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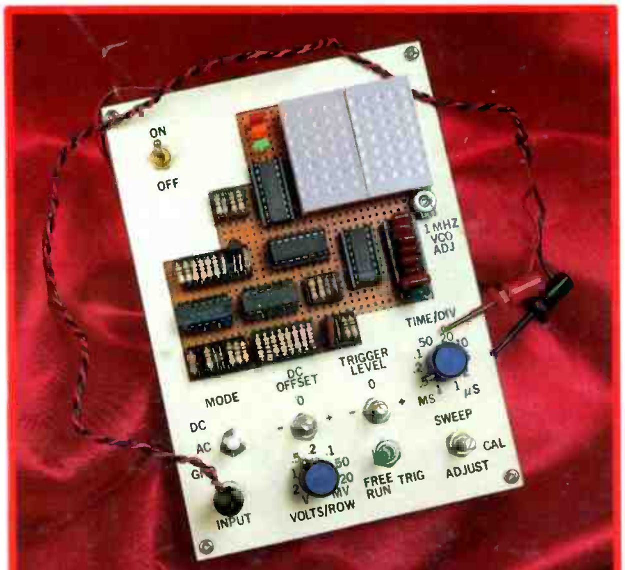
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

An All-Solid-State Portable Oscilloscope

An Alternative Timer— The New LS7210 Chip



An All-Solid-State Oscilloscope (p. 14)

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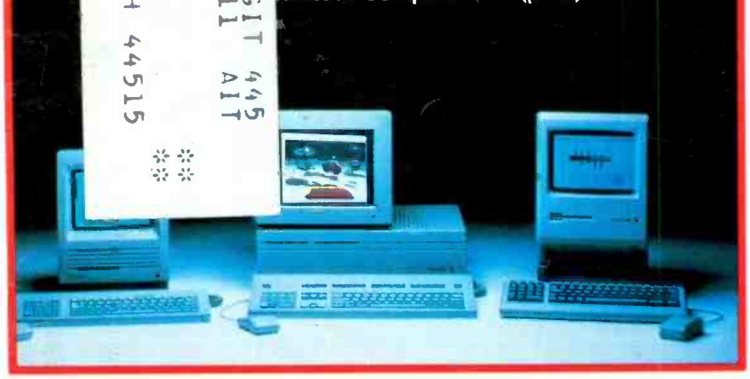

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450 MHz	< 3 mv	< 5 mv	< 3 mv	< 1 mv	< 5 mv
850 MHz	< 3 mv	< 20 mv	< 5 mv	NA	< 5 mv
1.3 GHz	< 7 mv	< 100 mv	< 7 mv	NA	< 10 mv
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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

NOVEMBER 1989

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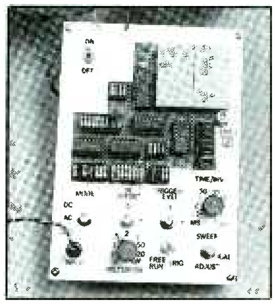

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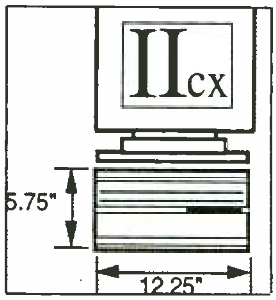

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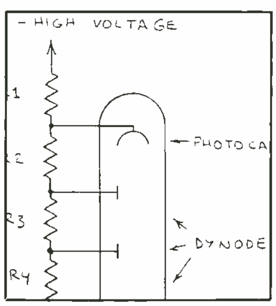

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EDITORIAL

SPICE

Increasingly, personal computers play an important role in electronics. Electronics designers know this as they check out parts information on computer databases provided by many manufacturers, including Motorola Semiconductor. They know it through using electronic design software programs, where one fills in the blanks with desired parameters to derive unknown values. Or have a computer draw the schematic, lay out a pc board, acquire data, and so on. Electronics team leaders and managers use PC's for a host of other purposes, from project management to budgets to inventory; for a service company there's service-contract tracking, work orders and scheduling, dispatching, customer histories, etc.

It's difficult today to avoid personal computers when you're involved in electronics. But you don't have to be a very knowledgeable computer user in order to use computers effectively. More important is having the underlying knowledge required to make a software application program meaningful, then utilizing the computer as a tool to make work easier to do while yielding greater productivity and better accuracy. Naturally, you'll have to learn fundamentals of computer operations and the in's and out's of some application programs. But you need not know how to write programs or set up a local area network, etc., unless you're directly in this work area.

The most proficient person in the computer field won't be able to use the electronics software you can because they simply don't have the type of technical background to do so (or the need to). An example of a popular professional application here would be simulating an electronic circuit design on a computer before building a prototype. You might use one of the SPICE (Simulation Program with Integrated Circuit Emphasis) family of programs, for instance. Developed at the University of California, Berkeley, a host of variations developed commercially are available for modern circuit development.

As many circuit design pro's know, you can't easily and inexpensively breadboard microcircuits to check out results because physical effects impact performance a great deal, unlike discrete components. With a computer, even a personal computer, you can do it all without even touching circuit hardware. Just model it with a SPICE-type program.

If you're unfamiliar with this design and analysis program, you might want to read a review of how it and a derivative program, PSpice, work by getting a copy of the July 1986 issue of *BYTE* magazine. There's an interesting guide on the subject that has been published by Prentice-Hall, too. It's entitled, "SPICE, A Guide to Circuit Simulation and Analysis Using PSpice" by Paul W. Tuinenga of Microsim Corp. (Its ISBN number is 0-13-834607-0.)

So keep your eye on the computer ball, much as you do on electronic test instruments. They're now both in your career bag of tricks. We'll cover some aspects of computers from time to time as it relates to basic hardware, interesting software, and applications relating to electronics. Our main thrust will, of course, continue to be on electronics.

Crowded Pot

• In my "PC Volume Control & Beep-Tone Converter" (August 1989), readers should change the value of R8 and R10 to 20 ohms, both in the schematic/Parts List and text. The use of the 200-ohm potentiometers I originally specified will crowd the volume adjustments at one end of the pots. Also, the value of C3 in the schematic should be changed to 0.01-μF, although the μF value shown will work, too. The preliminary checkout tests on the Volume Control circuit described on page 35 are to be performed with PL1 disconnected from the computer's motherboard to eliminate parallel resistance paths on the latter. Finally, the positive lead of C7 connects to R10, as stated in the text.

Adolph A. Mangieri

Early-Warning Errors

• I've been reading *Modern Electronics* for several years and have used many of the projects that have been featured in it for teaching electronics at the hobby level. As I was going through the September 1989 issue, I noted some errors in the "Early-Warning Intrusion Alarm" article. In Fig. 1, the designations for pins 3 and 7 for IC2 are reversed, and pin 8 is not shown going to the +5-volt rail. It also appears that the article was cut short after page 27 because on page 25 a reference is made to Fig. 8, which appears nowhere in the article.

Scott McAlpine
Renton, WA

Thanks for pointing out the schematic errors. Reference to Fig. 8 in the article is a typographical error, it should read Fig. 7.—Ed.

Master Index

• I am interested in obtaining an index of technical articles—specifically with regard to PC and computer construction projects—that have appeared in your excellent magazine. Also, are back issues available?

Robert J. Akridge
Warner Robins, GA

Each year, in the December issue, we publish a comprehensive Cumulative Index of all the articles and columns that have appeared in Modern Electronics *for that year. Back issues are available for most months since October 1984 for $2.50 each.—Ed.*

Setting Record Straight

• I was interested in reading Joe Carr's "Pulse Circuits Revisited" (July 1989). After doing so, I would like to suggest that Joe might wish to reconsider his statement that "All other waveforms have a fundamental—which sets the frequency of the waveform or pulse repetition rate of the pulse train—and a collection of harmonics." As a case in point, a square wave comprises a fundamental and an array of odd harmonics. If the square wave is passed through a notch filter that removes the fundamental, the output waveform does not have a fundamental and the frequency or repetition rate of the waveform remains the same. Thus, the output waveform has a repetition rate that is set by the beating harmonics. (This is from my forthcoming

(Continued on page 79)

CALIFORNIA LEADS ELECTRONICS EMPLOYMENT. Like heavyweight champ Mike Tyson, California keeps winning in the electronics-company employment arena, reports the AEA, which bases the information of U.S. Bureau of Labor Statistics. As of December '87, it more than doubles that of any other state with 590,000 workers. New York takes second place with 207,000, while Massachusetts breathes down its neck with 199,000. Following them are Texas, 154,000; New Jersey, 107,000; Florida, 105,000; Illinois, 104,000; Pennsylvania, 88,000; Minnesota, 73,000; and Maryland, 65,000, to round out the top ten in electronics-company employment. Rankings haven't changed within this group for the past three years.

Viewing this from another perspective, electronics employees per 1,000 population finds New Hampshire in the lead with 37 per thousand. Massachusetts is second with 34, followed by California (22), Vermont (20), Arizona (18), Minnesota, Connecticut and Colorado (17 each), Maryland (15) and New Jersey (14).

WRIST INSTRUMENTS. Casio has a host of "wrist instruments" built in with digital electronic watches. One, its model TS100-UV ($64.95) measures temperature. It can store the data for 12 months of high and low temperatures for 23 cities and can store hourly temperature for the last 24-hour period...model MAP-100 ($99.95) is a map meter that lets the user calculate time and distance using a conventional road map...model CGW50-1 ($49.95) picture planet rotation on the watch's face display.

NEW HAM BBS. Kenwood U.S.A. Corp. has set up, on a trial basis, an Amateur Radio computer bulletin board for anyone to use. System parameters are 2400 baud or slower, 8 bits, 1 stop bit, no parity. Operating hours, subject to change, are 5 P.M.-8 A.M. Pacific Time, Monday to Friday; 24 hours weekends and holidays.

ELECTRONIC RECOGNITION NEWS. Bellcore (Bell Communications Research) has patented a technology for personalized "smart cards" that work with spoken commands. An owner "trains" the card to recognize only his or her voice so that no one else can use it. Applications include increased credit-card security and expediting other transactions involving an access card. Examples are use with pay phones, automated teller cash machines, and security access to a building.

Heath/Zenith unveiled a voice-controlled computer system and robotic workstation to allow people with severe upper-body limitations to operate a personal computer. It uses proprietary voice-recognition software and hardware developed by PRAB Command Inc. of Kalamazoo, MI. Spoken commands are converted into traditional keystrokes for operating all of the system's components. A robot arm can retrieve documents from a printer, pick up heavy books and perform other manipulative tasks upon voice command. The system also has a telephone management system for placing and receiving calls, taking notes, etc.

NEW PRODUCTS

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

Pocket Audio Generator

New from B&K-Precision is the Model 3001, a low-cost, pocket-size audio signal generator that covers from 20 Hz to 150 kHz. It offers selectable sine- and square-wave outputs via a slide switch. Other features include a 23-position rotary switch and ×1/×100 slide-type switch for selecting frequency; a small rotary control for setting signal amplitude; a slide switch for selecting 0/−20 dB of attenuation; main output jacks; and sync output jack that provides a fixed-level signal of the same frequency and phase as the main output. A low-battery LED indicator is also provided.

This RC-type instrument generates sine waves with a specified 0.05 percent or less THD from 200 Hz to 15 kHz, 0.1 percent or less THD from 50 Hz to 28 kHz, and 0.3 percent or less from 20 Hz to 100 kHz. Specified rise and fall time for the square-wave output is 0.5 microsecond, and amplitude flatness is said to be within 0.5 dB over the entire frequency range of the generator. Maximum open-circuit output signal levels are rated to be at least 1.2 volts rms for sine waves and 5 volts peak-to-peak for square waves. Levels are fully adjustable with a 0-to-20-dB step and continuously variable attenuators.

Supplied with the Model 3001 audio signal generator are two test leads, a 9-volt battery (for power) and users manual. $67.

