signal. This indication can be used in conjunction with the manual gain control to provide for a quick visual reference of receiver gain setting during initial installation of the receiver module.

To communicate with the device(s) to be controlled, the received control signal must be reconstructed and output in its original IR energy. To accomplish this, the shared output of *U2* is passed to the IR output driver. This output is capacitively coupled by *C5*. This ac coupling provides overdrive protection for *Q3* and the power supply should the manual gain be set high enough to force the output of *U2* into a continually on (steady dc) state and/or should any front-end component fail and cause the same effect as excessive current drawn by the IR diodes.

Voltage-divider bias of the signal is provided for *Q3* by *R5* and *R6*. The required IR energy is generated by high-output IR-emitting diodes *D1* and *D2*. Buffer capacitor *C2* maintains the high current levels required for proper operation by *D1* and *D2* during reception and re-transmission.

When a positive-going signal is present at the base of *Q3*, a current flows though the emitter-collector pn junction of the transistor. This forward-biases *D1* and *D2*. The rate and frequency at which *Q3*, *D1* and *D2* operate exactly matches that of the signal originally emitted by the hand-held IR remote-control transmitter used with the project, though it is at a greatly increased energy level.

A simple regulated dc power supply for the receiver circuit is provided by *T1*, *BR1*, *C1*, *C3* and *U1*.

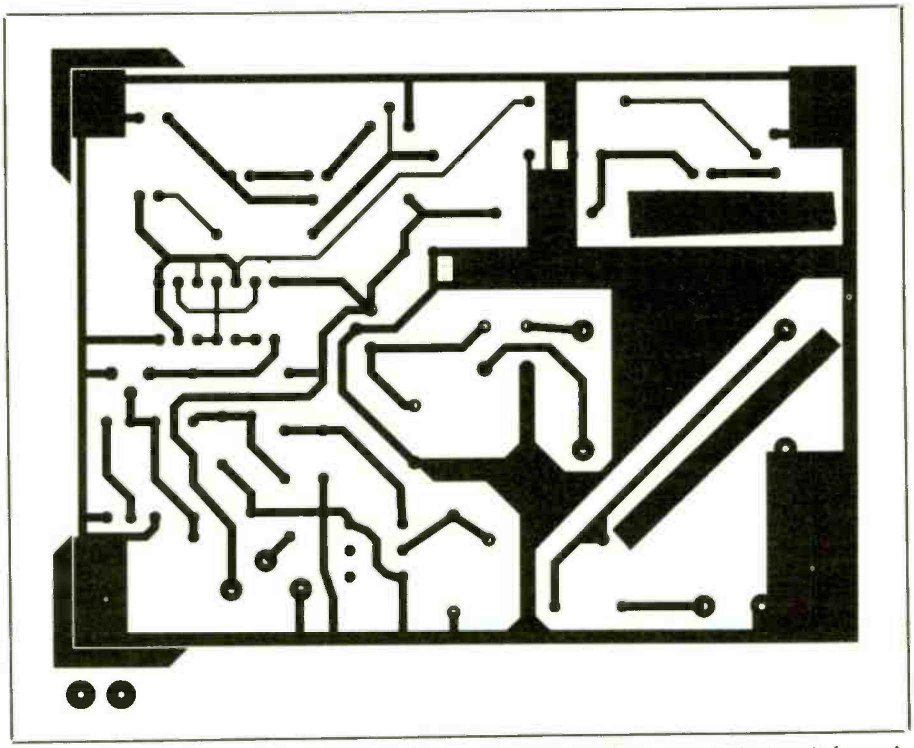


Fig. 9. Actual-size etching-and-drilling guide for receiver printed-circuit board.

Construction

For the receiver, you can use either a printed-circuit board or perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware on which to mount and wire the components. If you opt for pc construction and wish to fabricate your own board, use the actual-size etching-and drilling guide shown in Fig. 9. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts list.

From here on, we will assume that you are using pc construction. This being the case, refer to the wiring guide shown in Fig. 10. (If you go the

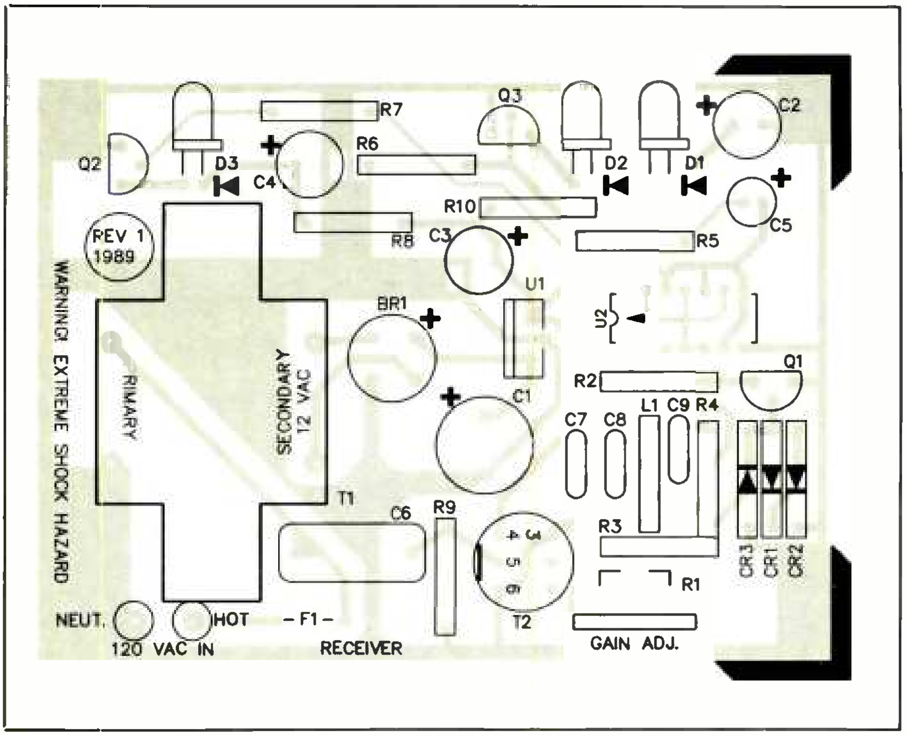


Fig. 10. Wiring guide for receiver pc board.

point-to-point wiring route, use Fig. 10 as a rough guide to component placement.)

Use the same assembly procedure to wire the receiver board as detailed last month for the transmitter board. That is, start by installing and soldering into place the sockets for DIP *IC2*. Do *not* plug the IC into the socket until after you have conducted a voltage check and are certain that the board has been properly wired.

Proceed with installation of the resistors, capacitors and diodes. Make sure the electrolytic capacitors and diodes are properly oriented before soldering their leads into place. Next, install the transistors and then GAIN ADJUST trimmer *R1* in their respective locations. Again, make sure that the transistors are properly based before soldering their leads into place.

Now install power transformer *T1* and coupling transformer *T2* in their respective locations. Make absolutely certain that you do not transpose the primary and secondary leads of *T1* and that the notch on the case of *T2* is oriented along the heavy straight line in the case outline for this component in Fig. 10 before soldering any leads or pins into place.

Install the three LEDs in their respective locations on the edge of the circuit-board assembly as shown. Note that if any LED overhangs the edge of the board, it should do so by no more than 1/16 inch, as illustrated in Fig. 11. Use a short length of No. 32 bare wire for fuse *F1*.

Machine the enclosure that will house the receiver module. This is done in basically the same manner that was described last month for the transmitter module, except that an extra hole, to provide access to trimmer GAIN ADJUST potentiometer *R1* is required in the rear panel. If you are using the type of enclosure supplied with the kit (see Parts List), use the actual-size machining templates provided in Fig. 12 as guides for the rear (A) and front (B) panels. If you are using any other type of enclosure, make suitable adjustments in the templates before using them for machining the panels.

When machining of the panels is complete, do *not* set the self-stick front-panel overlay in place. You must first mount the front panel in place on the enclosure, using the small screws provided, before attempting to mount the overlay, which then covers the entire panel, including the screw heads. Therefore, save installation of the front-panel overlays on both the transmitter and receiver modules until *after* the entire system has been checked out for proper operation.

Meanwhile, pass the unfinished end of the ac line cord through its hole in the rear panel and fasten it in place with a plastic strain relief, or tie a strain-relieving knot in it about 3 inches from the unfinished end on the inside of the panel.

Tightly twist together the fine wires in each line-cord conductor and sparingly tin with solder. Plug the conductors into the 120 VAC IN holes in the receiver circuit-board assembly and solder into place. (Note: Check which conductor you plugged into the hole labeled NEUT in the transmitter board. Regardless of whether its insulation is smooth or ribbed, plug the conductor with the *same* insulation in the NEUT hole in the receiver board.

Now perform voltage checks to ascertain that the receiver module has been properly assembled. For this, you need a dc voltmeter or a multimeter set to the dc-volts function. Clip the common lead of the meter to a convenient circuit-ground point on the receiver circuit-board assembly, such as the metal tab on the bridge-rectifier assembly. When you perform the following voltage tests, make absolutely certain that you do not touch the primary circuit of *T1*. Potentially lethal 117-volt ac line potential is present in this portion of the circuitry.

When you are ready to perform the

MASTER PARTS LIST

RECEIVER

Semiconductors

BR1—50-PIV bridge rectifier assembly
CR1,CR2,CR3—1N4148 switching diode
D1,D2—LD271 IR-emitting diode in T1¾ package
D3—Yellow light-emitting diode in T1¾ package
Q1—2N2222A general-purpose npn silicon transistor
Q2,Q3—MPSA13 Darlington transistor
U1—7808 +8-volt regulator in TO-220 package
U2—CD4584BC CMOS Schmitt-Trigger Inverter

Capacitors

C1—1,000-μF, 35-volt electrolytic
C2—1,000μF, 16-volt electrolytic
C3,C4,C5—47μF, 16-volt electrolytic
C6—1.0μF, 250-volt metalized polyester
C7—0.1μF, 50-volt metalized polyester
C8,C9—0.033μF, 50-volt metalized polyester

Resistors (¼-watt, 5% tolerance)

R2—10,000 ohms
R3—39,000 ohms
R4,R7—6200 ohms
R5,R6—1,000 ohms
R8—150 ohms
R9,R10—47 ohms, ½-watt
R1—50,000-ohm upright pc-mount, noninductive trimmer potentiometer

Miscellaneous

F1—¼-ampere fuse or No. 32 solid bare wire (see text)
L1—470-μH low-power inductor with iron or ferrite core and axial leads
T1—12.6-volt ac, 300-mA pc-mount power transformer
T2—100-μH coupling transformer (TOKO No. 707VX-A03YUK)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); socket for U2; polarized ac power cord; plastic strain relief (optional—see text); suitable enclosure; hookup wire; solder; etc.

TRANSMITTER

Semiconductors

BR1—50-PIV bridge rectifier assembly
CR1—1N5819 Schottky diode
D1—SFH205 photodiode
D2—T1¾ green light-emitting diode
Q1—TIP120 power Darlington transistor (TO-220 package)
Q2—MPSA13 Darlington transistor
U1—78L05 +5-volt regulator
U2—CD4584BC CMOS hex Schmitt-trigger inverter
U3—TDA4060 infrared amplifier with agc

Capacitors

C1—1,000-μF, 35-volt electrolytic
C2—47-μF, 50-volt electrolytic
C3—47-μF, 16-volt electrolytic
C4—47-μF, 35-volt electrolytic
C5—4.7-μF, 16-volt electrolytic
C6—1-μF, 250-volt metalized polyester
C7—0.22-μF, 16-volt metalized polyester
C8—0.33-μF, 16-volt dipped tantalum
C9—0.1-μF, 16-volt metalized polyester
C10—0.1-μF, 100-volt metalized polyester
C11—0.01-μF, 100-volt metalized polyester
C12,C13—220-pF, 16-volt monolithic ceramic

Resistors (¼-watt, 5% tolerance)

R1—100,000 ohms
R2—39,000 ohms
R3—6,200 ohms
R4,R5—1,000 ohms
R6—330 ohms
R7—47 ohms, ½ watt
R8,R9—4.7 ohms, ½ watt

Miscellaneous

F1—¼-ampere fuse (see text)
T1—12.6-volt ac, 300-mA pc-mount power transformer
T2—Coupling transformer (TOKO No. 707VX-A043YUK)
Printed-circuit board; suitable enclosure (see text); ac line cord with plug; sockets for U2 and U3; fine copper mesh for Faraday shield (see text); hookup wire; solder; etc.

Note: The following items are available from Scientific Engines, P.O. Box 2295, Everett, WA 98203: Complete Extended Play transmitter and receiver kit (includes pc boards, enclosures, all electronic components, copper screen and self-adhering front-panel overlays), $119.95 plus $3.50 P&H; additional receiver and transmitter kits, $62.95 each plus $2.50 P&H; ready-to-wire transmitter and receiver pc boards, $32.50 per set of two plus $2.50 P&H. Mail orders, make payment via certified check or postal money order; Visa/MasterCard orders, call: (206) 348-7754. Washington residents, please add state sales tax to all orders.

voltage test (*U2* should *not* be in its socket at this time) turn the thumbwheel of trimmer potentiometer *R1* fully counterclockwise, and place the circuit-board assembly on an insulated surface.

Plug the receiver's line cord into an ac outlet and touch the "hot" probe of the meter to pin 14 of the *U2* socket. The meter should register a reading of +8 volts. If you do not obtain the proper reading, touch the "hot" probe of the meter to INPUT pin 1 of regulator *U1*, where you should obtain a meter reading of approximately +20 volts. If you fail to obtain the proper reading at either or both points on the circuit-board assembly, unplug the receiver module from the ac line and carefully check over all component installations and wiring and soldering. Make sure each component is in its appropriate location and those that require polarizing and special basing are properly installed.

Turn over the circuit-board assembly and check all soldering. If you missed any connections, solder them now. If any connection appears grainy or otherwise suspicious, reflow the solder on it. Also, clear away any solder bridges, especially between the closely-spaced pads for the *U2* socket and *T2* with desoldering braid or a vacuum-type desoldering tool. Do not proceed until you have rectified the problem.

When you are satisfied that the circuit-board assembly has been properly wired, unplug it from the ac line. Allow the charges to bleed off the electrolytic capacitors in the power supply. Then install *U2* in its socket. Make sure the IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

Operational Checkout

Place the transmitter and receiver modules back-to-back (all LEDs on both boards facing away from each other) on an insulated surface and plug both units into ac outlets. Using a VCR, TV or other IR remote-control transmitter to activate the transmitter should cause the receiver board to respond. This activity will be evident by the visible LED on that module flashing when any transmitter key is held down.

Now place the Extended Play transmitter and receiver units so that they are face-to-face (all LEDs on both units facing each other). This should cause the system to self-oscillate from IR feedback. You may have to start the ball rolling with a little stimulus from your remote-control transmitter. Although not recommended for more than a few seconds at a time, this test will easily show that everything is working as it should.

When you are confident that both units are performing satisfactorily, it is time for a test using the actual components the system will control. Although the following procedure can be accomplished with a CD player, stereo system or any other IR-controlled appliance, a VCR and some means of sending its output to a remotely located TV receiver will be assumed. Of course, if you have any of these other devices, you can use one of them instead.

Mount the front panels on the transmitter and receiver unit enclosures with the provided screws and carefully install the overlays so that the translucent red filter sections are positioned over the rectangular cutouts in the panels. Slide the circuit-board assemblies into their enclosures and mount the rear panels in place, again with the supplied screws.

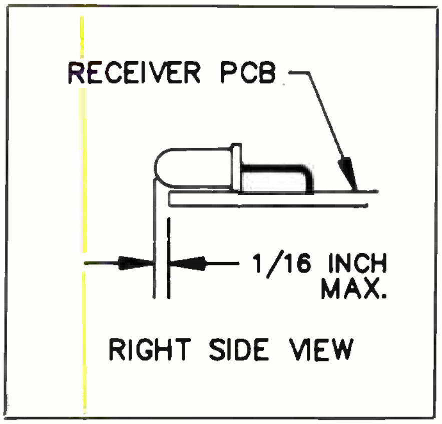


Fig. 11. Mounting details for the LEDs on the receiver pc-board.

Position the Extended Play receiver module across the room from your VCR so that its front-panel IR window faces the front of the VCR at a distance of not more than 18 feet. Plug the receiver's line cord into a convenient ac outlet. Use a small screwdriver to slowly adjust the GAIN control through its access hole in the rear panel clockwise until the LED just begins to glow very brightly. Then back off (counterclockwise rotation) until the LED either suddenly goes dark or suddenly glows dimly.

If the LED glows dimly even when the GAIN control is adjusted fully (or nearly) counterclockwise, excessive noise is present on the ac line. You may leave the unit plugged into this outlet or test others in the room for quieter operation. Alternatively, you can make either or both of the following modifications.

In the transmitter module, replace *C7* with a 0.1-microfarad polyester

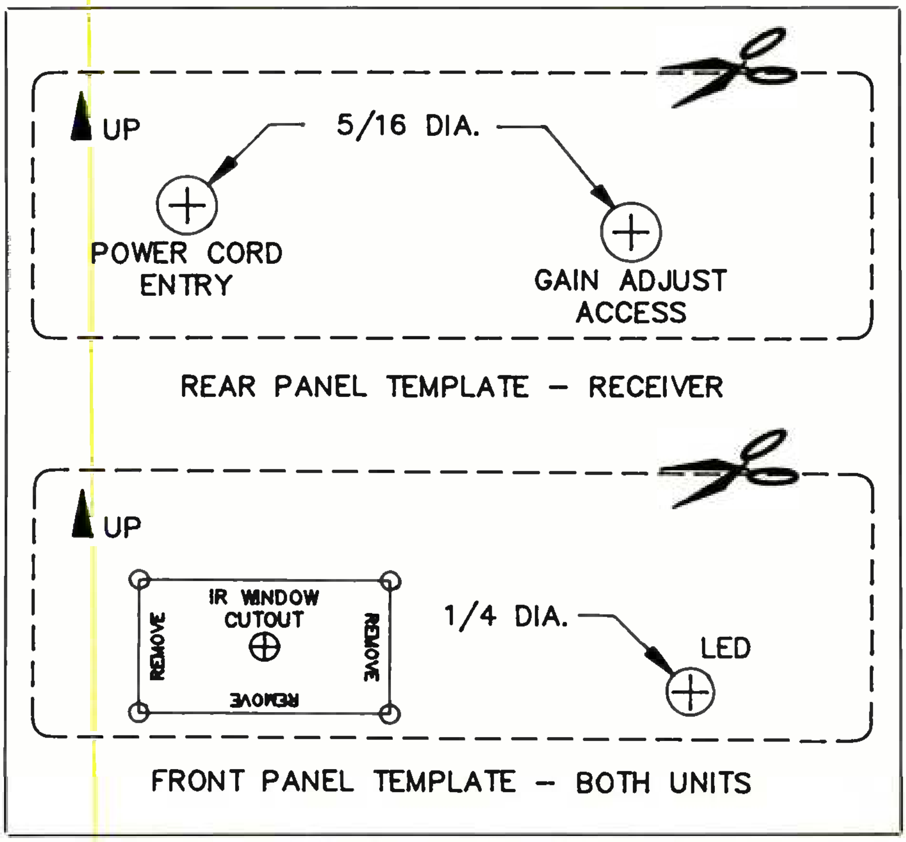


Fig. 12. Machining templates for rear (A) and front (B) panels of receiver enclosure.

or Mylar capacitor. This slightly reduces the threshold of the IR circuit but otherwise leaves unaffected the 18-foot-plus range of the project. In the receiver module, place a 1,000-ohm resistor across (in parallel with) C7. This effectively lowers the Q of the LC tank circuit to reduce noise-induced "ringing." Neither of these modifications will noticeably reduce the performance of the circuits.

Once you have set the receiver threshold, play a prerecorded videocassette through the VCR. After pressing PLAY, check the remote TV receiver (it is assumed that you have run video and audio cables from the VCR to the remote TV receiver beforehand) to be sure it is playing whatever is recorded on the tape.

Place the Extended Play transmitter on or near the remote TV receiver. Using the remote-control transmitter supplied with the VCR, press PAUSE (not being able to see the VCR indicator lights may take some getting used to if you have never used a remote-remote control system before). If you correctly assembled the Extended Play transmitter and receiver modules and your house wiring provides good coupling, the TV image displayed on the TV receiver screen should freeze to a still picture.

This simple test verifies that the system is, indeed, operating as it should. If you wish, you can resume picture action, stop it, fast forward or rewind to another section of the tape to check out these functions as well. However, if even one function works via the Extended Play link, all other functions will as well.

If your VCR does not respond properly during the system operational check, something is wrong with the wiring in either the transmitter or the receiver module or both. In this event, power down both units and carefully check over your work.

If you have a problem and use an oscilloscope to perform any tests in the Extended Play circuits, do *not* make any connections to ground. If the scope you use has a three-prong power-cord plug, use a three-to-two-prong adapter between it and the ac outlet before use.

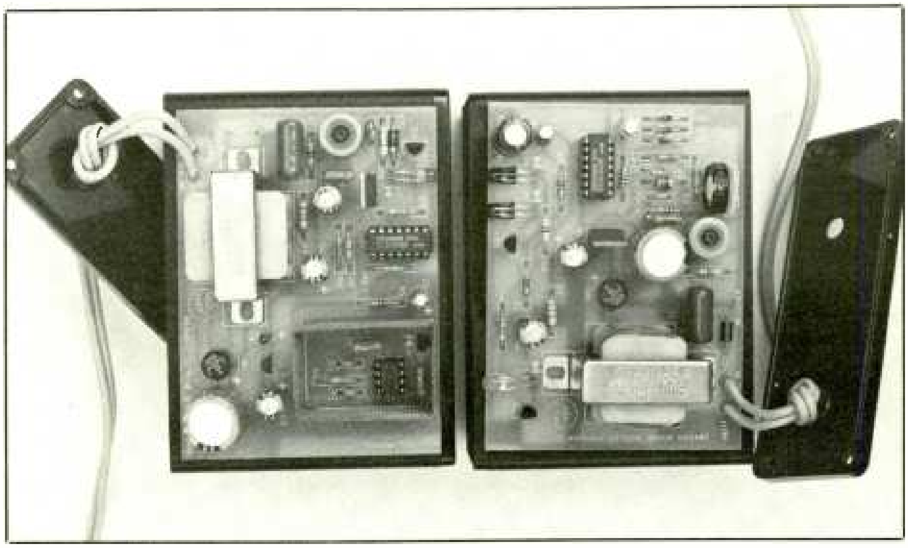


Fig. 13. Photo shows fully wired transmitter (left) and receiver (right) circuit-board assemblies just prior to installation in the enclosures atop which they sit.

System Installation

Placement of the Extended Play transmitter(s) and receiver in your home depends as much on room layout as on personal taste. You can pretest different locations for the receiver using a hand-held remote-control transmitter to emulate the proposed positioning. If a given location works well with the remote-control transmitter, it will almost certainly work as well with the receiver.

As a matter of convenience, you may want to experiment with placing the receiver directly on top of or alongside your VCR. If a window or light-colored wall directly faces the VCR from across the room, the receiver should be able to beam the control signals at the wall with enough energy that they reflect back to the VCR without significant loss.

The transmitter can be placed beside or atop most TV receivers without experiencing erratic behavior. However, computer monitors produce a great deal more emi (electromagnetic radiation, or noise) than do TV receivers. If your remote TV receiver is located close to a computer, try to keep the Extended Play transmitter at least 24 inches from the computer monitor. Any interference from the computer monitor can be identified by continuous erratic flashing of the transmitter LED.

Some Caveats

When you are setting up the Extended Play or any carrier-current system for permanent use there are several things to watch for. One is cable TV converter-box IR remote control systems. Although the majority of these systems are well designed, some are poorly designed with regard to method of IR transmission. A very few converters (the type distributed by some cable TV franchises) use an unmodulated IR signal to transmit the control codes. In affect, these systems simply use slow on/off pulses that make them susceptible to false signals and may or may not be accurately retransmitted by the Extended Play system.

High noise levels may appear on the ac power lines used to carry the Extended Play signals. Although this is not a significant problem, it appears at the receiver as a constant, dim glowing of the LED indicator. You can tackle the problem by modifying the transmitter or/and receiver as described above to deal with this problem.

A final consideration is the house wiring itself. Because of the manner in which the incoming 240 volts ac is divided into its two respective 117-volt ac legs, it is possible for two outlets in the same room to be on completely different circuits, each 180 degrees out-of-phase with the other (with respect to neutral). This single anomaly in the house wiring is the biggest hurdle to be overcome by any carrier-current system.

In effect, for an ac outlet on one circuit to communicate with another on a different circuit using carrier-current transmission requires that the signal make a round-trip via the step-down transformer located somewhere in your neighborhood.

The solution for this is as simple as placing a 0.01-microfarad high-voltage capacitor (rated at 400 volts or greater) directly across the 240-volt ac line somewhere in your home. This capacitor can be installed at the outlet of any 240-volt ac appliance or at the breaker box (or fuse panel) where the 240-volt line enters your home. A good choice for such a capacitor is the Radio Shack Cat. No. 272-160. Rated at 2,000 volts (2 kV), it will easily handle permanent installation across a 240-volt ac line.

If you decide to install this capacitor, exercise extreme caution! Bear firmly in mind that 240 volts ac is *lethal*. Therefore, before even attempting to make any connections, make sure to open the main breaker (or remove the main fuse) at the junction box to shut down *all* power within your home so that you can work in complete safety. As a further precaution, check the "dead" house wiring with an ac voltmeter prior to touching any house wiring.

This modification is recommended by several manufacturers of carrier-current controllers in their installation manuals and troubleshooting guides. Although this should be looked upon as a last resort (few homes actually need this modification), it will benefit any carrier-current accessories you presently own.

Now that you have established an IR link via the ac wiring in your home, some interesting possibilities are possible. For example, you can use the Extended Play system as a burglar alarm accessory, a remote appliance controller and more, assuming you come up with suitable interfaces. Add to this list lights, heaters, fans and air conditioners, all of which should be able to be controlled with the proper interfaces. Even a personal computer with an IR transmitter adapter is not inconceivable! With a bit of ingenuity on your part, you can probably think up dozens of other control applications for the Extended Play. **ME**

Interfacing 555 Timers

A hands-on look at real-world use of this ubiquitous and very versatile IC timer chip

By Joseph J. Carr

The 555 timer chip ranks as perhaps the all-time most popular device in the IC arena—with good reason. Its immense popularity derives from the fact that the 555 is inexpensive, well-behaved and is so utterly useful in an almost limitless variety of applications. Since a lot has been written over the years about the 555, we will not begin at the beginning here. We will assume that you either already know the basics or where to look for them. Instead, we will concentrate in this article on interfacing between the 555 device and the "outside world."

Definitions

Shown in Fig. 1 are the package and pinout details for the popular eight-pin mini-DIP version of the 555 timer. In reviewing pin function definitions and their uses, keep in mind that "high" means a potential that is greater than 2(V+)/3 and "low" means either a grounded condition, where V = 0 (as in the case of the RESET pin) or a potential that is less than (V+)/3 (as in the case of the TRIGGER pin).

Pin function definitions for the 555 timer are as follows:

• **GROUND** (pin 1) serves as the common reference point for all signals and voltages in the 555 circuit, both internal and external to the chip.

• **TRIGGER** (pin 2) is normally held at a potential greater than 2(V+)/3. In this state, 555 OUTPUT pin 3 is low. If the TRIGGER pin is brought low to a potential that is less than (V+)/3, OUTPUT pin 3 abruptly switches to the high state. The output remains high as long as pin 2 is low, but the output does not necessarily revert back to low immediately after pin 2 is brought high once again.

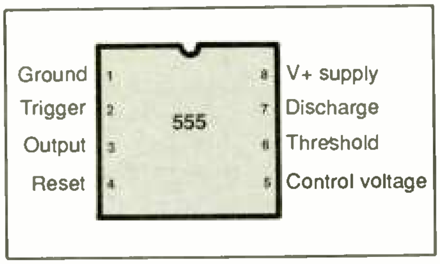


Fig. 1. Package configuration and pinout details for the 555 timer.

• **OUTPUT** (pin 3) is capable of either sinking or sourcing current up to 200 milliamperes, which is in contrast to other IC devices in which the outputs either sink or source current, but not do both. Whether the 555 output operates as a sink or a source depends on the configuration of the external load. Figure 2 illustrates both types of operation.

The arrangement shown in Fig. 2(A), in which external load R_L is connected between the 555 output and V+, allows current to flow in the load only when pin 3 is low. In this condition, the external load is grounded through pin 1 and small internal source resistance R_{S1}. In this arrangement, the 555 output is a current sink.

The circuit shown in Fig. 2(B) is for the case where the load is connected between pin 3 of the 555 and ground. When the output is low, the load current is zero. However, when the output is high, the load is connected to V+ through small internal resistance R_{S2} and pin 8. Here, the output is a current source.

• **RESET** (pin 4), when low, immediately switches the output of the 555 at pin 3 to a low state. In normal opera-

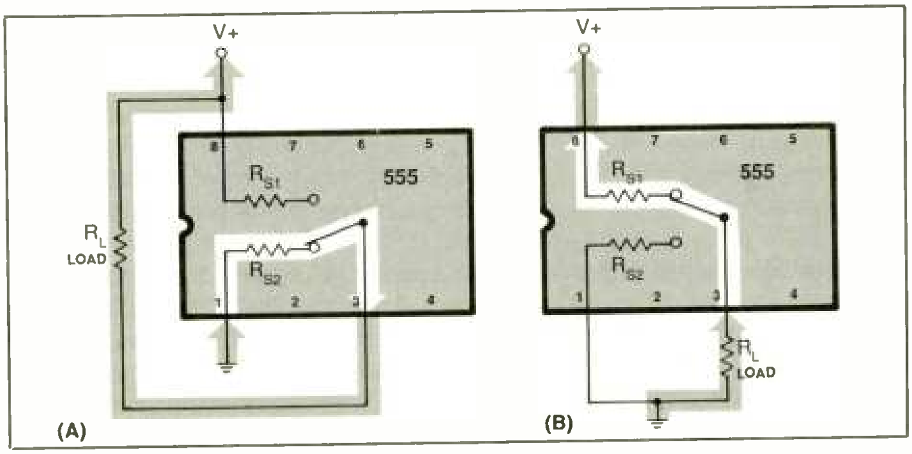


Fig. 2. Examples of a 555 used as (A) an output current sink and (B) an output current source.

tion, it is common practice to connect pin 4 to V+ to prevent false resets from noise impulses.

• **CONTROL VOLTAGE** (pin 5) normally rests at a potential of 2(V+)/3 due to an internal resistive voltage divider. Applying an external voltage to this pin, or connecting a resistor to ground, changes the duty cycle of the output signal. If not used, pin 5 should be decoupled to ground through a 0.01- to 0.1-microfarad capacitor.