CIRCLE 70 ON FREE INFORMATION CARD

Premium CD Player

Krell Digital, Inc. (Wallingford, CT) has a new CD player, the Model MD-1, that is said to produce a digital signal of exceptional clarity by eliminating virtually all sources of interference. A key feature is the top-loading turntable. This unique transport system is claimed to eliminate problems commonly associated with drawer-loading mechanisms. Electronic sensing confirms when a disc is on the turntable, and a special weight centers and stabilizes the disc without the need for rings and stabilizers. (This drive was originally designed for CD-ROM applications in the computer industry.)

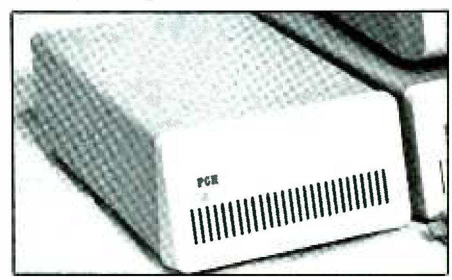
According to Krell, proprietary electronics recovers more of the signal recorded on a disc, which is then error-corrected and converted into standard digital format for conversion by a processor. Custom-designed toroidal transformers and two-stage regulation limit self-noise to lowest possible levels.

External noise is minimized by the design of the player's mechanical elements. The Philips transport is mounted in a piece of plastic that keeps extraneous resonances from reaching the assembly. Each suspension component, machined from solid aluminum, is mounted to a solid-aluminum base plate to produce a rigid system that minimizes unwanted vibration. Four suspension towers isolate the system from its environment and facilitate easy leveling. The exterior chassis provides additional shielding that further reduces outside interference.

CIRCLE 71 ON FREE INFORMATION CARD

Bus-Expansion Chassis

PC Horizons, Inc. (Santa Ana, CA) now offers a high-power PC-XTRA HP (for high power) expansion unit for PC users. It comes with a built-in 60-watt switching-type power supply and a cooling fan and contains five usable expansion slots. The PC-XTRA HP is said to hold any option card that will fit into the computer's system slots. Because it connects directly to the computer's I/O bus, no modifications are required to either the operating system or applications programs. The PC-XTRA HP chassis measures 9¼ inches wide and has the same height and depth as a PC system unit. It features easy cable installation to the computer system and is an IBM-chassis look-alike type. It uses flat cables with appropriate connectors for easy plug-in to one of the computer's expansion slots. $549.



CIRCLE 72 ON FREE INFORMATION CARD

(Continued on page 14)

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As you build your computer, performing key demonstrations and experiments at each stage of assembly, you get the confidence-building, real-

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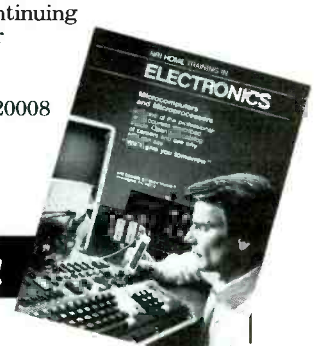

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Hand-Held Multimeters

The 80 Series of 3¾-decade hand-held digital multimeters from John Fluke Mfg. Co. consists of the full-featured Fluke 83, higher-accuracy Fluke 85 and top-of-the-line Fluke 87 true rms DMMs. They offer a powerful combination of measurement functions and safety features, including frequency, duty-cycle, capacitance and simultaneous minimum/maximum/average, Input Alert™ and MIN MAX™ features.

The MIN/MAX/AVERAGE recording mode allows the 80 Series to find intermittent failures and interference in a circuit. The audible MIN MAX alert pinpoints intermittent failures by signaling with a short beep only when a new minimum or maximum value is recorded. Input Alert warns when the leads are connected to the current jack while the meter is set to the resistance or voltage mode.

Updated 40 times per second, a high-resolution analog bargraph display featured in all three meters (with zoom mode on the Fluke 83 and Fluke 84) is fast. A relative (zero) mode with Fluke's Touch Hold capability generates a beep when a stable reading is sensed and locks the reading in the display for viewing after removal of the test leads from the circuit under test.

The Fluke 87 is claimed to have measurement capability available in no other hand-held multimeter in the world. Its user-selectable 4½/3¾-decade display, can be back-lit. Its MIN MAX recording mode captures transient events to 1 ms or sine-wave + or − peaks to 400 Hz. The Fluke 83's specified ac voltage response is 5 kHz and dc accuracy is within 0.3%. The more-accurate Fluke 85 and Fluke 87 extend the Vac to 20 kHz and Vdc accuracy to within 0.1%.

Overload protection to 1,000 volts in the resistance and diode-test modes is provided via patent-pending protection circuitry. All models are emi-shielded and packaged in splash- and dust-proof cases with protective holsters that include flexible stands for hanging the DMMs from doors or pipes or propping them up in the usual tilt position.

$189 for Fluke 83; $219 for Fluke 85; $259 for Fluke 87.

CIRCLE 73 ON FREE INFORMATION CARD

Dictionary/Thesaurus

Seiko Instruments now has a Word Power Professional 4000 Dictionary/Thesaurus, an electronic vocabulary aid that puts 90,000 definitions, 500,000 synonyms and a 95,00-word spell checker at your fingertips.

To use the package, one types a word on the WP-4000's keyboard and presses one of three function buttons, according to whether a definition, synonym or spelling check is required. Another key allows the user to scroll through memory. When not in use the linguistic aid automatically shuts itself off. $185.

CIRCLE 74 ON FREE INFORMATION CARD

Three-Way Power Supply

New from Elenco Electronics, Inc. (Wheeling, IL) is the Model XP-620 fully regulated power supply with three separate outputs. One output is at a fixed 5 volts dc at 3 amperes. The other two outputs, both variable (one from +1.5 to +15 volts, the other from −1.5 to −15 volts), can deliver up to 1 ampere to a load. The power supply features full short-circuit protection . It shuts off the outputs when a short circuit is detected, without causing internal damage. Each section in the power supply is regulated to better than 0.2 volt when going from no load to full load.

The power supply measures a compact 8¼" × 7" × 4" to take up minimum space on a workbench. It is available both factory-wired and in kit form, the latter supplied with assembly instructions and circuit descriptions. $89.95 factory wired; $59.95 kit.

CIRCLE 75 ON FREE INFORMATION CARD

Switching Power Supplies

Three new switching power supplies for PC applications have been announced by the Power Supply Division of Fortron/Source (Livermore, CA). These new introductions include the 250-watt Model FC 5250, 300-watt Model FC 5300 and 375-watt Model FC 5375. The Model FC 5250 delivers +5 volts at 30 amperes maximum, +12 volts at 8 amperes, −5 volts ar 0.5 ampere and −12 volts at 0.5 ampere. The Model

(Continued on page 37)

A Solid-State Oscilloscope

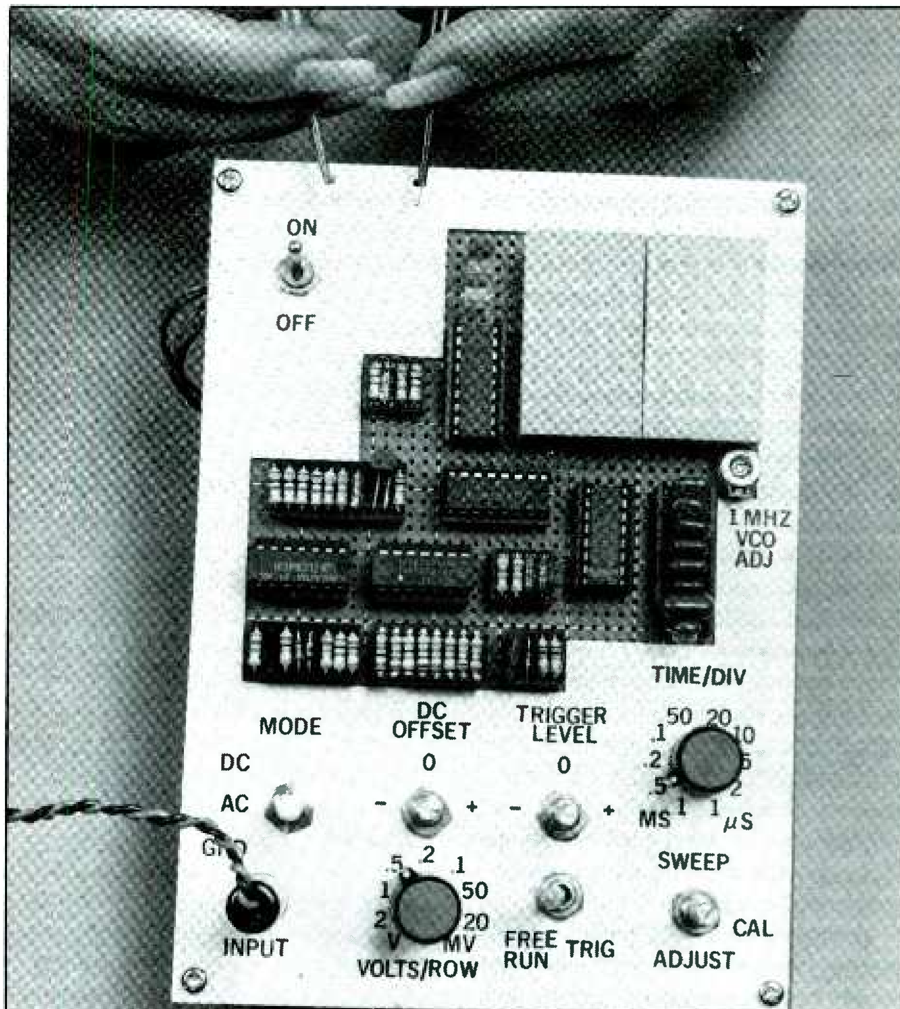
Use this low-cost ac/battery-powered instrument as your first oscilloscope or to supplement use of an existing one on your testbench and in the field

By Jeff T. Williams

There are many instances in which only an oscilloscope can tell you what you want to know about a circuit. Measuring the rise time of a clock signal, for example, or the propagation delay of a logic gate, or the magnitude and duration of a voltage spike generated by switching an inductive load, are just a few of the many tasks to which the oscilloscope is uniquely suited.

Although oscilloscopes can be very expensive, there is an easy way to begin to understand and take advantage of some of their capabilities. In this article, we will show you how to build a very-low-cost, completely solid-state scope. Although our Solid-State Oscilloscope is not nearly as advanced or accurate as its commercial counterpart, it is quite sophisticated and can be used for a wide variety of monitoring and measurement purposes in which high accuracy is not critical.

If you already own a scope, our solid-state version can be used as a reasonably accurate second one on your workbench, to monitor a signal when the inputs on your main scope are unavailable. Compared to more advanced commercial instruments, our scope is extraordinarily compact and ideal for field use, along with your multimeter and toolbox.



Oscilloscope Fundamentals

At its simplest level, the chief function of an oscilloscope is to display how a voltage changes with time. Most oscilloscopes employ a cathode-ray tube (CRT) on which a representation of some given input signal appears.

Internal circuitry generates an electron beam that produces a small bright dot when it strikes the phosphor coating on the inner face of the CRT. This dot is made to move vertically and horizontally in response to the signal at the input of the scope. Vertical and horizontal deflection of the dot represent changes in voltage and time, respectively. The result is a traced line that accurately represents the voltage-versus-time characteristics of the input signal.