• **THRESHOLD** (pin 6) monitors the voltage across the capacitor in the external RC timing network. If pin 6 is at a potential of less than 2(V+)/3, the output (at pin 3) is high. Alternatively, when the voltage on pin 6 is less than 2(V+)/3, the output is low.

• **DISCHARGE** (pin 7) is connected to the collector of an internal npn transistor. The emitter of this transistor is connected to the ground (pin 1) of the 555. When the 555 times out, the transistor turns on and can discharge the external timing capacitor.

• **V+ POWER SUPPLY** (pin 8) connects to the positive rail of the power supply that drives the 555 timer chip (and usually any other circuitry). Good practice dictates that a 0.1- to 1.0-microfarad decoupling capacitor be used between pin 8 and ground.

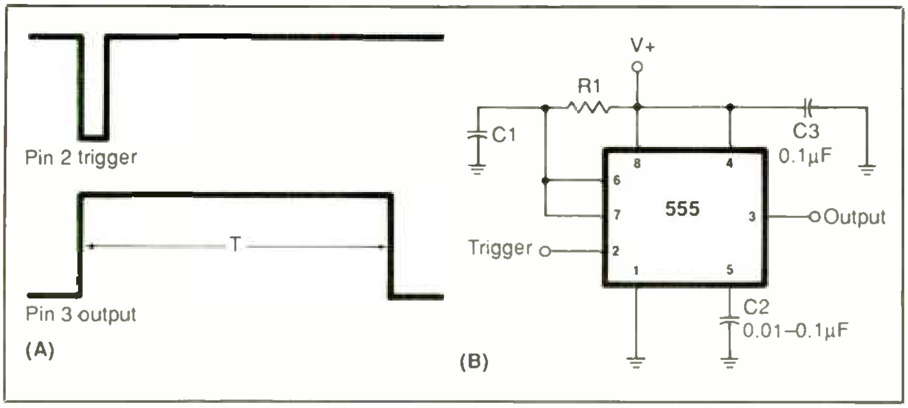


Fig. 3. Timing diagram (A) of a one-shot multivibrator built around the 555 timer and (B) details for assembling a 555 a one-shot multivibrator.

Monostable Operation

The monostable multivibrator (MMV), also called a one-shot multivibrator, produces a single output pulse of fixed duration when triggered by an input pulse, as illustrated in Fig. 3(A). The output of the one-shot snaps high following the trigger pulse and remains in this condition for a predetermined duration. When this time expires the one-shot is "timed-out" and, so, snaps low again.

The output of the one-shot remains low indefinitely, unless another trigger pulse is applied to it. The 555 timer can be operated as a monostable multivibrator with suitable connection of the external circuit, as in Fig. 3(B). It is this monostable multivibrator configuration of the 555 that we will use as the basis for our discussions here.

Input Triggering

The 555 MMV circuit triggers by bringing pin 2 from a positive voltage down to a potential of less than (V+)/3. Triggering can be accomplished by applying a pulse from an external signal source or through other means.

Figure 4(A) is the schematic diagram of the circuit for a simple push-button-switch trigger circuit. Pull-up resistor *R2* is connected between pin 2 and V+. If normally-open push-button switch *S1* is open, the TRIGGER input is held at a potential very close to V+. But when *S1* is closed, pin 2 is brought to ground potential. Because pin 2 is now at a potential that is less than (V+)/3, the 555 MMV triggers. This circuit can be used for contact debouncing in digital circuits.

A circuit for inverting the trigger pulse applied to the 555 is shown in Fig. 4(B). Here, a common npn bipolar transistor, such as the 2N2222, is used in the common-emitter mode to invert the pulse. Again, a pull-up resistor is used to keep pin 2 at V+ when the transistor is turned off. However, when the positive-polarity trigger pulse is received at the base of *Q1*, the transistor saturates, which

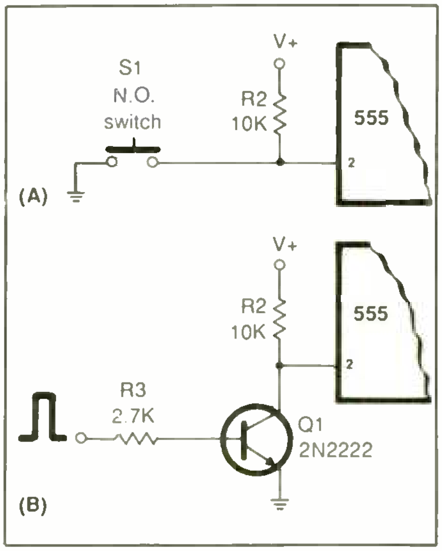


Fig. 4. Examples of (A) simple push-button switch triggering for the 555 timer and (B) transistor inverter that permits positive-going pulses to trigger the 555.

forces the collector (and pin 2 of the 555) to near ground potential.

Shown in Fig. 5 are two ac-coupled versions of the trigger circuit. In both circuits, a pull-up resistor keeps pin 2 normally at V+. But when a pulse is applied to the input end of *C3*, a differentiated version of the pulse is created at the TRIGGER input of the 555. Diode *D1* clips the positive-going spike to 0.6 or 0.7 volts, passing only the negative going pulse to the 555. If the negative-going spike

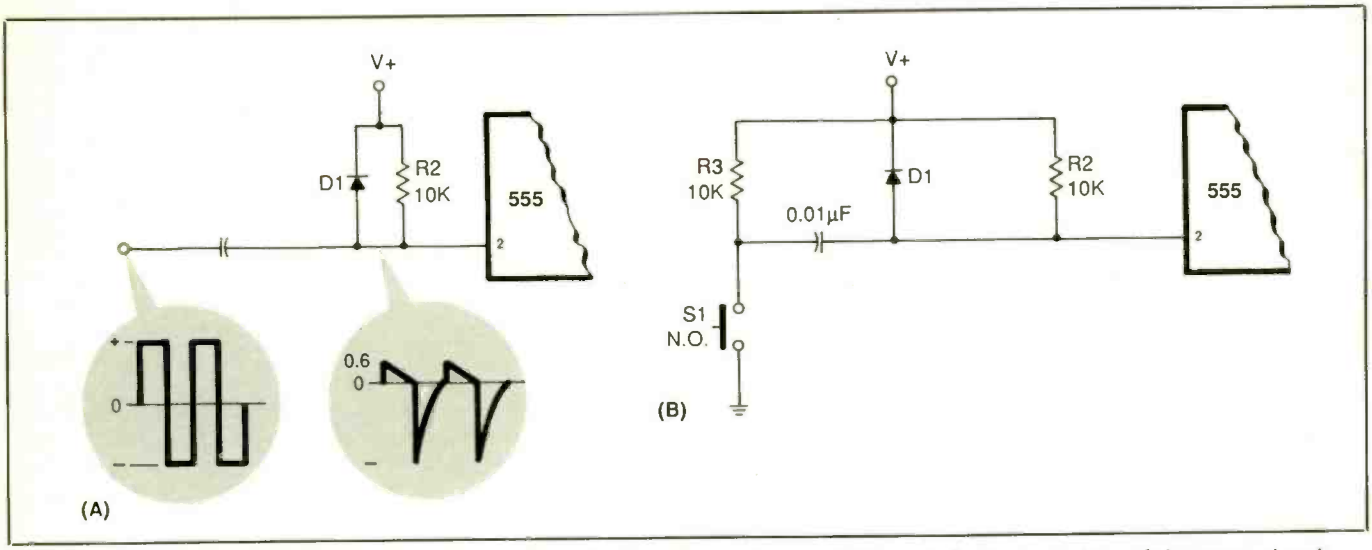


Fig. 5. Examples of (A) ac-coupled triggering of a 555 using pulses and (B) push- button version of the same circuit.

can counteract the positive bias provided by *R2* sufficiently to force the voltage lower than (V+)/3, the 555 will trigger. A pushbutton switch version of this same circuit is shown in Fig. 5(B).

A touchplate trigger circuit is shown in Fig. 6(A). Pull-up resistor *R2* has a very high value (22 megohms shown). The touchplate consists of a pair of closely spaced electrodes. As long as there is no external resistance between the two halves of the touchplate, the TRIGGER input of the 555 remains at V+. However, when a resistance is connected across the touchplate, the voltage (V1) drops to a very low value. If the average finger resistance is about 20,000 ohms, the voltage drops to: $V1 = [(V+ \times 20 \times 10^3)/(R2 + 20 \times 10^3)]$. Thus, when *R2* is 22 megohms, the voltage drops to 0.0009(V+). This is considerably less than the (V+/3) triggering criterion for the 555.

The same concept is used in the liquid-level detector circuit shown schematically in Fig. 6(B). Once again, a 22-megohm pull-up resistor is used to keep pin 2 at V+ in operation. When the level of the liquid rises sufficiently to short out the electrodes, however, the voltage on pin 2 (V1) drops to a very low level, forcing the 555 to trigger.

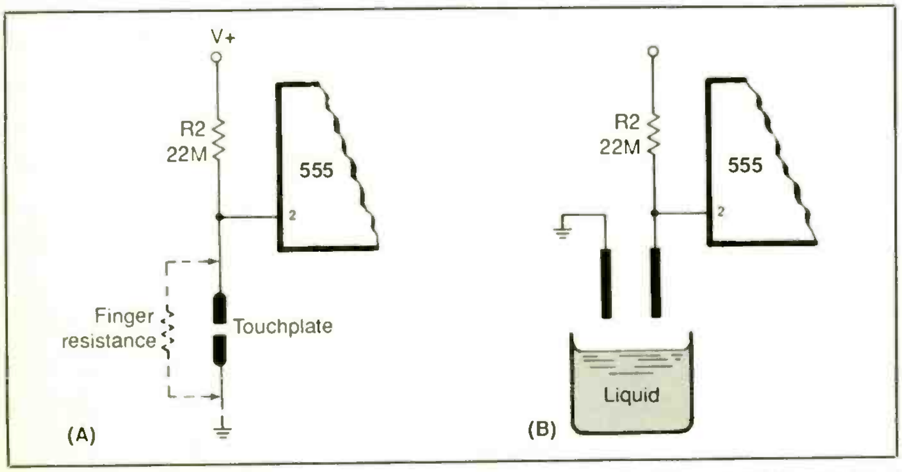


Fig. 6. Examples of (A) touch-plate sensor triggering of a 555 and (B) liquid-level alarm version of the same principle.

Output Circuits

As stated above, the output at pin 3 of the 555 can serve as either a current source or a current sink, depending on how you wire the circuit. The output can be made TTL-compatible by making V+ 5 volts dc. It can also be made CMOS-compatible by matching the 555 power supply potentials to the levels used in the particular CMOS circuit.

Figure 7 shows how light-emitting diodes can used as the load for the 555. Although LEDs are used here, almost any load that draws less than 200 milliamperes could be used instead. The usefulness of the 555 is demonstrated by these circuits. There are times when you might want a LED indication when the output of the 555 is low, other times when it is high. The 555 can accommodate either need without requiring an intervening open-collector inverter stage.

In Fig. 7(A), the LED, wired between pin 3 and ground, requires the 555 to act as a current source. When the output is low, there is no potential across the LED, no current flows, and the LED is off. When the

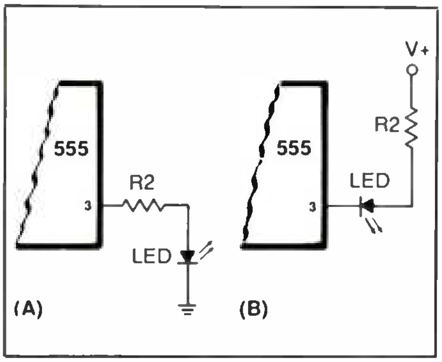


Fig. 7. Light-emitting diode load used with a 555 timer in (A) current-source and (B) current-sink modes.

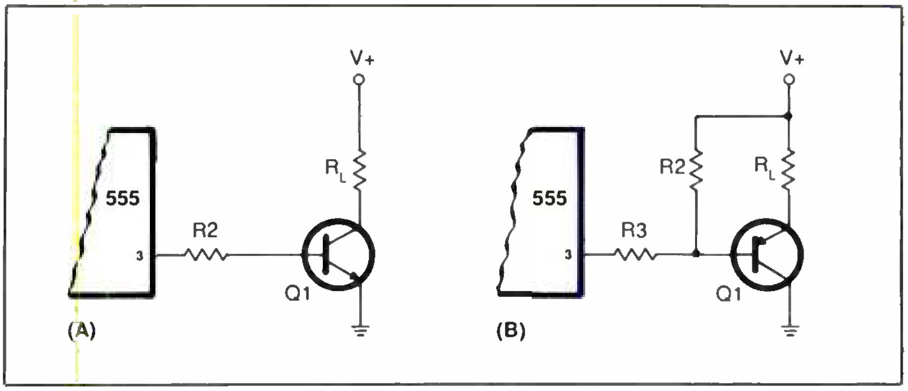


Fig. 8. Details of use of (A) npn and (B) pnp transistor switches to increase current-handling capability of a 555.

output is high, however, a potential appears at pin 3, current flows in the LED, and the LED turns on.

In Fig. 7(B) the opposite connection is shown. Here, the LED is wired between the OUTPUT terminal and V+, causing the output of the 555 to sink current. When the output is low, the cathode end of the LED is essentially grounded through a small resistance, so the LED is turned on. When the output is high, the potential at both ends of the LED is close to V+. Thus, with no differential voltage between cathode and anode, no current flows through the LED and the LED is off.

In both Fig. 7 examples, the resistor in series with the LED limits the current flowing in the LED. For most unmarked LEDs, maximum safe current is 15 mA (0.015 A). Therefore, you should set the value of *R2* to a value of (V+)/0.015 or greater.

When the current through the load exceeds the 200-milliampere output capacity of the 555, you can add an external transistor switch, as illustrated in Fig. 8, to handle the greater current. The output of the 555 is used to turn on and off the transistor. In Fig. 8(A), an npn transistor version is shown. When the output of the 555 in this circuit is low, no bias voltage is applied to the base-emitter junction of the transistor. This keeps the transistor in cutoff. But when the output of the 555 is high, the transistor is biased into saturation, causing it to turn on hard. The "cold" end of the load, connected to the collector of *Q1*, is thereby grounded and current flows. The value of the *Q1* base resistor is dependent upon the load current and the beta of the transistor. It can be found experimentally.

A pnp transistor is used in the same manner in Fig. 8(B). With the pnp transistor, the base must be less-positive than the emitter so that this circuit turns on when the output of the 555 is low. When the output is high, the emitter and base are at close to the same potential, so no action occurs.

Even greater currents can be accommodated if you use a relay as the load for the 555 output, as in Fig. 9. In addition, the relay makes it possible to use the 555 in a low-voltage dc circuit with other electronics to control a high voltage load circuit.

Select a relay with a coil rating of 18 volts dc or less (5, 6 and 12 volts are common). Match that voltage to the V+ used to power the 555. For example, if you are powering the 555 from a 12-volt dc source, select a 12-volt dc relay. Also, make sure that the rated coil current is less than 200 milliamperes. If you do not know the coil current rating, calculate it using the known or measured dc coil resistance (the most commonly listed relay specification) from the formula: $I_{coil} = (V+)/R_{coil}$.

(Continued on page 77)

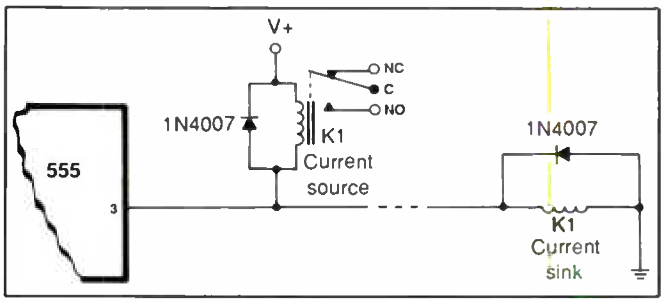


Fig. 9. Current-sink and -source details of a 555 used to drive relays.

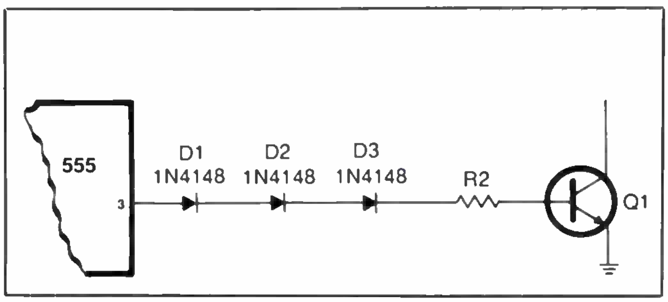


Fig. 10. Diodes can isolate the 555 output from transient pulses in the external load circuit.

Experimenting with Incandescent Lamps

By Forrest M. Mims, III

The ancient incandescent lamp may seem to be rather low-tech for a magazine with the name *Modern Electronics*. Actually, though, some very significant advances have been made in the field of incandescent lamps, about which I shall have more to say later. I'll then present some experiments and circuits you can try that may cast a new light on the versatility of an antique electronic component we all take for granted. First, let's pause for a brief review of the history of the invention of the incandescent lamp.

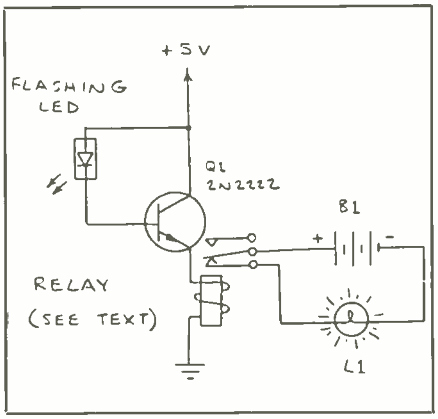


Fig. 1. A simple relay lamp flasher.

The Invention of the Incandescent Lamp

Though Thomas Edison is generally credited with the invention of the incandescent lamp, other inventors also played a prominent role in this area. In 1802, England's Sir Humphry Davy demonstrated that an electric current passing through a thin strip of platinum would cause the metal to emit a visible glow. All modern incandescent lamps are derived from this fundamental discovery.

In 1841, Frederick de Moleyns received an English patent for an incandescent lamp that consisted of a two closely spaced platinum electrodes installed in an evacuated glass sphere. Powdered carbon between the electrodes became incandescent when an electrical current flowed through the two electrodes.

In 1850, Sir Joseph W. Swan, another Englishman, devised incandescent filaments from paper and cotton thread. He treated the thread with sulfuric acid to remove everything but the carbon. The carbonized thread was installed inside an evacuated glass envelope to produce what Swan called an electric glow lamp.

In the United States, Thomas Edison announced, in 1878, that he intended to invent a practical electric light suitable for use in homes. Based on his reputation as a highly successful inventor, a syndicate of investors advanced Edison $50,000 for the electric light project. The investors even formed the Edison Electric Light Company before the inventor had made his first lamp.

Edison at first attempted to find a filament material that could be heated to a higher temperature than the carbon used by his predecessors, thereby providing a brighter and more practical light source. Oxides of thorium and zirconium seemed good candidates, but they could not be formed into filaments. Finally, Edison resorted to the carbonized thread filament, and on October 21, 1879, he demonstrated a lamp that operated continuously for 40 hours. Two months later, he demonstrated a pilot light and power station at his Menlo Park, NJ laboratory. The system powered 30 lamps, any one of which could be disconnected without affecting the status of the others.

Incidentally, it's interesting to note that, from the outset, Edison proposed to connect electric lamps in parallel circuits so that the failure of one lamp would not affect the remainder. Some scientists predicted the parallel method would not be practical. Sir William H. Preece, for example, said as much in a paper he read before the Royal Society in London. Fortunately, Edison had only three months of formal education in his youth, so he could safely ignore the pronouncements of formally trained scientists. Of course, the parallel electric light circuit proved practical and it greatly enhanced Edison's fame as a gifted inventor. (As for the skeptical Sir William's scientific legacy, I had never heard of him prior to preparing this column.)

Blackbody Radiation

Everything above the temperature of absolute zero, which is presumably everything, emits electromagnetic radiation. This is commonly known as blackbody radiation. As the temperature of an object increases, the flux of the radiation it emits increases and, conversely, its wavelength decreases.

Blackbody temperature is specified according to the Kelvin scale in which 0 Kelvin (K) equals −273.16 degrees Celsius. (The term degrees is not supposed to be used with the Kelvin scale but often is.)

Only when the temperature of an object becomes very warm does the radiation it emits become visible. As evidence of this, consider that the temperature of an electric heating element that emits a cherry-red glow is in excess of around 1,000 K. The filament of a white-hot tungsten-halogen lamp may reach 3,400 K. If the filament could be heated to 6,000 K without melting, it would emit light as white as that emitted by the sun.

It's appropriate to ask why the light from an object at 1,200 K appears to be a monochromatic red while that from an object at 6,000 K is white. The answer is that blackbody radiation has a very broad spectrum and is not monochromatic. Indeed, the peak wavelength of a cherry-red heating element at 1,200 K is around 2.4 micrometers in the infrared. In other words, the red glow from the heating element is only a small portion of the radiation it emits. Most of the radiation from the heating element is invisible. The peak wavelength of sunlight is around 555 nanometers in the green. The fact this happens to match the visible response of the human eye is certainly no coincidence.

Tungsten Filament Lamps

The simplest tungsten lamp consists of either a straight or coiled tungsten filament installed in an evacuated glass envelope. The filament begins to emit a dimly visible red light at a temperature of around 1,000 K. In normal operation, the filament of an evacuated tungsten lamp is typically heated to a temperature of 1,800 to 2,200 K. The peak wavelength of an evacuated tungsten lamp with a filament temperature of 2,000 K is around 1.5 micrometers in the near infrared. Only around 5 percent of the optical radiation emitted by the filament is visible light; the remainder is invisible infrared.

If the filament is operated at a temperature higher than about 2,200 K, the rate of tungsten evaporation from it will become so high that the inside of the envelope will quickly become coated with an opaque film of tungsten atoms. Once I mistakenly applied far too much current to a miniature incandescent lamp. The filament exploded in a brilliant flash and coated the inside of the glass envelope with a shiny film of tungsten.

Tungsten lamps can be operated at a temperature higher than 2,200 K if the envelope is filled with an inert gas, such as argon or krypton, which reduces the evaporation of tungsten from the filament. The upper limit is 3,600 K, the melting point of tungsten. Since gases conduct heat, the envelope of a gas-filled lamp will become much hotter than that of an evacuated lamp.

Even better performance can be achieved by adding to the fill gas a trace of a halogen, such as bromine or iodine. This sets up a regenerative chemical reaction that greatly increases the permissible operating temperature of the filament while simultaneously restoring the tungsten atoms that are boiled away. Here's what happens:

In an ordinary lamp, tungsten atoms boiled away from the incandescent filament can condense on the comparatively cool inside wall of the glass envelope. In a halogen lamp, evaporated tungsten atoms combine with the halogen to form tungsten bromide or tungsten iodide. While this gas does move toward the inside walls of the envelope, it does not condense there when the envelope is heated to 200 to 250 degrees C by the filament, which may have a temperature of from 2,800 to 3,400 K.

As the gas circulates back toward the heated filament, it disassociates back into tungsten and halogen vapor when the temperature exceeds 2,500 K. This process occurs in close proximity to the filament, thereby causing tungsten atoms to be deposited onto the filament and its supporting wires. The cycle then repeats as additional tungsten is liberated and combines with halogen vapor.

The very high filament temperature made possible by the halogen cycle provides an exceptionally bright light source. Moreover, after 75 percent of its rated life, a tungsten-halogen lamp emits 90 percent of its initial light output.

The brilliant white light of a tungsten-halogen lamp is accompanied by several drawbacks. The envelope temperature of a tungsten-halogen lamp must exceed 200 to 250 degrees C and may reach 350 degrees C. This means ordinary glass envelopes are unsuitable. Instead, fused silica (quartz) is required. Special ceramic sockets are usually necessary, and there may be restrictions on the operating orientation of the lamp to prevent thermal damage to the lamp's seals.

Due to the high temperature required to fabricate fused silica envelopes, halogen lamps are more expensive than are conventional lamps. They must never be operated near combustible materials. They must never be touched while in operation. Any fingerprints or other contamination must be completely removed from the envelope before operation. Finally, the very high brightness of halogen lamps, coupled with the ultraviolet that they emit, makes them potentially hazardous to unprotected eyes.

The filament of an incandescent lamp requires a finite rise time to reach its operating temperature after a current is applied. Likewise, the filament requires a

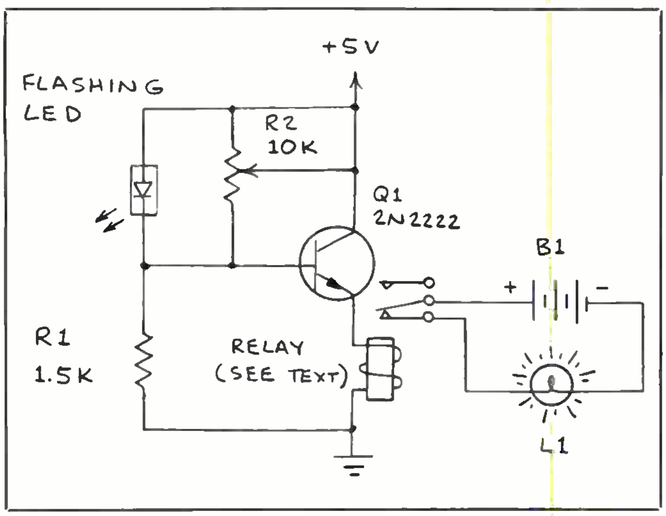


Fig. 2. An improved relay lamp driver.

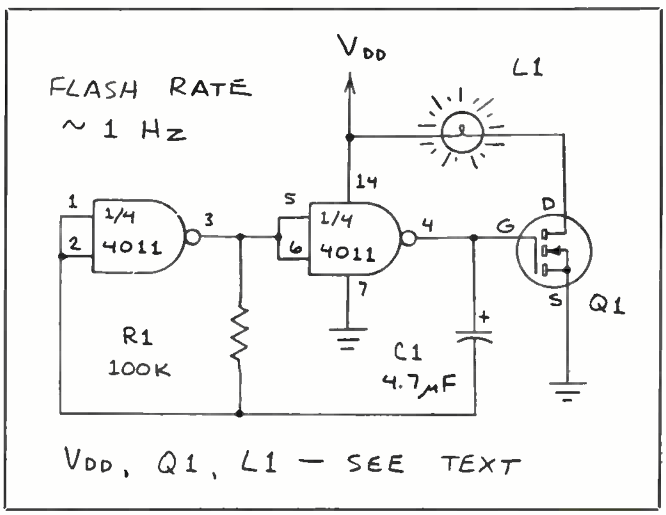


Fig. 3. A simple CMOS lamp flasher.

finite fall time to cool below the temperature where it emits visible light when the current is removed. These delays are sometimes known as thermal lag.

Thermal lag is directly related to the physical dimensions and mass of a lamp's filament. Because of the tiny size of its filament, the light from a flashlight appears to switch on and off instantaneously. Automobile headlights have very large filaments and require a noticeable time to achieve full brilliance when switched on and to be extinguished when switched off. The same applies to filament lamps used on tall antenna towers. The xenon strobe lamps used on some towers flash off and on almost instantaneously. The filament lamps used to mark most towers seem to switch off and on as if they were powered by an undulating sine wave.

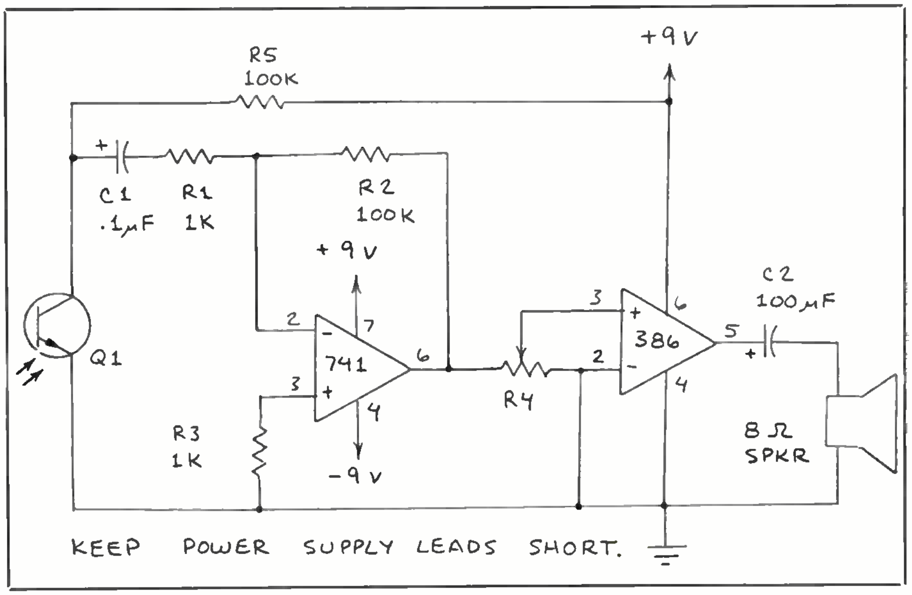


Fig. 4. A simple lightwave receiver circuit.

Relay Lamp Flashers

A relay is physically larger than a semiconductor switch, such as a silicon-controlled rectifier (SCR) or power MOSFET. Also, a relay requires a drive current that a semiconductor switch does not. Nevertheless, relays are exceptionally reliable and provide a very low on-resistance. Therefore, they are well suited for use in lamp flashing applications.

There are many ways to switch a lamp off and on by means of a relay. Circuits made from 555 timer chips are particularly popular since flash rate and duration is easily varied.

Figure 1 shows a super-simple relay lamp flasher you can assemble from a flasher LED and a single transistor. This flasher LED switches the transistor on each time it flashes, thereby pulling in the relay arm and switching on the lamp. I used an FRL-4403 flasher LED in the prototype of the Fig. 1 circuit. This LED flashes around three times per second. Other flasher LEDs should also work.

The relay should have a 6- to 9-volt, 500-ohm coil, such as Radio Shack's Cat. No. 275-004 relay does. Unfortunately, this relay is no longer stocked by Radio Shack; so you will have to search your spare-parts box or borrow one from a friend if you want to experiment with this particular relay. Other low-voltage (5-volt) relays with a high coil resistance may also work in the Fig. 1 circuit.

The flasher LED in Fig. 1 does not emit visible flashes when used as shown. Figure 2, a modified version of the circuit, permits the flasher LED to flash in step with the incandescent lamp. This verifies that the circuit is functioning properly in the event the incandescent lamp burns out.

In operation, *R2* must be adjusted until the lamp begins to flash. It may sometimes be necessary to readjust the setting of *R2* if the circuit stops flashing. While the flasher LED does emit a visible flash, it isn't as bright as when the flasher LED is used alone.