A block diagram of how all this is

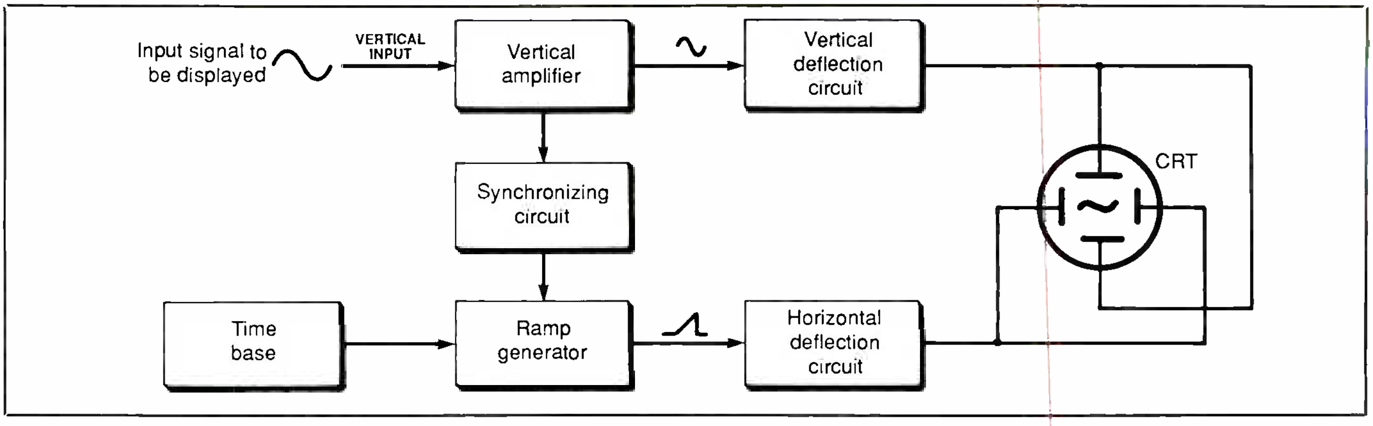


Fig. 1. Block diagram of the conventional oscilloscope.

accomplished is shown in Fig. 1. The signal to be observed is coupled to the vertical axis of the oscilloscope through amplification and deflection control circuitry that both generates the 10,000 to 20,000 volts required by the CRT and varies this potential in response to the input signal. The instantaneous magnitude of the input signal determines the degree of vertical deflection of the beam at any given time.

If the above were all that occurred, only a rather uninformative vertical line would appear on the screen as the input voltage varied. The electron beam is simply being moved vertically in response to variations in the magnitude of the input voltage. The horizontal "time" motion of the signal is still missing. To see this time component, a means is needed to "sweep" the electron beam steadily across the screen.

In conventional CRT-type oscilloscopes, sweeping is accomplished with a "ramp generator" circuit that generates a linearly-increasing voltage. When applied to the horizontal deflection plates of the CRT, this voltage moves the electron beam uniformly across the screen from left to right. The *slope* of the ramp voltage determines how quickly the beam is swept across the screen. The quicker the ramp voltage increases, the more rapidly the beam moves.

As an example of the above, a 1,000-volt potential is required for full horizontal deflection. If the ramp potential increases at a rate of 100,000 volts per second, the beam will move completely across the screen in 10 milliseconds. Thus, the horizontal sweep rate of the oscilloscope is 1/10 ms, which factors out to 100 Hz. Knowing this sweep rate, you can calculate the frequency of the input signal. If at a sweep rate of 100 Hz two full cycles of an input signal were on-screen, the input frequency must be 2(100 Hz), or 200 Hz.

Now let us see how the solid-state oscilloscope differs from the conventional CRT-type instrument. The most important difference, of course, is in the display screen. Our Solid-State Oscilloscope uses a screen made up of a matrix of light-emitting-diode points instead of a cathode-ray tube. This qualifies it as being 100 percent *solid-state* in design. (Some oscilloscopes on the market today replace the CRT with a liquid-crystal display, or LCD, matrix). As shown in Fig. 2, an input signal on our Solid-State Oscilloscope is displayed as a pattern of light and dark LEDs.

How does using an array of LEDs instead of a CRT change the horizontal and vertical deflection circuitry? Certainly, a ramp voltage will not sequentially light one LED after another. Instead, it will make a given LED brighter and brighter. However, a simple counter and decoder that sequentially addresses the LED columns would be ideal.

In our Solid-State Oscilloscope, the traditional ramp generator is replaced by a counter/divider circuit driven by a master clock. By varying the speed of the clock, the speed at which the columns of the LED display are addressed and, thus, the horizontal sweep rate across the screen of the scope is varied.

The vertical deflection section of our scope is not much different from that of a CRT oscilloscope. The most important difference is that the amplitude of the input signal must now be used to enable discrete rows on the LED screen instead of deflecting a beam of electrons. Higher input voltages should activate physically higher rows on the LED screen, and vice-versa.

The above is most conveniently accomplished using a bargraph display chip like the LM3914. This chip compares an input voltage to an internal reference potential and automatically determines which of its 10 available outputs most accurately represents the input signal level. If these outputs are used to activate 10 rows on a LED screen, the vertical section of our scope is essentially complete.

About the Circuit

Referring to the complete schematic diagram of the Solid-State Oscilloscope's circuit shown in Fig. 3, let us now follow a signal from input to display. Because of the complexity of this circuit, it's much easier to understand by examining it in sections.

Operational amplifier *IC1A* and its associated circuitry make up a unity-gain high-impedance input follower that buffers the input and isolates the circuit under test from the oscilloscope. Diodes *D1* and *D2* protect *IC1A* by clipping any input signal outside the power supply limits (about ±9 volts).

Switch *S2* selects the input coupling mode. Set to the DC position, this switch passes the input signal directly to *IC1A* through *R2*. If *S2* is set to the AC position, the input signal must first go through blocking capacitor *C1*. If the input signal is "riding" on a dc voltage, this mode blocks the dc component and permits only the ac portion of the input to pass. Finally, *S1* can also connect the input buffer to ground to permit a 0-volt reference trace to be positioned on the scope screen.

The buffered input signal from *IC1A* is scaled by inverting amplifier *IC1B*, the gain of which is determined by the the ratio of the values of the feedback resistor (*R6* through *R12*, whichever is selected by VOLTS/ROW switch *S3*) to input resistor *R4*. Switch *S3* controls the gain of this stage by inserting one of seven resistances into the feedback path. With the values specified, gains of 25, 10, 5, 2.5, 1.0, 0.5 and 0.25 are available.

When combined with a fixed reference voltage for the LM3914, the available gain values calibrate the vertical deflection on the oscilloscope display in volt (or millivolt) units per row. This permits voltage measurements to be made directly from the scope screen.

In principle, the output of *IC1B* could be coupled directly to the signal input of LM3914 bargraph display *IC3*. One of the two reasons why this isn't done is that the output from *IC1B* is an inverted version of the input signal (a second inversion is required if the scope is to properly display the input signal). The other, more important, reason is that the LM3914 input contains a diode clamp to ground that effectively removes all but the positive portion of any input to this device.

To display waveforms with negative portions, a dc offset voltage must be added to the signal to raise the entire waveform into the positive-voltage region. This is accomplished with *IC1C*, which sums the output signal from *IC1B* with a variable dc voltage taken from DC OFFSET control *R15*. When adjusted in combination with the input gain, this control permits both positive and negative portions of an input signal to appear on the screen.

Note that *IC1C* also operates in an inverting mode. Therefore, it reverses the inversion of gain stage *IC1B* so that the signal at the output of *IC1C* becomes a correctly oriented, scaled and dc-adjusted version of the input signal.

The summed output from *IC1C* is now applied to the input of *IC3*. The LM3914 responds by activating one of its 10 outputs and enabling one of the rows on the LED display. However, since the display screen in this project consists of seven rows, only seven of these 10 outputs are used to drive the main display. The remaining three outputs are connected to separate green, yellow and red OVER-RANGE light-emitting diodes *LED1*, *LED2* and *LED3*. The LEDs indicate when a portion of the input signal is being deflected vertically beyond the uppermost display row.

As with a commercial oscilloscope, you would like to be able to

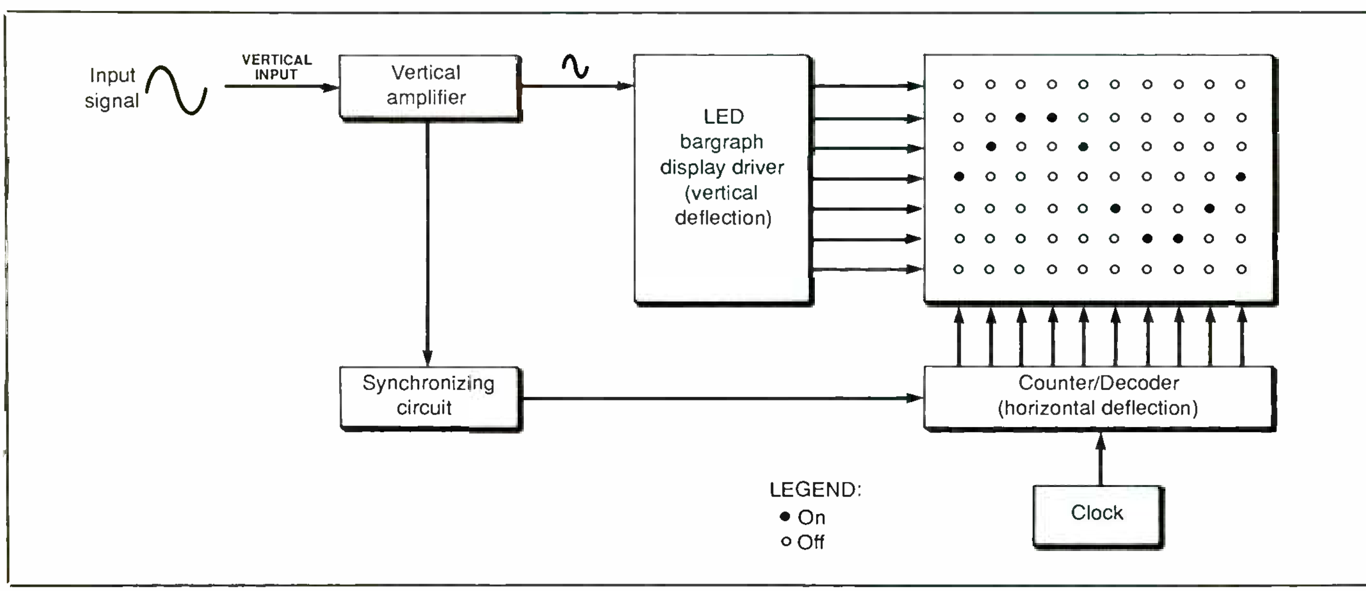
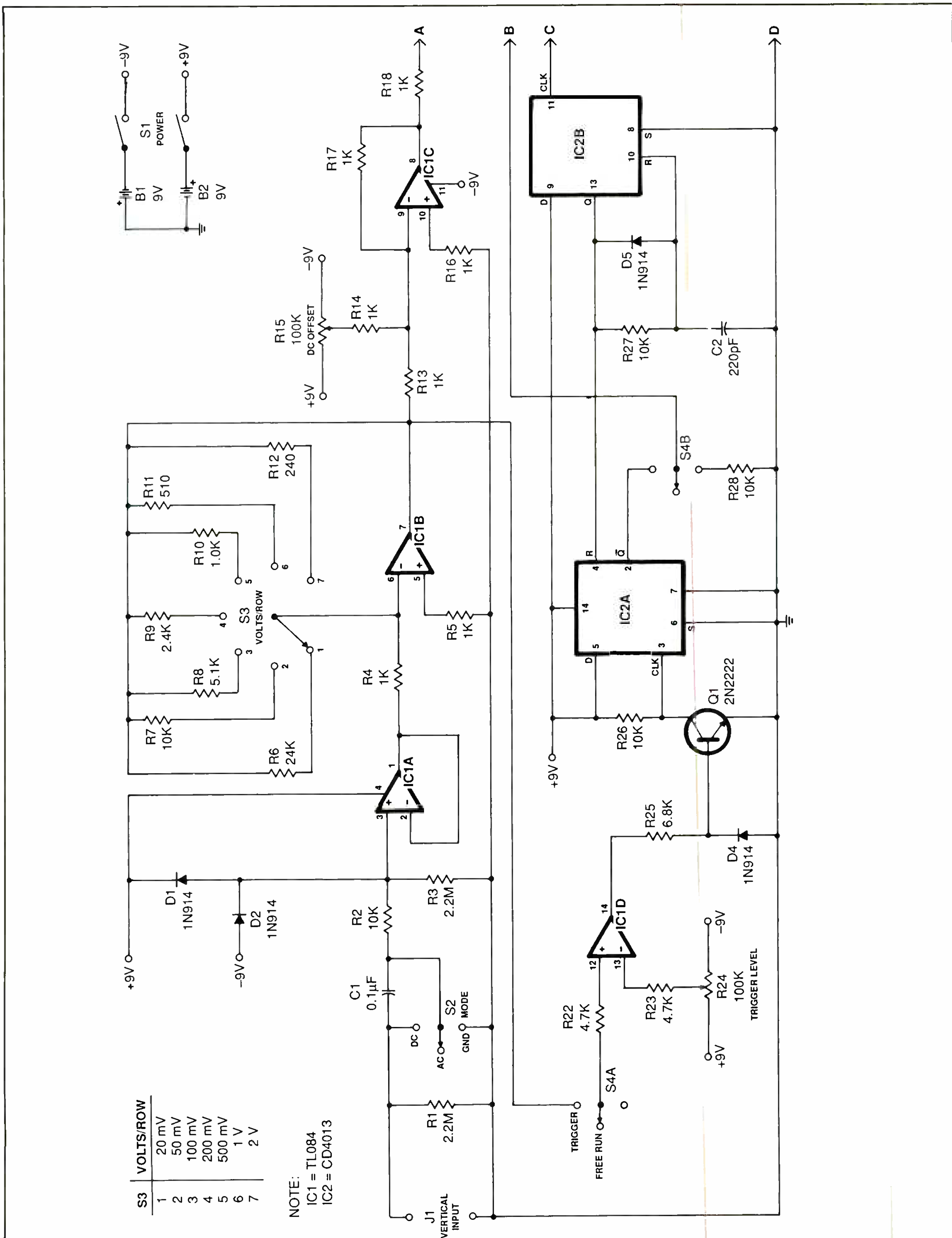
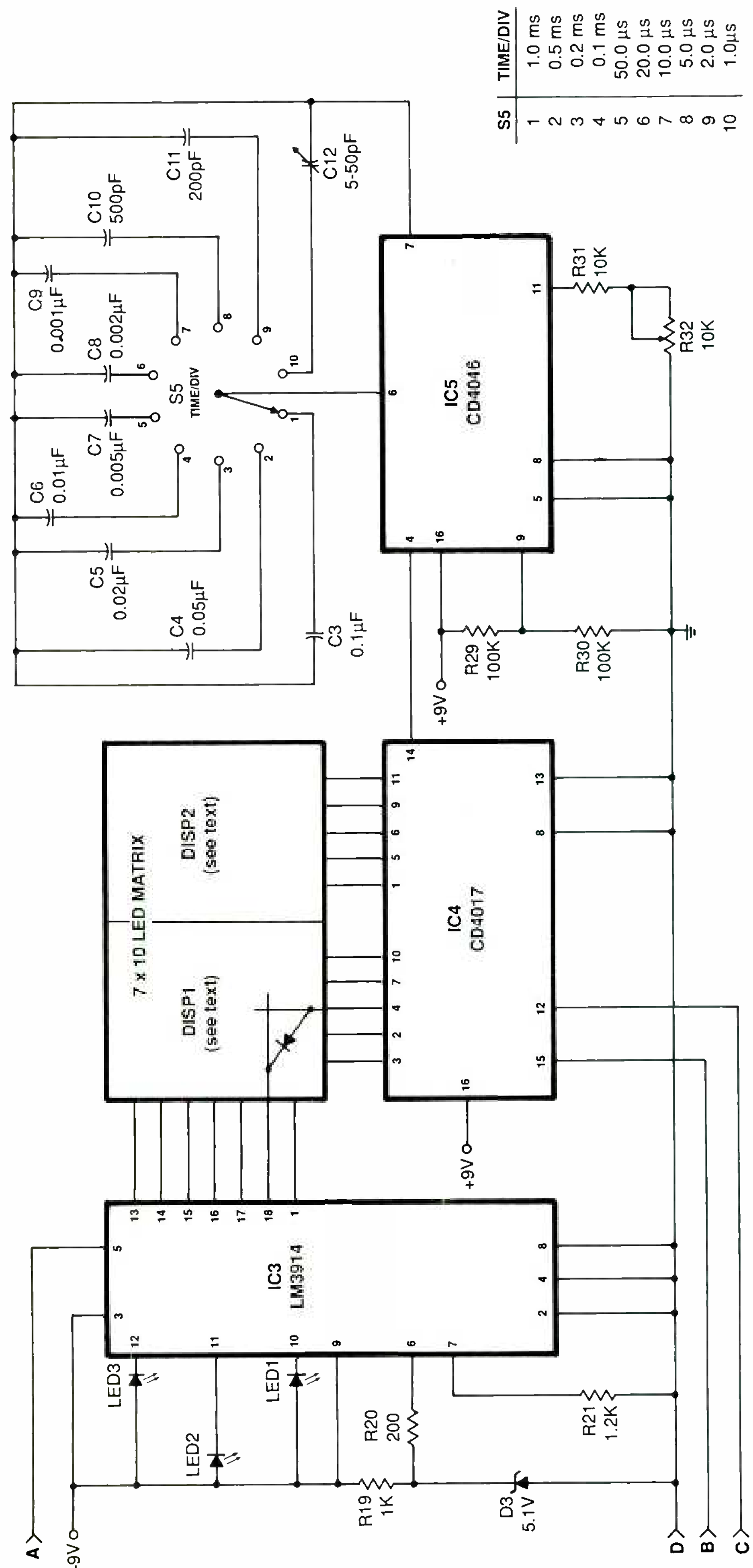


Fig. 2. Block diagram of the Solid-State Oscilloscope.


S3 | VOLTS/ROW
1 20 mV
2 50 mV
3 100 mV
4 200 mV
5 500 mV
6 1 V
7 2 V
NOTE:
IC1 = TL084
IC2 = CD4013
S1 POWER
B1 9V
B2 9V
-9V
+9V
D1 1N914
D2 1N914
R1 2.2M
R2 10K
R3 2.2M
R4 1K
R5 1K
R6 24K
R7 10K
R8 5.1K
R9 2.4K
R10 1.0K
R11 510
R12 240
R13 1K
R14 1K
R15 100K DC OFFSET
R16 1K
R17 1K
R18 1K
C1 0.1µF
S2 MODE
DC
AC
GND
J1 VERTICAL INPUT
S3 VOLTS/ROW
IC1A
IC1B
IC1C
IC1D
IC2A
IC2B
R22 4.7K
R23 4.7K
R24 100K TRIGGER LEVEL
R25 6.8K
R26 10K
R27 10K
R28 10K
C2 220pF
D4 1N914
D5 1N914
Q1 2N2222
S4A
S4B
TRIGGER
FREE RUN
CLK
A
B
C
D



make voltage measurements directly from the display. To be able to do this, the display screen be calibrated in units of *volts per row* so that by counting the number of rows over which a signal is deflected allows you to determine the voltage of the signal. To understand how this is done, we need to first review the internal calibration feature on the LM3914.

Before the LM3914 can be used to "measure" an input signal, its 10 outputs must be calibrated to respond to a certain range of input voltages. This is accomplished by supplying a reference voltage to pin 6 of *IC3*. This reference voltage is divided internally across a string of 10 comparators and 1,000-ohm resistors; hence, any input voltage to the LM3914 becomes "measured" in units of $V_{ref}/10$. If V_{ref} is 10 volts, for example, the 10 outputs of *IC3* will be sequentially activated by input signals of 1 volt, 2 volts, 3 volts and so on up to 10 volts.

In the Solid-State Oscilloscope, zener diode *D3* and resistor *R20* hold the reference input at pin 6 of *IC3* at 5.0 volts, which yields an internal calibration factor of 0.5 volt per output. The "effective" number of volts per row on the LED display then becomes the "actual" volts per row provided by the LM3914 divided by the gain of stage *IC1B*. If the gain of this stage is 0.25, for example, the vertical deflection factor becomes (0.5 volt/row)/0.25 = 2.0 volts/row.

A 6-volt input signal, for example, would produce a (6.0 volts × 0.25) = 1.5-volt output from stage *IC1B*, and at 0.5 volt per output this 1.5-volt signal will activate the third row on the LM3914. The 6-volt input signal will produce a three-row deflection on the LED screen; so the vertical axis is calibrated at 2 volts per row.

The other vertical scale factors can be determined in a similar fashion.

◀ *Fig. 3. Complete schematic diagram of the Solid-State Oscilloscope.*

PARTS LIST

Semiconductors
DISP1,DISP2—5 × 7 LED dot-matrix display (IEE1257R or equivalent—see text)
D1,D2,D4,D5—1N914 or 1N4148 general-purpose silicon diode
D3—5.1-volt zener diode (1N5231B, 1N4733A or equivalent—see text)
LED1—Green light-emitting diode
LED2—Yellow light-emitting diode
LED3—Red light emitting diode
Q1—2N2222 or equivalent silicon npn transistor
IC1—TL084 quad BiFET operational amplifier
IC2—CD4013 dual D-type flip-flop
IC3—LM3914 bargraph display driver
IC4—CD4017 decade counter/divider
IC5—CD4046 phase-locked loop
Capacitors (Minimum 35 WV)
C1,C3—0.1-μF ceramic disc
C2—220-pF ceramic disc
C4—0.05-μF ceramic disc
C5—0.02-μF ceramic disc
C6—0.01-μF ceramic disc
C7—0.005-μF ceramic disc
C8—0.002-μF ceramic disc
C9—0.001-μF ceramic disc
C10—500-pF ceramic disc
C11—200-pF ceramic disc
C12—6-to-50-pF trimmer
Resistors* (¼-watt, 5% tolerance)
R1,R3—2.2 megohms
R2,R26 thru R28,R31—10,000 ohms
R4,R10—1,000 ohms (1,020 ohms)
R5,R13,R14,R16 thru R19—1,000 ohms
R6—24,000 ohms (25,500 ohms)
R7—10,000 ohms (10,200 ohms)
R8—5,100 ohms (5,110 ohms)
R9—2,400 ohms (2,550 ohms)
R11—510 ohms (511 ohms)
R12—240 ohms (255 ohms)
R20—200 ohms (see text)
R21—1,200 ohms
R22,R23—4,700 ohms
R25—6,800 ohms
R29,R30—100,000 ohms
R15,R24—100,000-ohm linear-taper potentiometer
R32—10,000-ohm single- or multi-turn potentiometer
Miscellaneous
B1,B2—9-volt battery
S1—Dpst or dpdt toggle or slide switch
S2—Spdt center-off toggle or slide switch
S3—7-position non-shorting rotary switch
S4—Dpdt toggle or slide switch
S5—10-position non-shorting rotary switch
Perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware (or design and fabricate your own printed-circuit board); sockets for all ICs, two 9-volt battery snap connectors and clips; suitable enclosure (Radio Shack Cat. No. 22-153 or similar); spacers; machine hardware; hookup wire; solder; etc.

*For maximum accuracy, use values shown in parentheses.

Note: A good source for zener diodes and precision resistors and capacitors is Digi-Key Corp., 701 Brooks Ave. S., P.O. Box 677, Thief River Falls, MN 56701. IEE1257R displays are available from IEE, Inc., 7740 Lemona Ave., Van Nuys, CA 91405; there is a $250 minimum order requirement, but contact the company for the name of the nearest stocking distributor. MAN-2 displays are available from a variety of mail-order houses. One source of miniature rotary switches is All Electronics Corp., P.O. Box 567, Van Nuys, CA 91408. Request Cat. No. MRS-10 ($1.50 each, $10 minimum order).

With the 0.5-volt/row internal reference for the LM3914, the gain factors for *IC1B* listed earlier yield "effective" vertical deflection factors of 20 and 50 millivolts per row, and 0.1, 0.2, 0.5, 1.0 and 2.0 volts per row in the LED display.

Finally, since 5.0-volt zener diodes can be difficult to locate, *R20* is included to permit the use of zener diodes with greater breakdown voltages. For example, if you use a 5.1-volt zener for *D3*, choosing a value of 200 ohms for *R20* will drop the extra 0.1 volt and maintain the LM3914 reference input at 5 volts. If you can locate a 5.0-volt zener diode, *R20* can be omitted.

The horizontal sweep circuitry consists of *IC3* and *IC4* and their associated components. Here, *IC4* serves as the master clock for the horizontal sweep generator and *IC3* is a counter/divider that sequentially addresses the 10 columns of the display. After experimenting with a number of designs for the horizontal sweep clock, the voltage-controlled oscillator (vco) portion of 4046 phase-locked loop *IC5* was determined to give the most stable output and consistent performance over the rather large frequency range desired.