Power MOSFET Lamp Flasher

Figure 3 shows a simple incandescent lamp flasher circuit that uses a solid-state switch instead of a relay. The two cross-coupled gates form a multivibrator that oscillates at a frequency determined by *C1*. When the value of *C1* is 4.7 microfarads, the circuit oscillates at a rate of about 1 Hz. The output of the oscillator goes to the gate of VN67 or similar power MOSFET *Q1*, which is switched off and on by the changing state of the oscillator's output. The lamp is switched on when *Q1* is conducting.

Supply voltage for the Fig. 3 circuit should not exceed the lamp's rated voltage. Power dissipation of the lamp should not exceed *Q1*'s power rating. In some applications, when *L1* switches on, supply voltage might fall enough to alter the flash rate. If this is a problem, simply disconnect the lamp from the oscillator's power supply and provide it with a separate supply. The source lead of *Q1* should be connected to the ground side of both supplies.

For more versatility, replace the simple two-gate oscillator with a 555 or 7555 (CMOS 555) oscillator chip.

Modulating a Filament

In the spring of 1966 when I was a student at Texas A&M, I was experimenting with a lightwave communication system along a dark country road. The receiver's detector was a solar cell installed inside the reflector of a 6-volt lantern light. The receiver emitted a buzz when it was pointed at a distant neon sign. More surprising were the ringing sounds caused by the headlights of some passing cars.

Later, I tried pointing a flashlight at

the receiver, which produced nothing but changes in noise level. Tapping the flashlight with a pencil caused the receiver to emit the same ringing sound produced by the car headlights. The ringing is caused when the filament vibrates in and out of the reflector's focal point.

You can make a lightwave receiver to observe this phenomenon by connecting a silicon solar cell to the input of a battery-powered amplifier. Alternatively, you can assemble the basic lightwave receiver circuit shown in Fig. 4. In this circuit, *Q1* is any npn phototransistor. Do not place your ears close to the speaker since it is capable of emitting very loud sound levels.

The rise time of miniature, low-voltage lamps may range from 10 to 200 milliseconds. This means a small lamp can be modulated at audio frequencies. Indeed, during World War II, some amateur radio operators experimented with optical communicators based on voice-modulated incandescent lamps.

G. Wataghin and R. Deaglio of Torino, Italy first published a brief note on this method in a 1933 issue of the *Proceedings of the Institute of Radio Engineers* (Vol. 21, No. 10, pp. 1495-6). Hollis French presented complete construction details for a battery-powered filament lamp transmitter and receiver in the April 1944 issue of *QST* (pp. 22-25 and 86-88). French's system operated in either blinker or voice mode. The former yielded a range of up to 12 miles, the latter up to 0.5 mile.

Incidentally, French didn't feel that a filament lamp could react rapidly enough to a fluctuating signal to produce a modulated light beam. He attributed the modulation to physical vibration of the lamp filament: "An ordinary flashlight pointed at the photo-tube and tapped with a pencil or other solid object will give a bell-like tone at the receiving end, proving that mechanical vibration will produce sound." French's conclusion was wrong, but he was decades ahead of me in discovering that a vibrating lamp filament produces a modulated light beam.

In the "Experimenter's Section" of the October 1944 issue of *QST* (p. 38), Roger Houglum observed that, "In practically all the light-beam transmitters described in *QST*, the audio-frequency current from a low-impedance winding on an output transformer is used to vary the intensity of the light from a flashlight bulb . . . . Tests with several of these transmitters revealed that the audio quality at the receiver end was passable on voice but downright poor when music was used."

Houglum then demonstrated how a small battery and low-resistance rheostat in series with the lamp and transformer winding would provide a pre-bias to warm the lamp filament to around half its

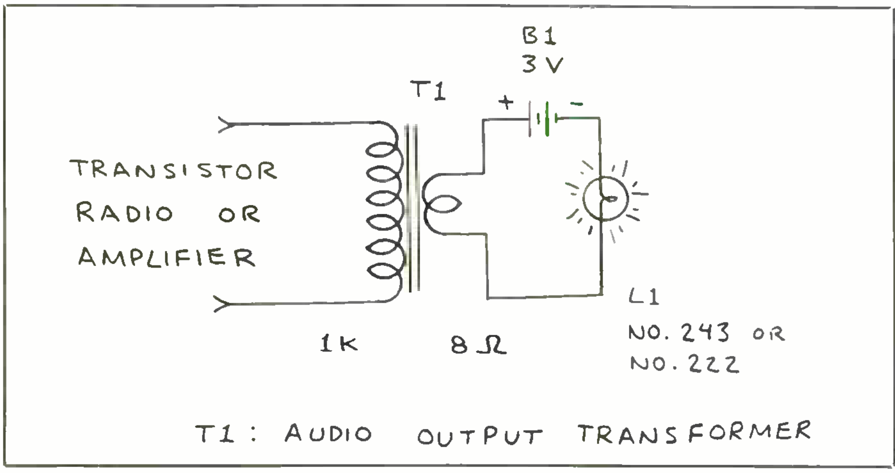


Fig. 5. An ultra-simple incandescent lamp audio transmitter circuit.

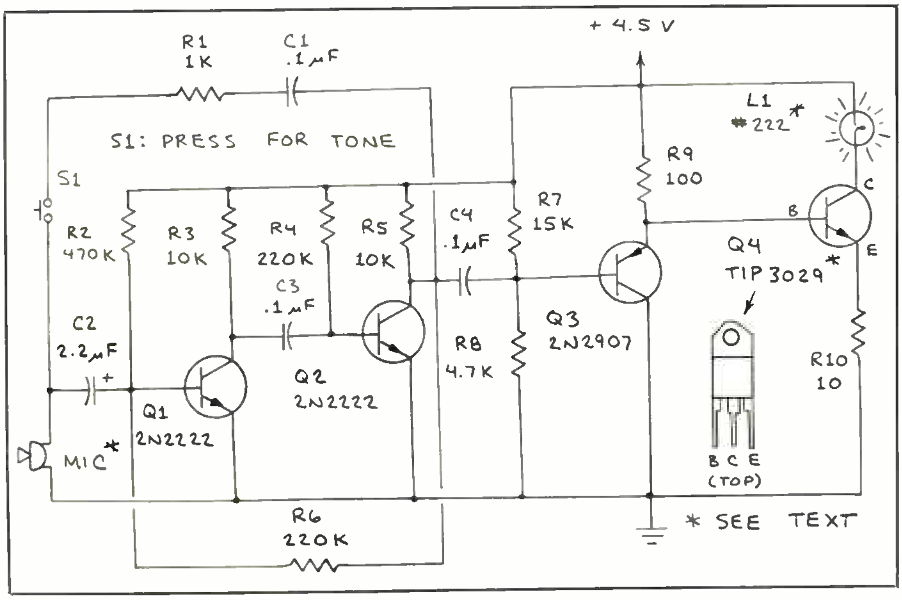


Fig. 6. An incandescent lamp modulator/driver circuit.

operational brilliance. This reduced the lamp's rise time and greatly improved its ability to be modulated by audio frequencies. The rheostat permitted the current to the lamp to be adjusted for optimum operation without zapping the lamp.

Lamp Modulators

Figure 5 shows the circuitry for an ultra-simple transformer lamp modulator based on circuits published nearly 50 years ago. You can assemble this circuit in just minutes. The simple receiver in Fig. 4 will receive the signal from this circuit. For initial tests, you can use a radio as an audio source or replace the radio with a small amplifier to transmit your voice.

While the low-impedance output from most transistor radios and amplifiers can be coupled into the 1,000-ohm (1k) winding of the audio transformer in the Fig. 5 circuit, much better results can be obtained if you connect a second transformer to the first. Connect together the 1,000-ohm winding of the two transformers. Then connect the 8-ohm winding of the new transformer to the output of the radio or amplifier.

You can control the brightness of the lamp by inserting a low-resistance rheostat in series with the lamp and *B1*. It's much simpler, however, to achieve the same effect by altering the volume of the amplifier or radio. In either case, it's important to keep peak current through the filament well below the point at which the filament melts.

Speaking of melted lamp filaments, chances are you will blow some lamps while experimenting with them in modulation circuits. Therefore, it's always a good idea to install lamps in sockets rather than soldering their leads into the circuit. Be sure to keep this in mind when building the following circuits as well.

In Fig. 6 is shown the circuitry of a transistorized filament lamp modulator/driver that modulates a small No. 243 or 222 lamp. As in Fig. 5, audio output transformer *T1* connects to a small radio or amplifier. The critical components are *L1* and *Q1*. If current through the collector-emitter junction of *Q2* is too high, *L1* may burn out or its life be excessively shortened. Momentary surges may not harm *Q2*, but the average current through the transistor and *L1* should not exceed 200 to 230 milliamperes.

You can measure the current through *L1* by breaking the circuit at point "X" in Fig. 6 and inserting an ammeter. Current can be reduced by lowering the level of the signal applied to *T1* or by inserting a current-limiting resistor at R_X.

If *Q2* becomes warm, install a heat sink on its case. For higher current operation, use a power MOSFET for *Q2*.

Self-Contained Lamp Transmitter

Figure 7 is the schematic diagram of a complete lightwave voice and tone lightwave transmitter that uses a miniature No. 222 lamp as a light source. Transistors *Q1* and *Q2* amplify the signal from the microphone and apply it to the modulator/driver circuit formed by transistors *Q3* and *Q4*. Resistor *R6* provides negative feedback to reduce the gain of the preamplifier formed by transistors *Q1* and *Q2*.

When *S1* is closed, the input preamplifier oscillates and causes the lamp to be modulated by an audio-frequency tone.

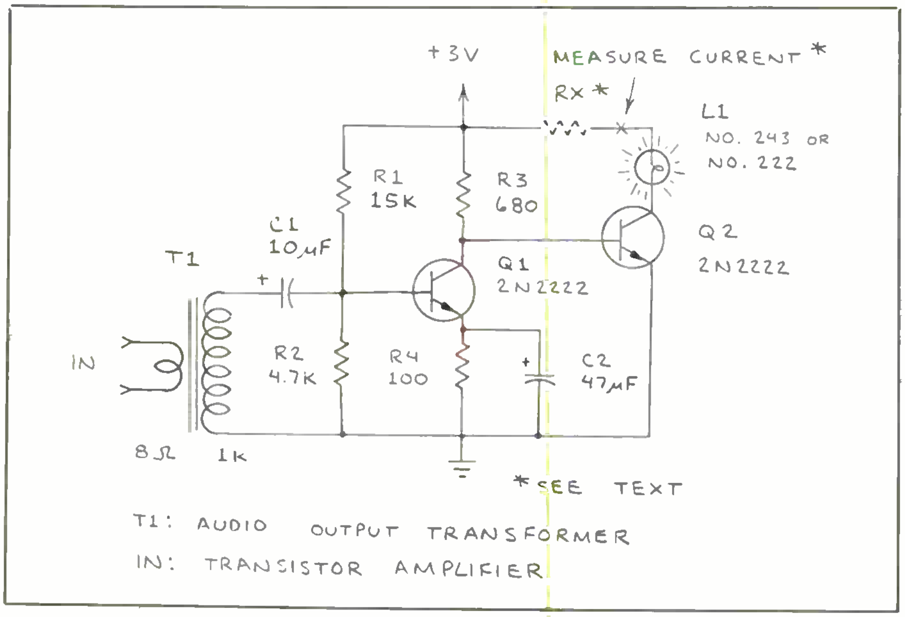


Fig. 7. A transistorized incandescent lamp voice and tone transmitter.

Frequency can be changed by altering the values of *R1*, *C1* or both.

The circuit should be powered by three 1.5-volt cells connected in series. Before connecting the cells to the circuit, however, connect the microphone and carefully check all wiring to make sure no errors have been made. When power is applied, the lamp should glow at around half its normal brilliance. If it glows a dim yellow in color, increase pre-bias current by connecting a second 10-ohm resistor across *R10*.

When you speak into the microphone, the lamp filament should flicker. Pressing *S1* may cause the lamp's brightness to change, but the lamp will not flicker.

Most dynamic microphones should work well with this circuit, but high-impedance types will not work. Though I used a TIP3029 for *Q4*, other npn power transistors should also work.

Going Further

Try placing a magnifying lens between a small incandescent lamp and a white wall. As you move the lens back and forth, an image of the lamp's filament will be projected onto the wall when the filament is at the focal point of the lens. This simple demonstration shows that a small fraction of the light emitted by a filament can be collected and collimated into a narrow beam.

You can make your own lens collimator or use binoculars or a small telescope. My son, Eric, and I have placed a small lamp at a telescope eyepiece and projected an image of the filament on a building more than a hundred meters distant. We then sent voice and music signals over the collimated beam to a receiver.

Since only a tiny fraction of an incandescent lamp can be collected by a lens, a reflector provides a more-efficient means for collimating light from a lamp. A laser, of course, provides a much better source of collimated light. But flashlight lamps and simple lenses are very inexpensive and with them, flashing signals, music and voice can be sent a fair distance on a dark night.

You may wish to do as I've done and assemble filament lamp transmitters and receivers inside plastic 6-volt lantern light housings. These large flashlights are equipped with reflectors and plenty of space for circuits and batteries. ME

Filters, FIFOs and other Devices

By Joseph Desposito

This month, we'll take a look at several types of analog and digital devices. The analog devices are a voltage controlled filter/oscillator, a low-noise filter and quad and dual low-power operational amplifiers. The digital devices are an 80C52 BASIC processor and a family of bidirectional FIFOs.

Analog Devices

A Voltage-Controlled Filter/Oscillator. As an alternative to switched-capacitor filters, Precision Monolithics Inc. (1500 Space Park Dr., P.O. Box 58020, Santa Clara, CA 95052) makes a four-pole voltage-controlled filter/oscillator. This product, the SSM-2044, offers a 1-MHz bandwidth and is appropriate for a wide range of applications, including medical imaging, ultra-sound and instrumentation systems. However, the design of the SSM-2044 has been optimized for use as an electronic music low-pass filter. A typical connection is shown in Fig. 1.

In Fig. 1, the SSM-2044 is connected as a four-pole low-pass electronic music filter. The differential signal inputs will accept any signals up to ±18 V peak-to-peak. If two oscillators are used in a voice, the output of the second should go to the opposite filter input from the first with a 3-dB signal level difference. This can be accomplished by scaling the input attenuators as shown, thus preventing cancellation as the oscillators phase with each other.

The sense of the Q control is from GND up with minimum resonance at GND. Oscillation will occur when the current into the Q pin reaches approximately 425 μA. With the input resistor shown, this corresponds to +7.5 V.

The control summer adds voltages from various control sources, such as the fc panel control, transient generator, lfo, etc. Any number of signals can be summed by applying them through resistors to the summing node of the op amp. Frequency offset adjust is required in polyphonic and programmable systems to make the filter(s) sound the same for an identical input control voltage. For best control rejection, the control summer and input attenuator should be designed so that maximum swing at the 2044 control pin corresponds to extremes of the intended sweep range when the control summer is driven to the supplies. With the values shown, one will obtain ±90 mV at the input pin, which corresponds to a 1000-to-1 sweep range for ±15 V supplies.

The V/octave trim and the Tel Labs temperature-compensating resistor are required in applications where the filter has to produce accurate musical intervals when in oscillation. If this is not necessary, the control op amp feedback network and the Tel Labs resistor can be replaced by 1% 300K- and 1K-ohm resistors, respectively.