Instead of fixing the RC component values for the vco and varying the input voltage to control output frequency (the traditional arrangement), the vco input voltage was fixed at V+/2, and the values of R and C were made variable. There are at least two advantages to doing this. One is that the clock circuit becomes largely independent of changes in the supply voltages, an especially important consideration in a battery-operated device. The other advantage is that the values for the capacitor can be selected which step the output frequency of the vco in the standard 1-2-5 pattern found on commercial oscilloscopes.

Switch *S5* is used to select one of 10 time base values for the horizontal sweep circuit. With *R32* set to its 0-ohm "calibrate" position, the setting of *S5* determines the time per division (actually, time per column) on the display. If *R32* is any resistance other than 0 ohm, however, the time base is no longer equal to the value indicated by *S5*, and the actual time per division may be increased to twice the calibrate value.

With *R32* set to 0 ohm, for example, setting *S5* to 0.1 ms inserts a 0.01-microfarad capacitor into the vco circuit. The master clock frequency will be 10 kHz, and the effective horizontal sweep rate will be one-tenth of this (1 kHz). A complete left-to-right sweep of the display will require 1 millisecond to accomplish. When divided among the 10 columns of the display, this yields a horizontal time base of 0.1 ms per "division" (column) on the LED screen. This is the "calibrate" position. Control *R32* will smoothly increase the horizontal time per division to twice this value, from 0.1 to 0.2 ms per division (the same as halving the effective horizontal sweep frequency).

The vco frequencies, horizontal sweep frequencies and horizontal time base values are summarized in the Table for the various capacitor values. Notice that since a single horizontal sweep across the screen requires 10 clock cycles, the effective horizontal sweep frequency is one tenth the vco output frequency. Thus, if the clock output is 1 MHz, the scope screen is being swept at a frequency of 100 kHz. That is, the sweep clock must be capable of performing at 10 times the highest desired oscilloscope sweep rate. With the component values specified, maximum vco frequency is about 1 MHz, which yields an effective horizontal sweep rate of 100 kHz, or 1 microsecond per column.

The output of the vco drives the clock input of 4017 1-of-10 divider/decoder *IC4*. This latter chip counts the number of clock pulses it receives and activates the appropriate output. After three clock cycles, for example, output 3 goes high; after four clock cycles, output 4 goes high; and so on. This cycle repeats every 10 clock counts.

With the outputs of *IC4* connected to the anodes of the LED screen, the 10 columns of the oscilloscope display are sequentially and continuously activated as this 4017 chip cycles through its count. As each LED column becomes enabled (an *IC4* output goes high), the voltage at the input of *IC3* determines which LED row will also be active (the chip's output goes low). The result is that a single LED, corresponding to the instantaneous amplitude of the input signal, lights on the screen. As the display is repeatedly scanned horizontally, a picture of the input signal appears on the screen.

Horizontal Sweep Rates and Time Base Values

Position of S4	Capacitance Value	VCO Frequency*	Horizontal Sweep Frequency	Time Per Column*
1	0.1 uF	1 kHz	100 Hz	1.0 ms
2	0.05 μF	2 kHz	200 Hz	0.5 ms
3	0.02 μF	5 kHz	500 Hz	0.2 ms
4	0.01 μF	10 kHz	1 kHz	0.1 ms
5	0.005 μF	20 kHz	2 kHz	50 μs
6	0.002 μF	50 kHz	5 kHz	20 μs
7	0.001 μF	100 kHz	10 kHz	10 μs
8	500 pF	200 kHz	20 kHz	5 μs
9	200 pF	500 kHz	50 kHz	2 μs
10**	6-to-50 pF	1.0 MHz	100 kHz	1 μs

*Values listed are for SWEEP control R32 set to CALIBRATE position; R32 can be used to double the Time/Column from any CALIBRATE position. Time per column is one-tenth total time required for a single screen sweep.

**Stray capacitance can considerably affect observed frequency in this range. Use a trimmer capacitor and adjust value of C for 1 MHz operation.

One of the most important features of this oscilloscope, and a feature that really makes this project a practical test device, not just a breadboarded curiosity, is its triggered-sweep feature. Briefly, triggered sweep is the ability of an oscilloscope to synchronize its horizontal display sweep with the input signal to initiate a sweep only when the input signal reaches some preset level. In older recurrent sweep oscilloscopes, horizontal sweep occurs continuously and independently of the input signal. With triggered sweep, an input signal can be "frozen" in the display and then expanded or compressed simply by adjusting the horizontal time base.

Triggered sweep is provided by the *IC1D* and dual D flip-flop *IC5* stages. Switch *S4* permits selection between triggered and free-running horizontal sweep modes. To understand how the trigger circuit works, assume that *IC2A* is in its RESET state. Then the not-Q output at pin 2 is high, which resets *IC4*, which does not count. Thus, no sweep occurs.

Meanwhile, comparator *IC1D* compares the input signal with the trigger voltage level set by TRIGGER LEVEL control *R24*. If the input signal at pin 13 of *IC1D* is greater than the trigger voltage at pin 12 of the chip, the output of *IC1D* is high, *Q1* is conducting and the CLK input at pin 3 of *IC2A* is low. The not-Q output at pin 2 of *IC2A* remains high and *IC4* remains reset.

Now suppose that the input signal level drops below the selected trigger level. When this occurs, the output at pin 14 of *IC1D* goes low. This turns off *Q1* and pulls the CLK input of *IC2A* high (*D4* prevents the base of *Q1* from going negative when the output of *IC1D* is low). This clocks a logic 1 into *IC2A* so that its pin 2 output goes low. This brings RESET pin 15 of *IC4* low and initiates a screen sweep.

At the end of this sweep, pin 12 of *IC4* goes from low to high. This clocks a logic 1 into *IC2B* at CLK input pin 11, causing its Q output at pin 13 to go high. This immediately resets *IC2A* and temporarily disables any further sweep. As *C2* charges through *R27*, however, *IC2B* eventually resets, after which *IC2A* is ready to be triggered again.

As soon as *IC2B* resets, *D5* quickly discharges *C2* and prepares it for an-

(Continued on page 71)

Using the LS7210 Timer

This versatile IC lets you program time delays ranging from a few milliseconds to hours and even days

By Jan Axelson

Any circuit that waits before it acts is a candidate for a time-delay circuit. Timer chips like the popular 555 are often used to handle the timed-delay functions for such circuits. Though the 555 is the chip that usually comes to mind for a timing application, a new timer chip, the LS7210, is especially suited for these uses.

A versatile device, you can use the LS7210 to time delays milliseconds, seconds, minutes, hours or even days in length. On-chip frequency dividers allow you to program long delays without the need for huge timing resistors and capacitors that many other IC timing devices require. The LS7210 can also be used as a one-shot monostable multivibrator, or as a low-frequency oscillator.

Manufactured by LSI Computer Systems, Inc., the LS7210 is widely available. Versatile as it is, this chip can be confusing to design with because a simple formula for choosing values of timing components does not exist. In this article, we will describe a simplified circuit-design method for the LS7210 and discuss sample circuits that may give you ideas for your own time-delay applications.

About the IC

Shown in Fig. 1 are the pinout diagram of the LS7210 and a summary of some of the design characteristics of this chip. CLOCK SELECT pin 4 selects an internal or external clock source for timing the delays. The internal clock requires a resistor and capacitor at OSCILLATOR pin 5, the external clock an oscillator connected to EXTERNAL CLOCK pin 6.

A prescaler inside the LS7210 divides the clock frequency by 1,023. This causes the output delay to always be at least 1,024 times longer than the clock period. Five weighting inputs can increase the delay even further. A logic low (0) on one or more of the weighting inputs multiplies the delay by approximately the sum of the low weightings. With all five weighting inputs low, the delay length is multiplied by 31 (1 + 2 + 4 + 8 + 16), for a delay almost 32,000 times longer than the clock period. The delay is calculated using $D = (1 + 1{,}023N)/F$, where D is the delay seconds, N is the weighting factor, and F is the clock frequency in Hz.

A pulse at TRIGGER pin 3 causes the LS7210 to begin timing a delay. How the IC responds to a trigger pulse depends on the mode of operation selected at MODE SELECT A pin 2 and MODE SELECT B pin 1. Figure 2 illustrates the four modes.

In delayed-operate mode, a high-to-low trigger causes the output to pause for the programmed delay time before turning on (going high), and a low-to-high trigger causes the output to turn off (go low) immediately.

Delayed-release mode is just the opposite of the delayed-operate

Mode Select A	Mode Select B	Mode
0	0	One-Shot Multivibrator
0	1	Delayed-Operate
1	0	Delayed-Release
1	1	Dual Delay

Clock Select	Clock
0	Internal Oscillator
1	External clock

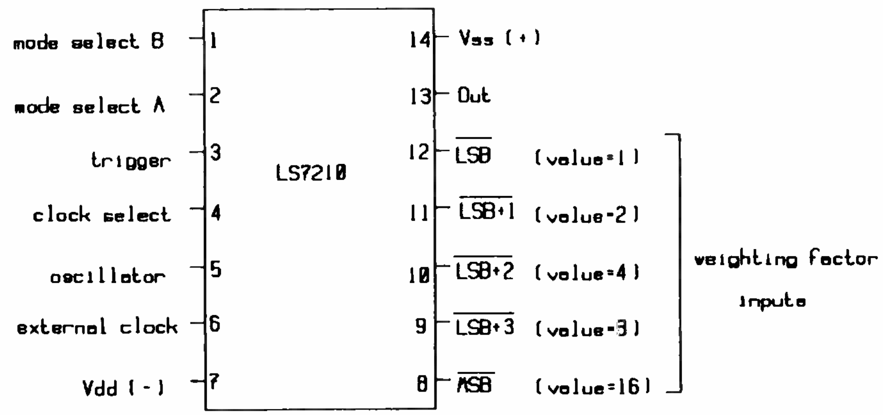


Fig. 1. The LS7210 delay timer has four modes of operation and a user- programmable delay period.

mode in that a high-going trigger causes a delay in turning the output off and a low-going trigger causes the output to turn on immediately.

In dual-delay mode, the output is delayed both in turning on and in turning off.

In one-shot mode, a low-going trigger causes the output to turn on immediately and remain on for the programmed delay time. High-going triggers are ignored in this mode.

All four operating modes are retriggerable, with additional triggers during the delay restarting the delay timing.

Mode, weighting, trigger and clock-select inputs all have internal pull-up resistors; so leaving them open sets them high automatically. These inputs can be tied directly to ground to set them low.

OUTPUT pin 13 of the IC connects internally to an open-drain field-effect transistor (FET) that can serve as a current source. For currents that exceed a few milliamperes, the output at pin 13 can be used to drive an external transistor, power MOSFET or other amplifying device. If the output is used to drive a logic input, a pull-down resistor from the output to ground is required to bring the output to a logic low level.

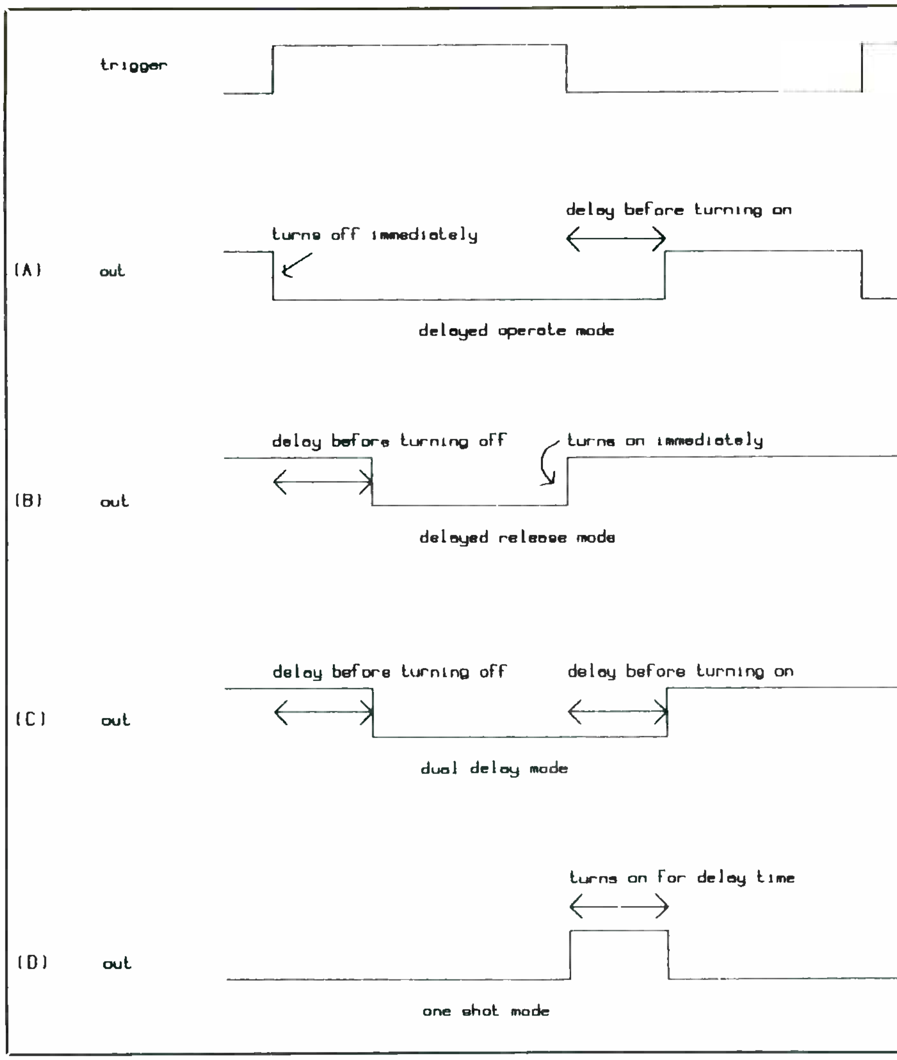


Fig. 2. In delayed-operate mode (A), a high-to-low trigger causes the output of LS7210 to delay before turning on; in delayed-release mode (B), a low-to-high trigger causes a delay in turning off the output; in dual-delay mode (C), delays appear both in turning on and turning off the output; and in one-shot mode (D), chip is configured as a retriggerable monostable multivibrator.

Programming the Chip

A basic LS7210 circuit is shown schematically in Fig. 3. In this circuit, pin 4 of the IC is grounded. Therefore, the internal oscillator is selected and the values of *R1* and *C1* set the clock frequency.

If you are familiar with the popular 555 timer IC, you know that its output pulse length can be determined by plugging resistance and capacitance component values into a formula. Unfortunately, the data sheet for the LS7210 gives no such formula. Instead, a chart is provided that gives sample resistor and capacitor values and the clock frequencies obtained with them. From these, you can estimate resistances and capacitances needed for the clock frequency and delay length you require.

A portion of the chart provided with the LS7210 chip is reproduced in Fig. 4. Of course, you can use component values other than those listed, adjusting them experimentally for the results you desire. The frequencies given are those obtained with the LS7210 powered from a 10-volt dc source. Greater or lesser power supply voltages than this will cause the output frequency to vary slightly from the values given.

For a clock frequency of 2,000 Hz, the chart recommends a 470,000-ohm resistor and a 0.001-microfarad capacitor. With all five weighting inputs grounded as shown, the delay length (calculated from the formula given above) is about 16 seconds.

Because pins 1 and 2 are both open, the timer is in dual-delay mode. Closing switch *S1* starts the delay timing. After 16 seconds pin 13

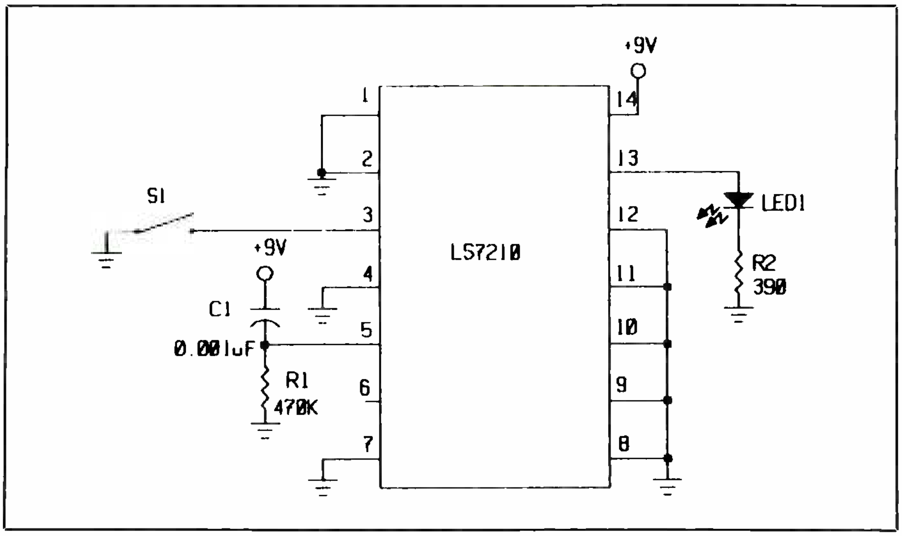


Fig. 3. Closing or opening S1 causes LED1 to turn on or off after a delay, period for which is set by R1, C1 and weighting inputs at pins 8 through 12 of LS7210.

goes high and *LED1* lights. Opening the switch restarts the delay, and pin 13 goes low after 16 seconds, extinguishing the LED.

You can test the operation of the other three modes by grounding pins 1 and 2 in different combinations. Ground pin 1 for a delay only in turning off the LED, or ground pin 2 for a delay only in turning on the LED. Grounding both pins 1 and 2 and closing *S1* causes the LED to turn on immediately and then off after the programmed delay has timed out.

Choosing Timing Elements

To set up the LS7210 for a specific delay time, you must take into account resistor and capacitor values and the weighting inputs. Because there are many ways of achieving the same result, it is sometimes difficult to know where to begin. The following steps offer one way of designing a circuit around an LS7210 using a minimum of calculations and/or guesswork. We offer two procedures, your choice of which one to use depending on the length of the delay you need.

For a delay of about half a second or longer, the procedure is as follows:

(1) Ground pins 8 through 12 to give the maximum delay. By doing this, you can use the smallest possible resistor and capacitor values.

(2) Estimate the clock frequency, using the formula F = 32,000/D, where F is the clock frequency and D is the desired delay in seconds.

(3) Using the chart given in Fig. 4, find resistor and capacitor values for a frequency close to the value you have calculated. Use these values for the timing resistor and capacitor at pin 5 of the LS7210 timer chip, as shown in Fig. 3.

If you need a precisely timed delay, substitute a potentiometer for the timing resistor. Use a value that is greater than that recommended for the resistor, and adjust the resistance until you have the delay time you need.

For delays of less than 0.5 second, use the following procedure:

(1) Ground pin 12 and leave pins 8 through 11 open to generate the minimum delay possible.

(2) Estimate the clock frequency using the formula F = 1,024/D, where *F* is the clock frequency and *D* is the delay wanted in seconds.

(3) Follow Step 3 in the above procedure to select component values.

As a design example, to change the Fig. 3 circuit to yield a delay of 0.2 second, use the short-delay procedure: Ground pin 12 and leave pins 8-11 open. From the formula, you need a clock frequency of 1,024/0.2, which calculates out to 5,120 Hz. The closest frequency to this on the data sheet is 4,700 Hz, which is obtained with a 2-megohm resistor and a 100-picofarad capacitor. Substitute components of these values for *R1* and *C1*, to program the LS7210 for a delay of about 0.2 second.

Low-Frequency Oscillators

The LS7210 can also serve as an oscillator that generates frequencies of about 50 Hz and lower, as shown in Fig. 5. Here, pins 1 and 2 of the IC are open, putting the timer in dual-delay mode. The output at pin 13 feeds back to provide the trigger pulses. Each time pin 13 changes state, the timer begins counting down a delay period. Estimate the output frequency of the Fig. 5 circuit using the formula $F_o = F/2,046N$, where *F*

Timing Resistor Value	Timing Capacitor Value	Frequency of Oscillation
47k	100 pF	139 HZ
	200 pF	83 HZ
	500 pF	37 HZ
	0.001 µF	21 HZ
	0.05 µF	500 HZ
470k	100 pF	16 HZ
	200 pF	9.5 HZ
	500 pF	4 HZ
	0.001 µF	2 HZ
	0.05 µF	51 HZ
2M	100 pF	4.7 HZ
	200 pF	2.7 HZ
	500 pF	1.1 HZ
	0.001 µF	617 HZ
	0.05 µF	14 HZ
10M	10 µF	0.015 HZ

Fig. 4. From this chart of timing resistor and capacitor values, you can select appropriate values for the required clock frequency for LS7210.

is the clock frequency and N is the weighting at pins 8 through 12.

At the 0.01-Hz lowest recommended clock frequency for the internal oscillator and maximum weighting factor with all weighting inputs grounded, the output of the Fig. 5 circuit should theoretically oscillate at a frequency of 0.00000016 Hz, or one cycle every 73 days! In reality, the output frequency of this circuit is not quite that low; the clock frequency is 2 kHz, yielding an output frequency of about 1 Hz.

The weighting inputs enable you to create an oscillator with a variable duty cycle, or ratio of "on" time to total period. Fig. 6 is the schematic diagram of such an oscillator that operates at a frequency of 0.2 Hz and has a duty cycle of 0.1. The clock frequency is again about 2 kHz. WEIGHTING INPUT 1 pin 12 is low, and WEIGHTING INPUT 8 pin 9 is controlled by the signal at pin 13.

When pin 13 goes low, total weighting is 9 (1 + 8), for triggering of a 4.5-second delay. When the delay times out, pin 13 goes high and again triggers the delay timing at pin 3. This time, WEIGHTING INPUT 1 pin 12 is the only weighting input that is low; so pin 13 delays just 0.5 second before going low and triggering the next delay. The output cycles on for 0.5 second and off for 4.5 seconds, for a duty cycle of 0.1.

Other duty cycles can be created by tying different combinations of weighting inputs to ground and pin 13. However, bear in mind that the "on" part of the cycle must always be equal to or less than the "off" part.

Technical Specifications

Recommended power-supply potential	4.75 V minimum 15 V maximum
Typical supply current	3.0 mA
Output source current:	
V_{out} = +4.0 V, V_{ss} = +5 V	+1.0 mA
V_{out} = +9.0 V, V_{ss} = +10 V	+2.8 mA
V_{out} = +14 V, V_{ss} = +15 V	+4.2 mA
Internal oscillator frequency	0.01 Hz minimum 100 kHz maximum
External oscillator frequency	dc minimum 160 kHz maximum

A Sequencer

In Fig. 7 is shown the schematic diagram of a sequential timer circuit that alternates turning on the outputs of two LS7210 chips. Pin 4 of each timer is left open to select the external clock source. An oscillator generated by CMOS inverters *IC3D* and *IC3E* provides the clock signal, which is at a frequency of about 100 Hz at pin 6 of timers *IC1* and *IC2*. Pins 1 and 2 of the timers are grounded, putting *IC1* and *IC2* in one-shot mode.

The duration of the delay from each timer is controlled independently at its weighting inputs. For *IC1*, a weighting of 1 gives a delay of about 10 seconds, while for *IC2*, a weighting of 3 gives a delay of about 30 seconds.

A high-to-low transition at pin 3 of *IC1* causes *LED1* to turn on. Ten seconds later, pin 13 of *IC1* goes high. This turns off *LED1* and triggers

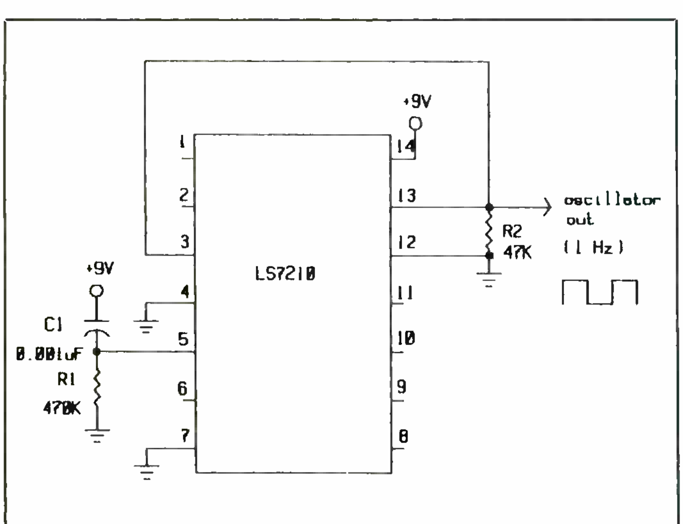


Fig. 5. Output feeds back to provide trigger pulses for this 1-Hz oscillator.