The SSM-2044 is a −24 dB low-pass filter with a 10,000-to-1 variable cutoff frequency. Cutoff frequency is determined by a control voltage, making the device ideal for real-time analog filtering

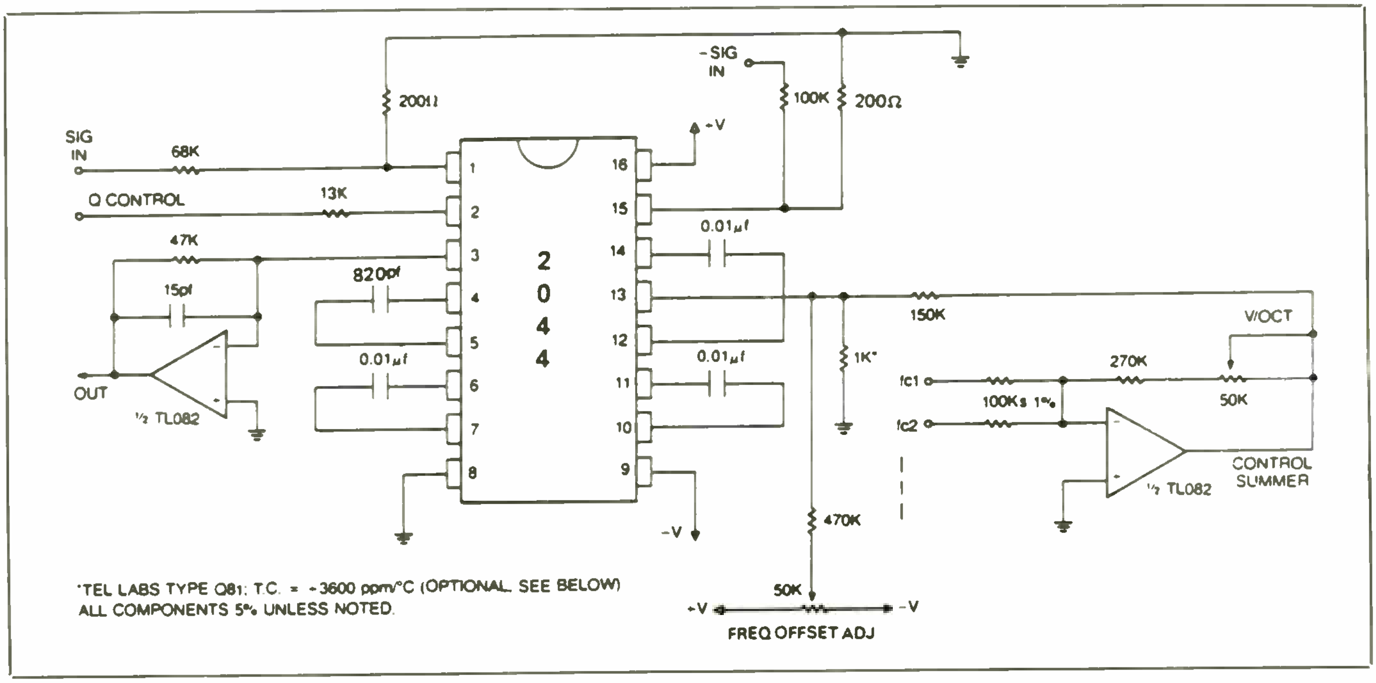


Fig. 1. Precision Monolithics' SSM-2044 voltage-controlled filter/oscillator is shown here connected as a four-pole low-pass electronic music filter.

under microprocessor control.

A unique feature of the SSM-2044 is its on-chip resonance control, which can produce a low-distortion sine wave for use in voltage-controlled oscillator (vco) applications. With a dynamic range of 90 dB and 1-MHz bandwidth, the SSM-2044 is a low-noise alternative to switched-capacitor filters in a wide variety of applications, including antialiasing and reconstruction filtering.

The SSM-2044 can operate with supply voltages ranging from ±5 V to ±18 V and, therefore, offers better pc-board layout flexibility than some CMOS devices.

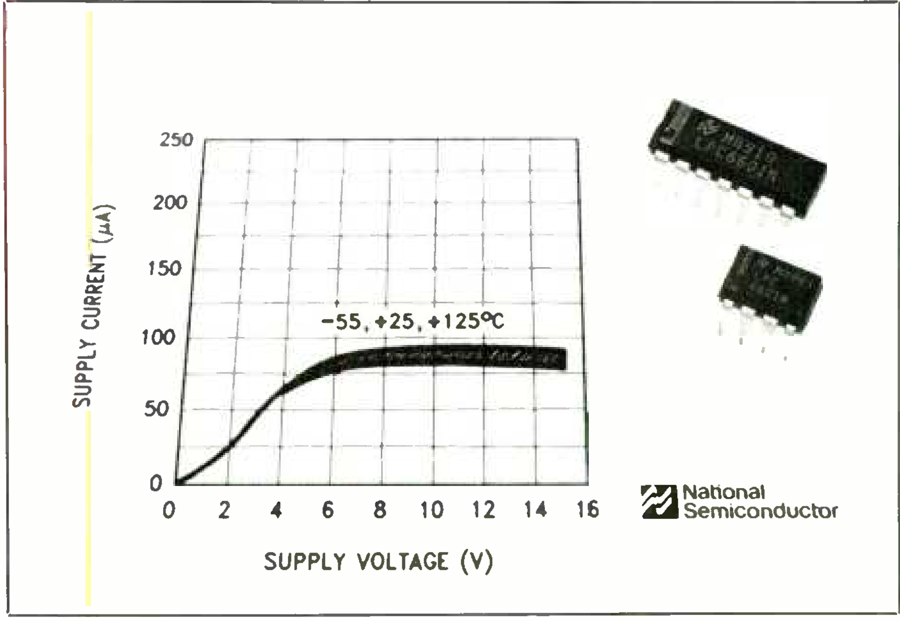
The SSM-2044's performance and characteristics are guaranteed over the 0°C to 70°C temperature range. The product is priced at $2.60 each in quantities of 100 and is available in 16-pin epoxy DIP packages.

Eighth-Order 100-KHz Low-Noise Filter. Linear Technology (1630 McCarthy Blvd., Milpitas, CA 95035) has announced the LTC1064-3, an eighth-order filter with a maximum corner frequency of 100 kHz and only 80 μV (rms) total wideband noise. The new device requires no external components for a 100-kHz filter implementation with a total harmonic distortion of 0.005% or less.

Applications for the device include antialiasing filters, smoothing filters and tracking high-frequency lowpass filters. The LTC1064-3 is a monolithic lowpass Bessel filter that provides a linear phase response over its entire passband. An external TTL or CMOS clock programs the filter's cutoff frequency with clock-to-cutoff frequency ratios of 75:1 or 150:1. The LTC1064-3 has low wideband noise and low harmonic distortion, even for input voltages as high as 3 V (rms).

The LTC1064-3 is available in a 14-pin DIP and 16-pin surface mounted SOL package. Pricing in quantities of 100 and up for the military temperature range is $27.85 and for the commercial temperature range is $9.95.

CMOS Op Amps Require Only 40 Microamps. National Semiconductor (2900 Semiconductor Dr., P.O. Box 58090, Santa Clara, CA 95052) has introduced new quad and dual micropower CMOS



National Semiconductor's new micropower operational amplifiers require a current of only 40 μA per amplifier. The curve shows current-versus-voltage for the LPC662.

operational amplifiers that require a supply current of only 40 μA per amplifier. The devices also feature true single-supply operation, rail-to-rail output swing and extremely low input bias current.

The LPC660 quad and the LPC662 dual op amps are micropower versions of National's popular LMC660/662 CMOS op amps. Since they require very little supply current and can operate from a single-ended power supply (+5 to +15 V), the new op amps are ideally suited for many low-power applications. Examples include battery-powered hand-held meters and medical instrumentation.

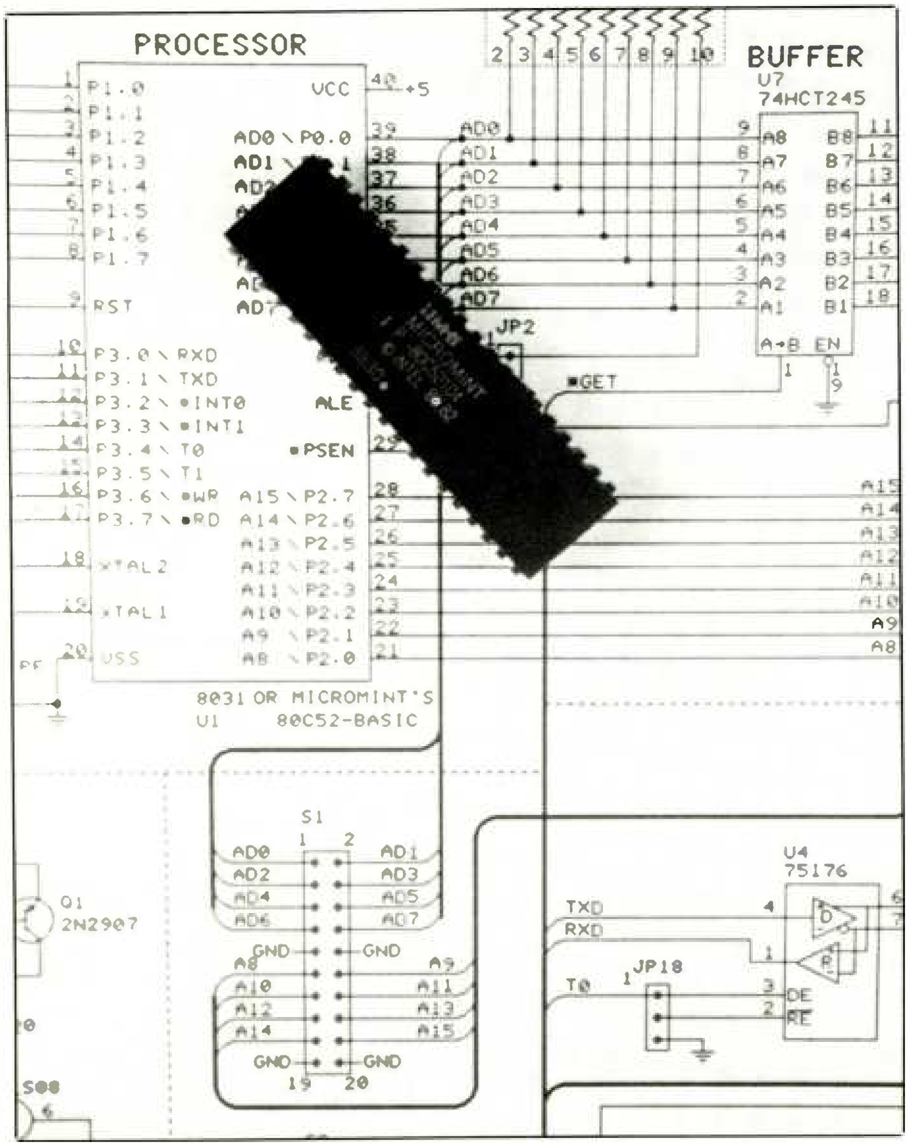
Types of circuits that take advantage of the features of these op amps include low-leakage sample-and-hold circuits and low-frequency filters. In a filter circuit, the low input bias current of the LPC660/662 allows the designer to use larger resistor values and, therefore, smaller capacitors, saving board space without degrading performance. In a sample-and-hold or peak-detector circuit, the same low bias currents improve signal accuracy by decreasing the leakage current from the holding capacitor.

The devices are fabricated with National's advanced double-poly silicon-gate CMOS process and have an operating range of +4.75 to +15.5 V.

The LPC660 and LPC662 are available in 14- and 8-pin plastic DIPs, respectively, in industrial temperature range units priced at $1.40 in quantities of 100 for the LPC660IN, and at $0.90 for the LPC662IN.

Digital Devices

80C52-BASIC Processor. The 80C52-BASIC processor from Micromint (4 Park St., Vernon, CT 06066) is a CMOS microcontroller with on-board BASIC. Based on Intel's popular 8052, the 80C52-BASIC contains a full BASIC interpreter in on-chip ROM. This implementation of BASIC includes the following features: BCD floating-point math; built-in real-time clock; access to programs in RAM, EPROM or EEPROM; built-in radix conversion from hex to decimal and decimal to hex; ability to handle interrupts in BASIC or assembly language; and gen-



Micromint's 80C52-BASIC processor chip with on-board BASIC language interpreter in ROM offers tremendous flexibility and a wide variety of features.

eration of all timing required to program EPROMs and EEPROMs. The 80C52-BASIC's full language resources allow software development directly on the target hardware.

The 80C52-BASIC is guaranteed to perform without error at clock speeds from dc to 12 MHz over the full industrial temperature range. If power consumption is critical, the 80C52-BASIC offers two reduced-power modes that slash power consumption while retaining all RAM, register and flag status information. The microcontroller's features make it a good choice for intelligent power-sensitive and temperature-sensitive applications. The 80C52-BASIC is available at $14.50 each in quantities of 100.

A Family of Bidirectional FIFOs. Integrated Device Technology (3236 Scott Blvd., P.O. Box 58015, Santa Clara, CA 95052) has announced a family of bidirectional FIFOs that are optimized for use in microprocessor communications. The family includes four members that are "bus-matching" eight-bit peripherals to any size microprocessor. Two additional members of the family can be used to match 16-bit microprocessors to other 16-bit systems.

The "bus-matching" biFIFOs, with an x18 width on one side and an x9 on the other, act as funnels interfacing 16-bit systems with eight-bit systems. These biFIFOs are available as 1K (IDT7252 and IDT72520) or 0.5K (IDT7251 and IDT72510) devices. The x18 to x18 biFIFOs are also available as 1K (IDT72521) or 0.5K (IDT72511) devices.

An IDT biFIFO gives designers a single-chip buffering solution that replaces up to 17 devices. This translates into higher integration, reduced board space and lower power consumption. Another benefit is that the x18 to x9 width allows designers to match the bus from RISC microprocessors to any standard 8-bit or 16-bit peripheral.

A pass-through feature of the biFIFO provides a direct data path through the biFIFO, while bypassing buffers, to speed communication and eliminate extra external logic.

Eight flags are available on the biFIFOs. Empty, full, almost-empty and almost-full are generated internally for both FIFO memories. Programmable flag offsets for almost-empty and almost-full can be set at any depth. Programmers can assign any four of the eight flags to four external flag pins.

The family of biFIFOs features a processor interface that determines the "personality" of the biFIFO by programming the flags and the DMA handshake structure. On the IDT72521 and the IDT72511, the processor interface programs the I/O logic as well.

The IDT7251 and IDT7252 in 48-pin plastic DIP packages sell for $77.49 and 86.10, respectively, in 100 and up quantities. The IDT72520 sells for $90.41, and the IDT72510 for $81.36 in a 52-pin PLCC package. The IDT72521 and the IDT72511 are $94.93 and $85.43, respectively, in a 68-pin PLCC package.

Laser Wars

By Ted Needleman

I have to admit to being a bit ambivalent about Hewlett-Packard. Its test equipment is first rate, as are its calculators. On the other hand, I've never been all that impressed by the company's Vectra PC line, considering it overpriced and with a keyboard not up to H-P's fine standards, as demonstrated on its other equipment. And PAM, H-P's Personal Application Manager, gives me hives—it's just nowhere near as well done as many other DOS shells, including some inexpensive shareware products, such as Magee software's Automenu.

Where H-P does shine in the PC world, though, and shine brightly, is in the area of laser printers. As detailed in last month's review of the LaserJet IIP, Hewlett-Packard introduced the world's first affordable desktop laser printer in 1984, and has lead the market ever since.