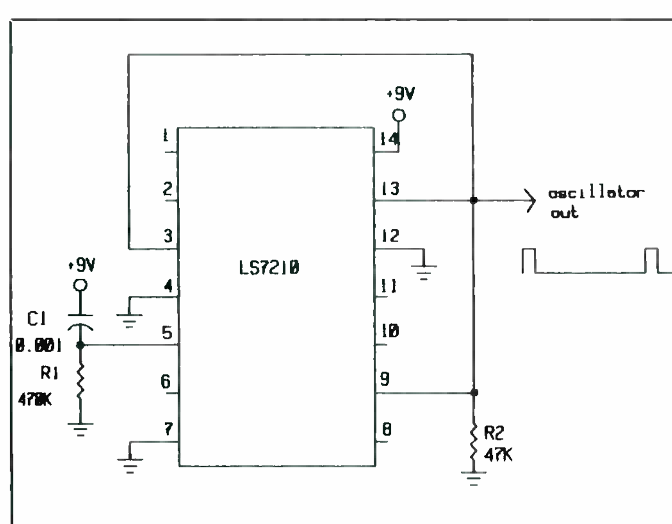


Fig. 6. Output of this oscillator alternates 0.5 second on and 4.5 seconds off.

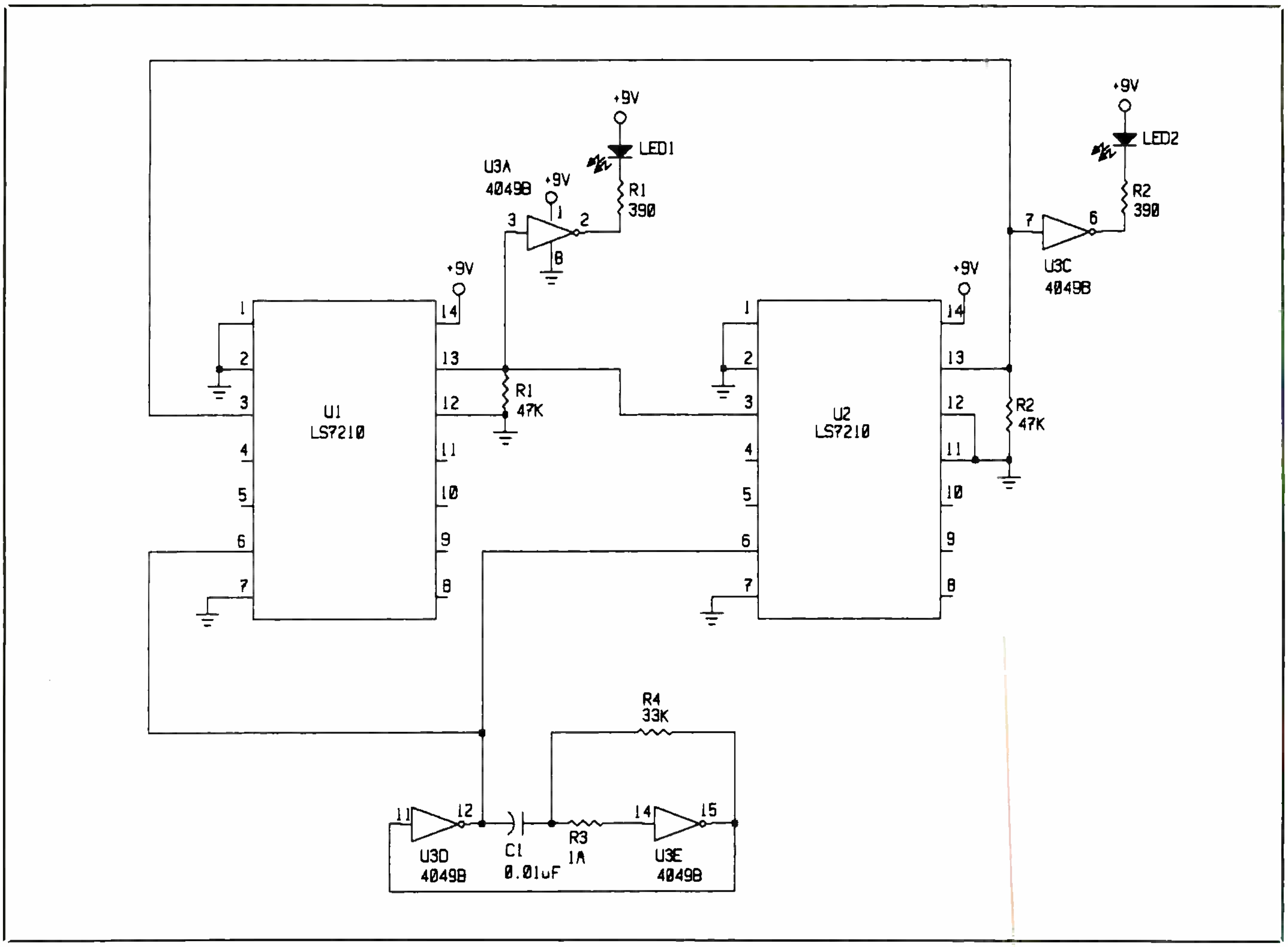


Fig. 7. Two timers cause LED1 and LED2 to light in timed sequence. An external clock is provided at pin 6 of each LS7210 timer chip.

IC2, which now turns on *LED2*. After 30 seconds, *LED2* turns off and *IC1* again turns on *LED1*. The two LEDs continue to alternate on and off in this way.

The LEDs make it easy to observe what is happening at the outputs of the timers. You can also control other devices with the outputs that drive the LEDs. To time more than two events in sequence, additional timers can be added to the chain. To change the "on" time of any timer output, vary the weightings at pins 8 through 12 for the associated chip. Alternatively, change the value of *R4* or *C1* to change the clock frequency of both timers.

A Watchdog Circuit

A so-called "watchdog" circuit that monitors a signal at its trigger input and operates a relay if any pulses are missed is shown schematically in Fig. 8. Here, pins 1 and 2 are grounded to put the LS7210 in one-shot mode. The trigger input at pin 3 is a 1-Hz square wave (such as that generated by the circuit in Fig. 5). The output pulse of the one-shot circuit is set to be slightly longer than the 1-second period of the trigger signal.

A high-to-low trigger at pin 3 causes pin 13 to go high immediately. This turns off transistor *Q1* and de-energizes relay *K1*. Pin 13 remains high for a little more than 1 second. Before the delay times out, another trigger pulse arrives, restarting the delay timing and preventing pin 13 from going low.

The circuit times out only if a trigger pulse is missed. The output then goes low and *Q1* causes the relay to switch. If the trigger signal reappears, the output turns on and the relay is deenergized again.

Time's Up Indicator

Our final circuit example, shown schematically in Fig. 9, is a "time's up" indicator that gives a warning after a user-selectable delay between

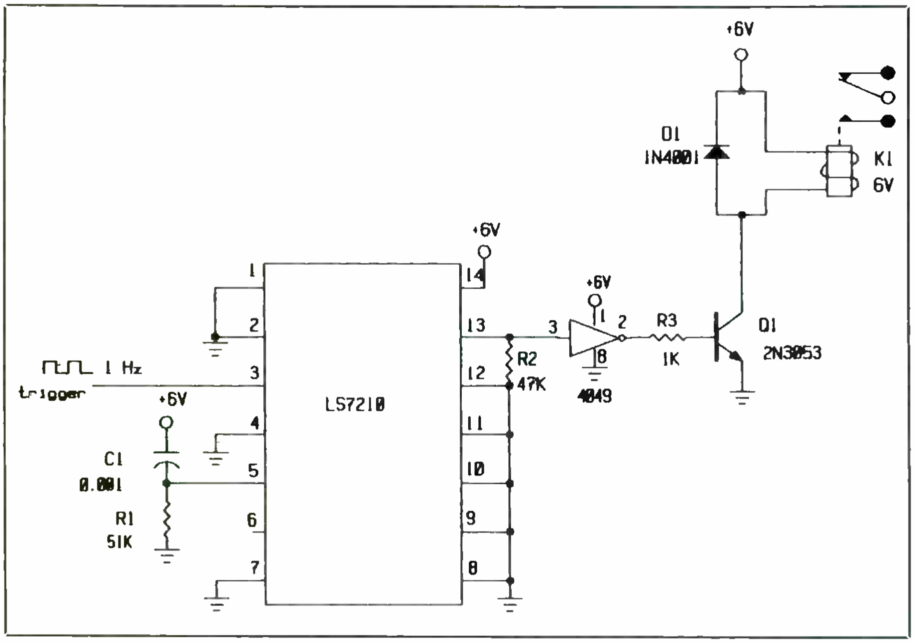


Fig. 8. "Watch-dog" circuit operates a relay when a trigger pulse is missed.

1 and 31 minutes. Pin 2 is grounded to select delayed-operate mode.

The weighting inputs for the Fig. 9 circuit are controlled by *S2* through *S6*, which can be toggle or slide switches, or even binary-coded-decimal thumbwheel switches. The output controls piezo buzzer *PB1*.

The values of *R1*, *R2* and *C1* provide a delay of 1 minute with a weighting of 1. Potentiometer *R2* provides a means of fine-tuning the delay time. When *S1* closes, the delay timing begins. Then when the delay times out, pin 13 goes high and turns on *PB1*. Opening *S1* turns off the buzzer.

To calibrate the time's-up timer, close *S2* and leave *S3* through *S6* open. Adjust *R2* so that the buzzer turns on one minute after closing *S1*.