When I reviewed the $1,495 IIP last month, I wondered at H-P's marketing. After all, the IIP gave you everything except the speed of its Series II, and a few things such as rotatable fonts that the more expensive printer doesn't offer. It seemed destined to blow away the sales of its mid-range laser printer line.

The question was answered on March 1st, with the introduction of the LaserJet III. I've had one for several weeks now, and have to admit I'm impressed. H-P has really done its homework with this printer, and set some new standards, both in features and price/performance.

Hewlett-Packard's new LaserJet III laser printer.

H-P LaserJet III

Hewlett-Packard has gone through four releases of their 8-ppm laser printer. The original LaserJet gave way to the LJ Plus, Series II, and the Series IID, the latter a duplex printer able to print on both sides of a piece of paper. H-P's IIP, the 4-ppm personal laser reviewed here last month redefined the low end of the laser printer market. While the IIP defines the low end of the laser market, the new LaserJet III will most likely do the same for the 8-ppm market in laser printers.

The latest model is based on the same Canon SX laser engine used in the Series II, which it replaces. Though it uses the same laser engine, it is nonetheless a major upgrade to H-P's laser printer line. While the internal mechanicals remain the same, almost everything thing else about the printer has been improved.

The most noticeable difference, on a first look, is the case. Although the printer has the same basic footprint as the Series II, it has had a complete styling redesign and looks much sleeker. The control panel is still located on the front right side of the printer but has also been redesigned to be easier to use and matches that on the IIP. Even though the paper cartridge has been refined and smoothed, along with the case, you can still use any Series II paper cassettes you might have. The cassettes look sleeker, but are mechanically identical to the older ones.

Inside the new case are several enhancements that will redefine what H-P compatibility means in the beginning of the '90s. These include a new internal font technology, an upgrade to H-P's PCL language (PCL 5), and improved output though a technology called "Resolution Enhancement."

The LaserJet III contains the same bit-mapped Courier fonts as its predecessor. In addition, though, are two new typefaces, CG Times (a Times Roman face) and Univers, a sans serif face. These two new faces are scalable from 1 point to 999.75 points (over 13 inches high) in 0.25-point increments. They are available in medium, bold and italic weights.

One major difference from the old font technology used on the Series II is that the new built-in fonts are scalable on-the-fly. As with PostScript fonts, you don't have to have a specific type size before you can use it. Both the internal scalable fonts, the internal bit-mapped Courier fonts, and any downloaded softfonts can also be rotated. Unlike the Series II, you no longer need portrait and landscape fonts; the portrait fonts can be rotated when producing documents in landscape mode.

One major benefit of this is that while you can use Series II (and earlier) font cartridges in the LaserJet III's cartridge slots, the new font cartridges and download softfonts being produced for the IIP and LaserJet III printers contain only portrait fonts. Because the landscape

PC CAPERS...

fonts have been eliminated, these collections generally include more fonts for the same (or lower) price.

On-the-fly font scaling and rotation features are derived from the AGFA Compugraphics Intellifont technology that has been incorporated into the new PCL 5 version of H-P's Printer Control Language. There are several other major benefits that PCL 5 provides. AutoFont support, which provides the font metrics for outline and bit-mapped fonts directly to an application that supports this technology (and most major software vendors have committed to do this), eliminates the user having to provide this information when installing new applications or fonts.

Recently, Al Burawa (Managing Editor of ME) and I were discussing the IIP printer. Al made the comment that he wished the IIP could also make use of the HPGL graphics language—it would make the printer particularly appropriate for CAD applications such as producing board layouts and schematics. Well, Al, maybe H-P has our phones tapped, because this feature has been implemented in the LaserJet III. PCL 5 provides vector graphics for the first time on the LaserJet!

Vector graphics is a method of producing graphics by drawing a line between two previously defined points. This capability is achieved by incorporating HP-GL2, the graphics language used in H-P's plotters, into PCL 5. While it will take software vendors some time to make use of this feature, eventually this feature will provide many of the special effects now available only on PostScript printers.

Another feature of PCL 5 is the ability to overlay images in either a transparent or opaque mode. This feature is standard in most PostScript applications, and its inclusion in PCL 5 brings the LaserJet III closer to meeting the requirements of both PCL and PostScript users.

If you simply must have PostScript compatibility in your PCL printer, H-P will be introducing a PostScript emulation in a few months. If you can't wait, or don't want to spend the thousand-or-so dollars that this cartridge will cost, you can gain PostScript compatibility by using one of the software products currently available, such as UltraScript, GoScript, or Freedom of the Press. These cost considerably less, but require that you first print a file to disk, then process the file through the software package to print it.

As you might expect, this takes considerably more time than just printing the file with a hardware emulation cartridge. Pacific Data Products makes a PostScript cartridge for the Series II and IIP laser printers, so I wouldn't be at all surprised to see these companies bring one out for the LaserJet III (if they haven't already done so by the time this review appears). Pacific's cartridges for the IIP and Series II cost under $700, so if they follow the current pricing, it will be several hundred dollars less than an equivalent unit from H-P. An additional emulation cartridge will give the LaserJet III, Epson FX and IBM Proprinter compatibility. A hardware option will add AppleTalk to the printer, easing its use with Apple's Macintosh computers.

From a technology point of view, the most impressive new feature of the LaserJet III is "Resolution Enhancement." One problem with any printer that uses dots to form characters is that these characters often show some jaggedness. While laser printers use extremely small dots that minimize these effects, a close examination of laser output, especially of extremely large or small type, often reveals the dot heritage of this printing method. The jaggies are more noticeable where a character curves, or at the intersection of two lines, such as in the valleys of letters such as y and x.

Two factors contribute to the "jaggies." The first is that all characters are made up of dots of the same size. This dot size is most obvious where a character tapers off to a point, such as at a serif. Another factor is that the dots are all placed in the same plane. Curves are constructed by "ramping" the dots—leaving several dots off successive lines. This creates a stair-step effect that can give a curved area a jagged appearance.

H-P's "Resolution Enhancement" fills in the gaps with smaller dots, smoothing the ramps much like filling in a gap in a wall with spackle. In the vertical mode, these smaller dots are created by lowering the power of the laser beam, resulting in a smaller charge on the photoconductor drum and less toner being placed on the paper during printing.

Being the leader has both advantages and disadvantages. If you are successful, you get to set the standards. At the same time, the competition gets to ride on your coattails by offering the same features for less money or more features for the same money. This has proved true in the volatile laser printer market. With the LaserJet III, H-P has set a new level of feature performance. At the same time, it has also set a new level of price performance.

The Series II, with 512K of RAM, was priced at $2,695. The LaserJet III has 1MB of RAM built in and can be expanded to 5MB. It also has PCL 5, scalable on-the-fly fonts and font rotation, and the "Enhanced Resolution" feature. It gives you all of this for $2,395. And H-P has sweetened the pot even more by dropping the prices on its disk-based scalable typeface products from $195 to $99.

I thought the IIP was a good deal at $1,495. I still do. But the LaserJet III, at $900 more, gives you a lot for that extra $900. If the IIP is a good deal, the LaserJet III is a great one. It's going to make choosing between them a hard choice.

Horizontal smoothing is accomplished by using smaller dots and by offsetting dot placement by varying on/off timing of the laser beam. This allows dots of increasing or decreasing size to be placed close together, creating a gradually rising ramp rather than an abrupt "stair-step." The enhancement can be set to light, medium or dark (or turned completely off) from the control panel.

Resolution Enhancement is not something that jumps out at you. If you aren't looking for the effect, you might not notice any difference. The overall visual effect, though, is that the pages just look slightly crisper, as if they were printed at a higher resolution. If you already have a Series II LaserJet, and really want the enhanced resolution, you won't have to sell or discard your old printer to get it. H-P will offer an upgrade later in the year that will give Series II owners PCL 5 and Resolution Enhancement. Also, third-party add-in boards, such as Intel's Visual Edge and others available from LaserMaster and DP-Tek, also allow a Series II printer to produce up to 1,000 dpi horizontal resolution.

In most other respects, the LaserJet III is very much like the Series II. It uses the same EP-S cartridge containing the photoconductor drum, developer and toner, and sets up in about 2 minutes. The new PCL 5 is downward compatible with earlier versions. It worked perfectly with all of the applications I had configured for a Series II printer. Without performing a formal printer benchmark, I can't tell if the new printer is any faster than the Series II. It doesn't seem to be, but then the Series II has always delivered performance very close to the 8 pages per minute Hewlett-Packaged claimed for it. ME

Manufacturer Address

LaserJet III
Hewlett-Packard Co.
(800) 752-0900
Price: $2,395
1 MB memory board: $495
2 MB memory board: $990

Enhance Your Math Prowess *(from page 23)*

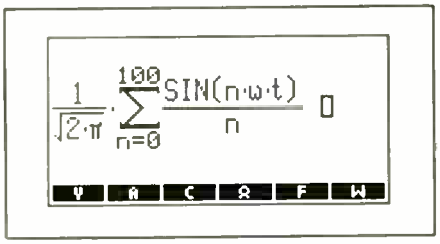


Fig. 1. The Equation Writer mode of the HP 48SX displays a formula the way it would appear in a textbook or journal.

(LCD), two expansion slots, an RS-232C port and a two-way infrared interface. All of this is contained in a product about one-third the size of a standard textbook, powered by three AAA cells that will last for about six months with normal use.

Naturally, features like the above do not come cheap. At a suggested retail price of $350, the HP 48SX can be considered the Mercedes Benz of scientific calculators. And you can even order advanced options for the already well-equipped base model. The options include a serial interface to connect to an IBM PC or an Apple Macintosh for $99.95; a 32K RAM card for $79.95; a 128K RAM card for $250; an HP Solve Equation Library Application card for $99.95; and a portable infrared printer, the HP 82240B, for $135.

Operating the HP 48SX

The first things you notice about the HP 48SX are its 2.5- by 1.4-inch LCD and the keys and key legends on its face. What you're less likely to notice are the serial port and infrared LEDs on its back panel. When turned on, the LCD shows a status line, four storage areas (the first four levels of the stack for RPN calculations) and a menu bar. With a press of two keys, the screen blanks and becomes an electronic chalkboard where you can enter formulas almost exactly as they appear in a textbook (see Fig. 1). Nothing special is required to enter equations in this way; just press the appropriate keys.

Of the 49 keys, 12 perform at least four functions, and 22 perform at least three. Like most calculators, the main function of the key is printed on its face, and its other functions are printed in different colors around it. However, some things, such as lower-case characters, are not even included on the keyboard, most likely due to the lack of space. To get a key to perform a function other than the one described on its face, you first check the color of the function you want and press a special blue, orange or alpha key, before pressing the key itself. You can select functions from the menu bar by pressing one of the six keys placed just below the display.

If you are familiar with RPN calculators, you'll have no trouble performing operations on numbers. The sequence of keystrokes for most operations is press a number, press Enter, press another number, and then press the operation. Sometimes you can press an operation right after pressing the first number, such as with the square-root key.

If the above sounds easy, it is. But be forewarned: the HP 48SX has more than 2,100 functions, some hidden in the deep recesses of the menu bar. With all of these functions, learning to do even basic things like entering a formula, plotting a graph and doing symbolic math takes a commitment—one that includes reading a manual of over 800 pages. And it is unlikely that you can get by without the manual, for the HP 48SX learning curve is a steep one, and performing advanced functions is not an intuitive process.

The difficulty in learning the HP 48SX stems from its inability to perform functions while in the equation mode. To enter the equation mode you press the unit's orange arrow key and Equation key. This blanks the display. Then you press the alpha key twice (to lock it) and enter an equation, such $y = x^2$, which displays just as it would in a textbook. Once you've done this, you are staring at an equation. Logically, you expect to be able to do something with it, such as plot it. If you try to plot it by pressing the orange arrow and Plot keys, you get an error beep.

To actually plot the equation, you have to enter it on the stack first by pressing Enter, then press Plot, then press STEQ (store equation) on the menu bar, then press PLOTR (plot parameters) on the menu bar, and then press DRAW on the menu bar. And this is just one way of doing it!

Suffice it to say that advanced operations performed on the HP 48SX require a lot of keystrokes. And anytime you are in the equation mode or the plot mode, the calculator takes some time to do its work. For example, it takes 15 seconds to draw the plot for $y = x^2$.

It's possible to draw diagrams with the HP 48SX. The way to do this is to press the orange arrow and Plot keys and select PLOTR and ERASE from the menu bar. Then you press the orange arrow and Graph keys. This brings you to a blank screen. You then press the Nxt key to access the drawing menu. This menu bar has commands such as DOT+, DOT−, LINE, BOX and CIRCL. You use these commands in

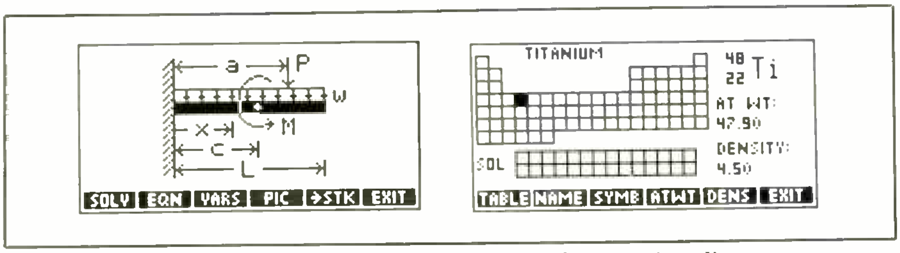


Fig. 2. The HP 48SX includes commands for drawing diagrams.

conjunction with the cursor keys to draw pictures. A drawing done this way is shown in Fig. 2.

To do unit conversions on the HP 48SX, you press the orange arrow and Units keys. This brings up the units menu. The menu displays words like LENG, AREA, VOL, TIME, SPEED and MASS. To see more menu items, you press the Nxt key. Many menu words have a little bar on top of them to indicate that a sub-menu exists for that menu. For example, if you choose AREA, a menu appears with M^2, CM^2, B, YD^2, FT^2 and IN^2. To attach units such as in^2 to a number, you type the number and press the key under IN^2.

Like many Hewlett-Packard calculators, the HP 48SX is programmable. To enter programs into the HP 48SX, you begin by pressing the orange arrow and program symbol keys. The program symbol key looks like this: << >>. To facilitate entering commands such as IF and WHILE, you can bring up a programming menu bar by pressing the Prg key. This lets you enter a command by pressing a single menu key. To store a program, you place it on the stack with the Enter key and then name it by pressing the single quote (') key, typing the program name, and pressing the Sto key. To run a program you type in the name of the

HP Kit Turns Dedicated Hardware into PC Software

One of the options available for the HP 48SX scientific expandable calculator is a serial interface kit. Although the kit was not available to *Modern Electronics* for a hands-on review at press time, we can give you some information about it. The kit comes with a serial cable and data communications software on 3.5- and 5.25-inch disks. The cable and software link the HP 48SX to IBM PC and compatible computers and Apple Macintosh computers.

To access the serial port from the HP 48SX, there is an I/O key that brings up a communications menu on the display. The menu has the following choices:

SEND RECV SERVE KGET FINIS SETUP

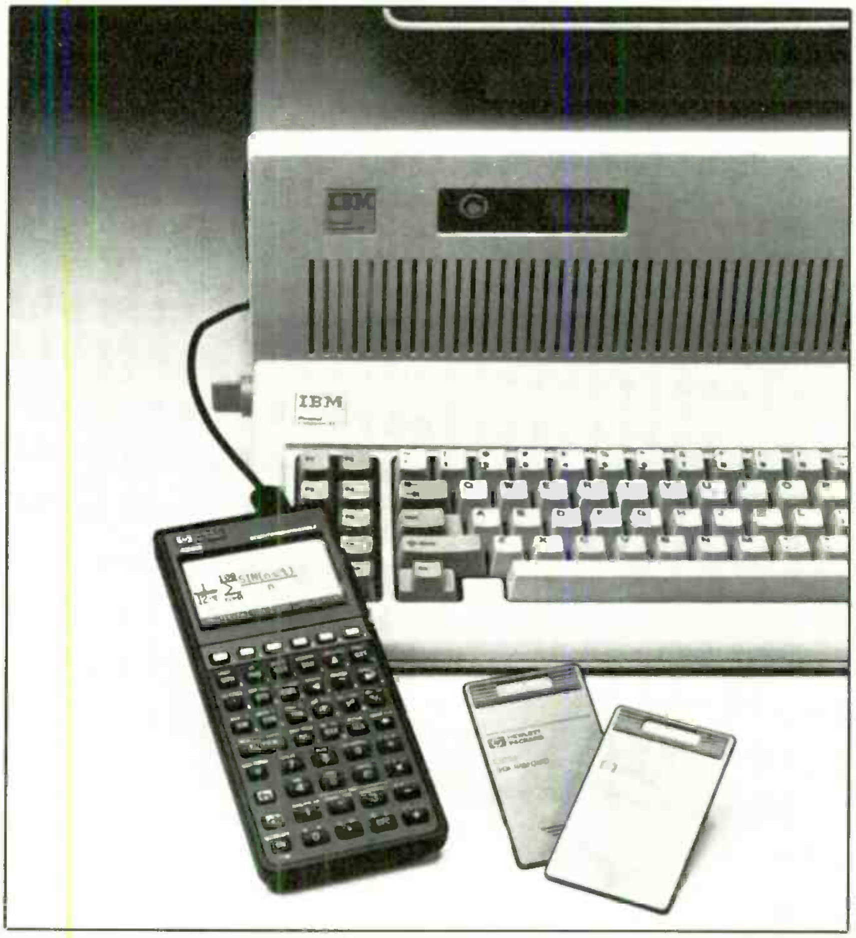
The only one of these choices that has a sub-menu is SETUP. This menu lets you configure the I/O port for wire or infrared transmission, and ASCII or binary transmission. It also allows you to select a baud rate between 1,200 and 9,600 bps, set the parity, set the checksum type, and set the translate code. When you press the NXT key, five more menu choices appear:

RECN PKT KERR OPENI CLOSE

Another press of the NXT key reveals five additional menu choices:

XMIT SRECV STIME SBRK BUFLE

In general, these commands allow the HP 48SX to send and receive files with a PC using the Kermit protocol.



The interface kit gives the advantages of using a large monitor and standard QWERTY keyboard for programming the HP 48SX. While linked to a PC, the HP 48SX can share the computer's printer to generate high-quality printouts and use the computer's disk drive to store data and programs.

Operating the HP 48SX from a PC is like adding software to the computer. Unlike traditional software, however, the HP 48SX can be disconnected from the computer and used alone.

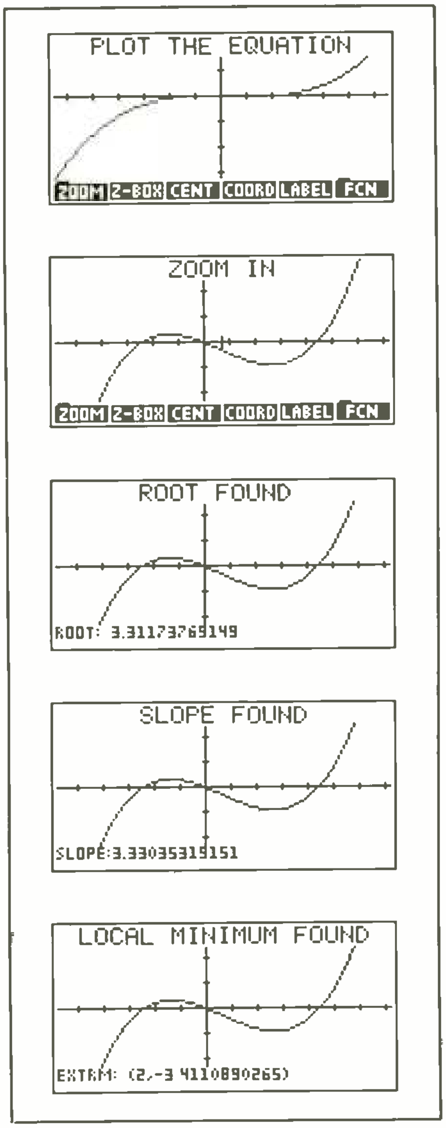


Fig. 3. Some of the things you can do with the HP 48SX (top to bottom): plot an equation; zoom in on points of interest in the plot; obtain values for the roots of the equation; find the slope of the equation at any point; and find the point where a local minimum or maximum occurs.

program and press Enter. The programming language is full-featured in that you can include such things as variables, loops, conditions and tests in your programs.

To send data from one HP 48SX to another, you must first line up the computers back to back along an arrow marked on the face of the calculator. Then you press the orange arrow and I/O keys. This brings up an I/O menu. This menu contains all commands needed to send data along the IR link or through the serial port. The HP 48SX uses Kermit protocol to transfer data.

HP 48SX Features

The wealth of features of the HP 48SX reminds me of the sign you often see in stores: If you don't see it, ask for it! For the HP 48SX, you could say: If you don't know if it can perform a mathematical operation, check the manual! You'll probably find the feature you are looking for.

If you want to operate in the graphics mode, the HP 48SX can zoom in on a portion of a graph and automatically find roots, slopes and local extremes, as shown in Figs. 3(A) through 3(E), as well as find the area under a curve. The unit can also display graphs in eight formats: function, bar charts, histograms, scatter plots, conic section, polar, parametric and truth plots (see Fig. 4).

In equation-writer mode you can enter integral signs, derivative signs, summation signs (sigma), greek letters and superscripts. Any division operation is shown as one number over the other. About the only thing you can't do is enter subscripts. Once you enter an equation, you can perform algebraic operations, such as collecting like terms or solving for one variable in terms of another; and the new equation also can be displayed just as it would be in a text book. One algebraic function that you can't perform is finding the factors of a polynomial. You can, however, solve quadratic equations.

The HP 48SX can solve calculus problems, too. It does differentiation, integration and summations, and will also do Taylor's polynomial approximations. However, you may not always get answers in the form that you expect. For example, taking the derivative of x^2 with respect to x should give you an answer of 2x. The calculator gives you an answer that shows the derivative of x with respect to x multiplied by 2x raised to the 2^{-1} power—a correct answer but not exactly what most people expect.

The unit-management function of the calculator converts 148 different units in 16 categories. In addition to these, you can build compound units, such as kilograms per second (kg/s), or add your own units.

Among its other features, the HP 48SX has a built-in clock (and, therefore, you can set alarms and do date and time arithmetic), a wealth of trigonometric, hyperbolic, exponential, logarithmic and statistical functions, and the ability to work with complex numbers, vectors, arrays and even binary numbers.

The huge manual that comes with the calculator does a respectable job in terms of style and presentation, but is lacking in one important area. It fails to give you an overview of the more than 2,100 functions that the calculator can perform. For example, it would be nice to have a sheet that shows the complete menu structure. It would also be nice to have a list of all the hidden operations in one place—operations such as lower-case letters. With enough effort, the manual will teach you how to use the calculator, but it doesn't do much to streamline the learning process.

The serial port on the back panel is used to connect to an IBM PC or Apple Macintosh. A special cable is needed for this since the port has only four pins. The infrared LEDs on the back panel are used to transmit or receive information from another HP 48SX or to send information to an infrared printer.

One of the optional accessories for the HP 48SX is an HP Solve Equation Library Application card. This card, which is about the size of a credit card, fits into an expansion slot inside the calculator. You can get to this slot by removing a section of the back cover. The application card

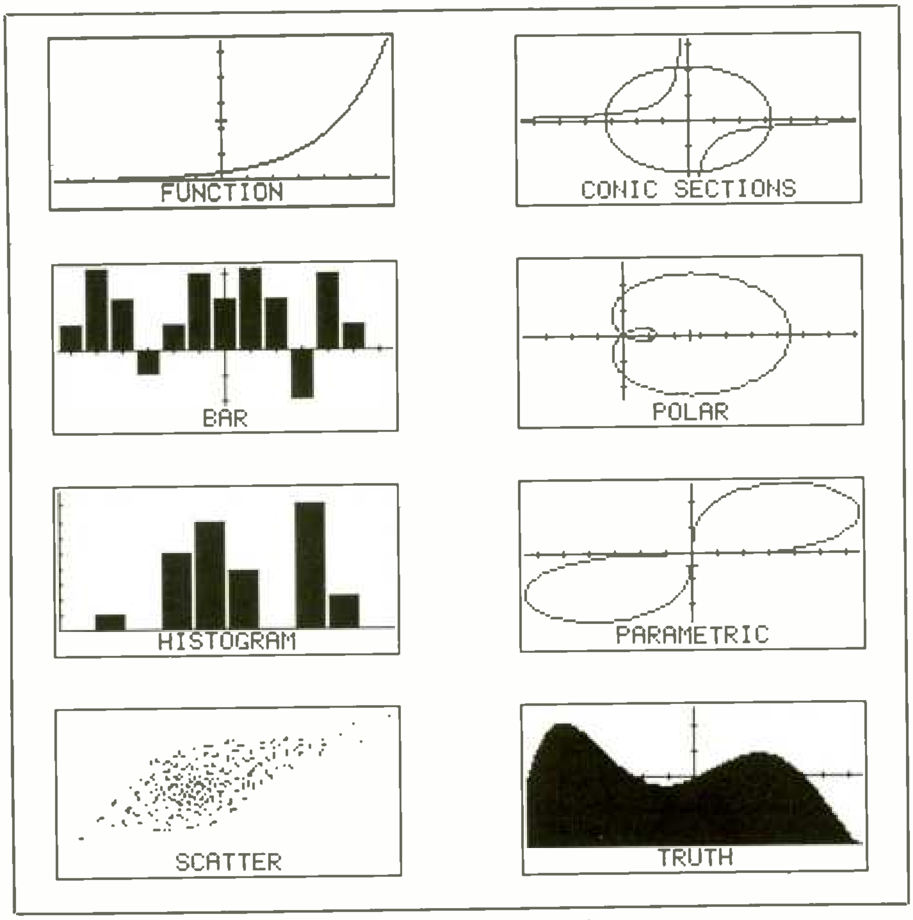


Fig. 4. The HP 48SX has eight plot types.

contains an equation library of more than 300 science and engineering equations, a constants library, a finance library, a periodic table, labeled diagrams, a multiple equation solver and even a game. The way to access the features of the card is by pressing orange arrow and Library.

Comments & Conclusions

Anyone trying to decide between the HP 48SX and mathematical software that runs on a PC has a few things to consider. First of all, any scientific calculator has the twin advantages of portability and a dedicated user interface designed specifically for engineering problem solving. This particular calculator has another advantage—it can link to a desktop PC (see the sidebar for more information about this feature). And not only is the HP 48SX a very powerful scientific calculator, it also advances the state of the art with features like the equation writer and units management. However, it is often difficult to implement these and other features without spending considerable time studying a hefty manual.

If you are experienced with scientific calculators and want to upgrade to a more powerful model, the HP 48SX is certainly an excellent choice. But if you are a novice in this area, the choice is not so clear cut. If you need a scientific calculator as sophisticated as this one, be prepared to spend many hours of often frustrating time learning to harness its power. If you need the functionality of the unit but not the frustration, you might be better off considering math software for the PC that meets your needs but is easier to learn. ME

555 Timers *(from page 57)*

The two configurations shown in Fig. 9 are for current-source and current-sink operation, just as in the case for the LEDs above. Make sure that you use only one of these in a given circuit, of course.

Note in Fig. 9 that each relay coil is shunted with a 1N4007 rectifier diode. Diodes are used for spike suppression when the relay coil is de-energized. The back-emf generated when a relay coil deenergizes can be a high-voltage spike that can destroy the 555 and other components in a circuit. It has a reverse polarity with respect to V+. Thus, the diodes are normally reverse-biased, except when a large inductive spike from the relay is received. Keep firmly in mind that these diodes are *not* optional.

Shown in Fig. 10 is a method for solving a problem that is sometimes encountered with 555 relay drivers and certain other 555 circuits in which digital pulses or noise spikes appear. The spikes can get inside the 555 via its OUTPUT pin, where it forces the internal digital chip circuitry to reset. The diodes shown provide some crude isolation for the output of the 555.

If you have ever experienced seemingly unstable operation from a 555 timer, an unusual occurrence with this well-behaved chip, first determine whether the problem is external pulses coupled through pin 3. If so, the Fig. 10 circuit may well solve the problem.

In summing up, remember that the low-cost 555 provides a variety of functions at very low cost for it and any additional components needed to configure a circuit around it. In this article, we have examined a small number of different ways to interface the ubiquitous 555 timer to the external world, at both input and output ends. Now it is up to you to broaden your use base of this extremely versatile chip, through further study and experimentation. You will be glad you did. **ME**

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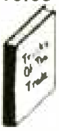

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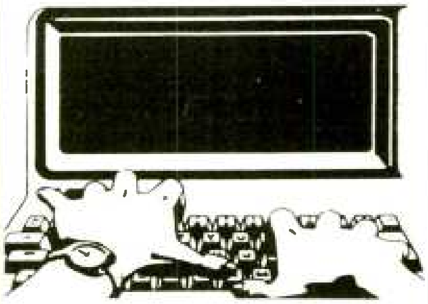

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(from page 15)

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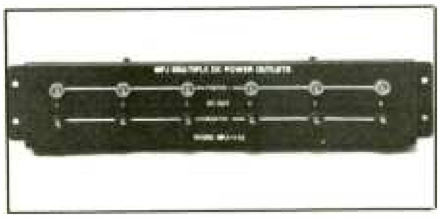

viding six pairs of heavy-duty color-coded binding posts for connection to circuits. The device connects directly to any 12-volt dc power supply and includes bypassing to keep r-f out of the supply from the dc line outlet. It measures just 13½ × 2¾ × 2½ inches. $24.95.

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Slide Projector *(from page 43)*

the control unit might trigger on the projector and change a slide. If this occurs, back off on the setting of the trimmer potentiometer just a bit. The only loss in doing this will be that the projector will not switch on at the very bottom of the travel of the slide control.

You may be concerned that the projector will not have time to cool down if it is switched on and off in normal operation. This is not the case, however. In tests with a number of different slide projectors, no excessive temperature was reached. If the projector is on for a long period of time, the temperature tends to stabilize after about 4 minutes. If the projector is used intermittently for short periods, it never gets hot enough to reach even this stabilized temperature.

Provided the time period is adequate between the end of T_2 and the end of T_1 in Fig. 5(A) (this can be adjusted with *R16*), consecutive slides can be shown without the projector turning off between each slide. If the projector is still running when the slide-type FADER control is opened again, it will continue running without a break and maintain the correct sequence of events.

Although the Electronic Controller described here was designed specifically to work with Kodak Ektagraphic slide projectors, almost any other projector can be controlled by it. Even a projector that uses a low-voltage lamp powered by an internal transformer can be faded in and out with no change in component values in the circuitry.

With a low-voltage, high-wattage lamp, the triac specified for *Q5 must* be bolted to a sizable heat sink, perhaps the metal body of the projector itself. However, provided a break in the supply to the lamp can be found, the circuit will yield good control of the brightness of the lamp and all other slide functions.

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