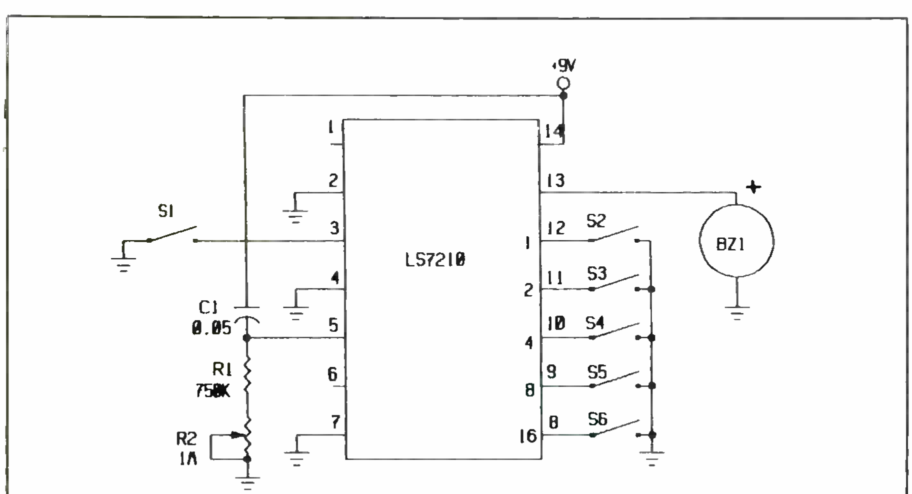
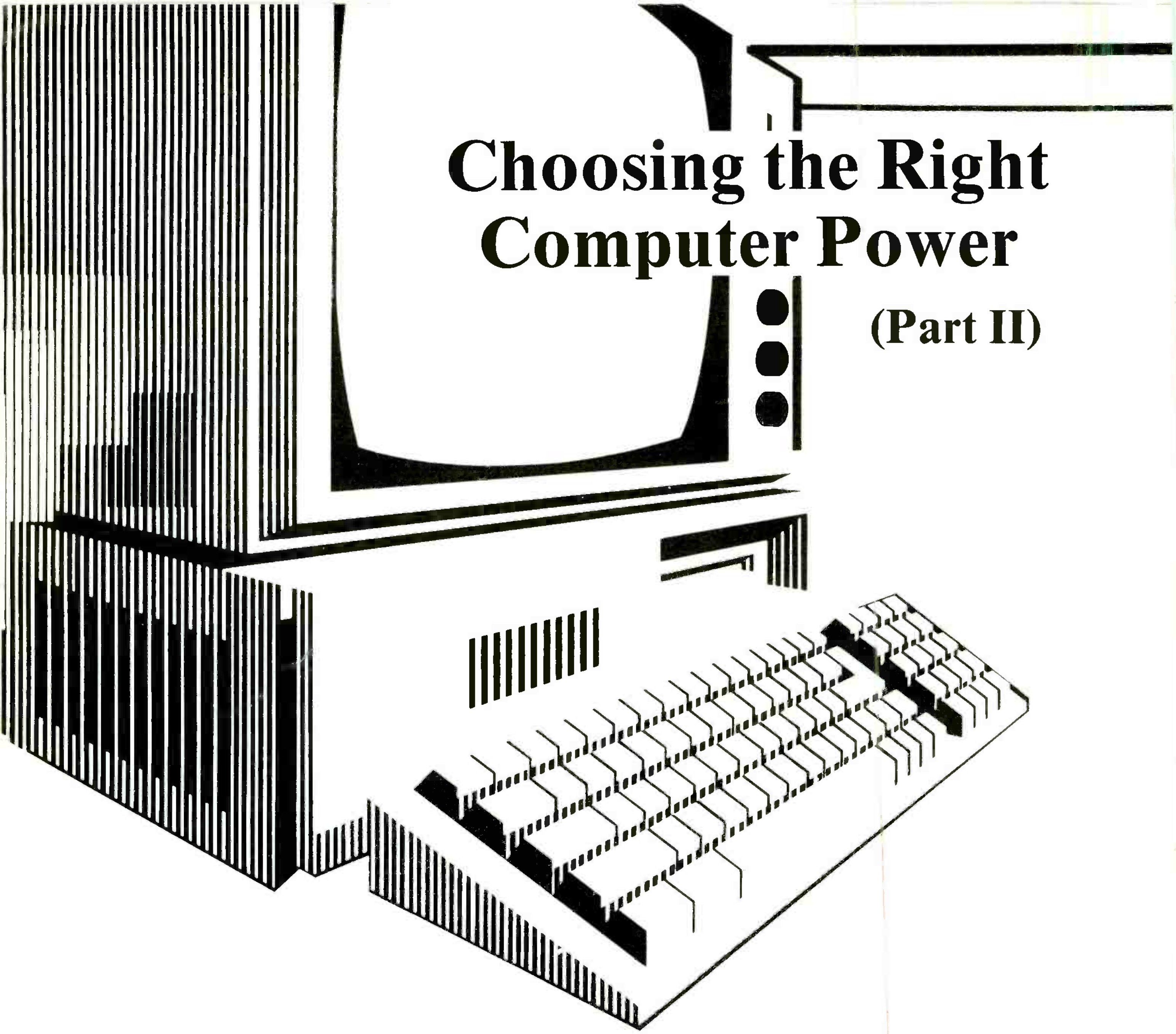


Fig. 9. This "time's-up" timer sounds a piezoelectric buzzer after a delay of 1 to 31 minutes, selected via S2 through S6.

To use the timer, set the weighting for the delay you need by closing the appropriate switches. For example, close *S3* and *S5* for a delay of 10 (2 + 8) minutes. Close *S1*, and 10 minutes later the buzzer will sound, warning you that the programmed time has elapsed. For a silent alarm, substitute a light-emitting diode and current-limiting resistor of appropriate value for the buzzer, as in Fig. 3.

Summing Up

We have covered here just a few examples of what you can do with the versatile LS7210 timer chip. From the foregoing, you can see that this is a relatively simple device to use in electronic timing applications. It is fairly inexpensive. So the next time you have a need for timing circuit, think beyond the usual 555 timer to the LS7210 timer to fill your needs.



Choosing the Right Computer Power

(Part II)

Beyond IBM and Compatibles: Apple Macintosh Series

By Joseph Desposito

In the first part of this article on personal computers, which appeared last month, we covered IBM and compatible PCs. Now we'll cover PCs produced by Apple Computer (Cupertino, CA), Commodore Business machines (West Chester, PA), and Atari Computer (Sunnyvale, CA).

A good starting point for describing a PC is its microprocessor. In the previous article on the IBM PC and compatible computers, we categorized the various models this way. This technique will be used to categorize the computers from Apple, Atari, and Commodore, with one big difference—there are no compatibles to worry about. All three companies have produced unique personal computers. Each may sell a variety of computers within one or more product lines, but there are no serious competitors with compatible models. For example, no one sells a computer that is compatible with the Apple Macintosh.

68000 Computers: Apple Macintosh Series

The Apple Macintosh

The most successful personal computer company selling non-IBM compatible computers is Apple Computer. Some 13 years ago, Apple started up in a garage with two Steves, Wozniak and Jobs, selling a personal computer board named the Apple I. A year later, they moved to a small building and produced a personal computer system, the Apple II. Although the company owes its success to the Apple II, and still sells a descendant of the original model, the Apple IIGS, which we will cover later, the Apple Macintosh computer has been its dominant line.

The Macintosh, or Mac, as it is commonly called, was the first personal computer to use Motorola's powerful 68000 microprocessor. The 68000's power enabled the Mac to use software with a graphic interface. A graphic interface is one that uses graphic elements such as icons (pictorial representations of computer peripherals or commands), pull-down menus, and windows to assist the user in communicating with the computer.

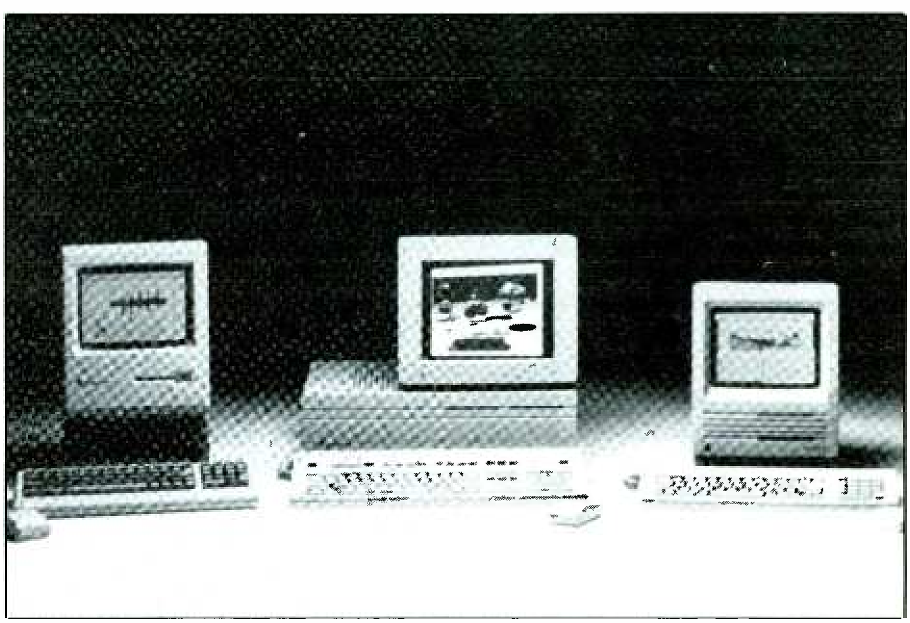
For example, instead of a user having to type: ERASE REPORT.DOC to erase a report from a disk, he would move an icon of the document —a picture of the report—to an icon of a garbage can. The icons and menus on the screen are generally controlled by moving and clicking buttons on a mouse, but they can also be controlled from the keyboard.

When it first appeared, the Macintosh was quite an innovative computer in both function and design. And as the years passed, Apple drastically improved the functionality of the Macintosh by increasing its power and changing its design. Now there is a whole line of Macintosh computers that range from the Macintosh Plus, which is a lot like the original Macintosh, to the Macintosh IIcx, which is very different hardware-wise, but still uses the familiar graphics interface of the original Mac.

Since everyone is interested in what's new, let's discuss the powerful Macintosh IIcx first. It's very unlike the original Mac. For starters, it has a modular design with separate computer system unit and video monitor, much as an IBM machine has. Moreover, a color display can be used. This contrasts with the integrated computer/monitor and black-and-white display of Mac models resembling the original model. The IIcx uses the Motorola 68030 microprocessor (a more powerful version of the 68000) running at 16 MHz. The IIcx, IIx and Macintosh SE/30, which are discussed later in this section, are only three microcomputers that use this chip. Also included as a standard feature is the 68882 math coprocessor.

The 68030 has separate 256-byte caches for data and instructions, plus a built-in Page Memory Management Unit (PMMU) used by multitasking operating systems such as A/UX, Apple's UNIX system. (For more information on the 68030, see "The Motorola 68030 Microprocessor" box.)

Unlike the original Macintosh, but similar to its predecessor, the Mac II, the IIcx contains NuBus expansion slots. (For an explanation of the NuBus, see the "A NuBus Primer" box.) There are only three of these slots, which means the IIcx has a footprint that is more like the original Mac than the Mac II (for more information, see the "Honey, They Shrunk the Mac II" box).



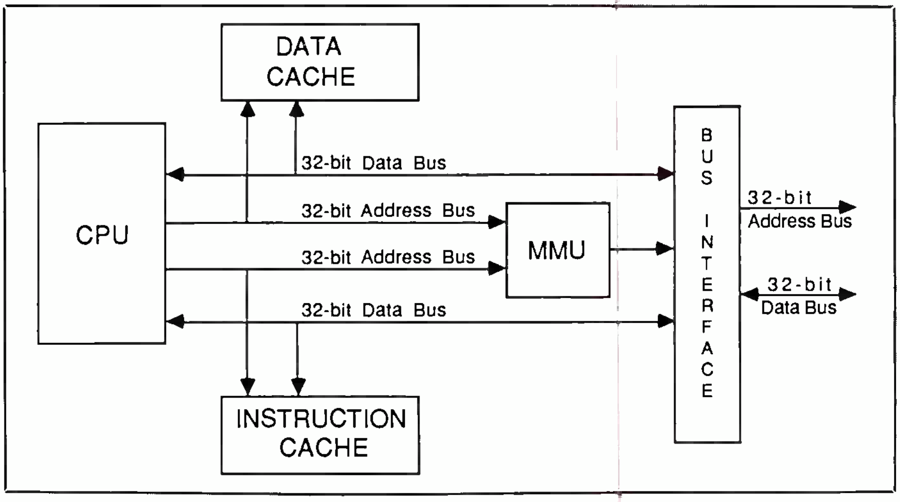
Apple's Macintosh 68000-microprocessor-based computers: the Mac Plus, II and SE, left to right.

Motorola's 68000-Series Microprocessors

The 68030 is the top-performance chip in a series of 32-bit microprocessors from Motorola, Inc. (Austin, TX). Motorola introduced its first 32-bit microprocessor, the 68000, in late 1979. It was the first microprocessor to feature a 32-bit internal architecture and, consequently, was the first to run software written for 32-bit machines.

In 1984, Motorola introduced the 68020, the first full 32-bit microprocessor. A full 32-bit processor is one whose essential data paths and processing elements (such as data buses, execution units and program counters) are all 32 bits wide. In contrast, the original 68000 is technically classified as a 16/32-bit microprocessor: its internal processing is 32 bits, while it employs 16-bit communications to external circuitry. Because the 68020's predecessor had 32-bit core architecture, the 68020 was able to build on the earlier chip's design with no loss of compatibility. Full 32-bit application programs developed for the 68000 could be used on 68020 systems immediately and without modification.

The Motorola 68020 can be considered to be competitive with Intel's 80386, though the latter is somewhat more powerful. The Motorola 68030, in turn, is reportedly somewhat more powerful that the 80386. Both companies have a new generation in the wings: the Motorola 68040 and the Intel 80486.



Internal details of the Motorola 68030 32-bit microprocessor.

The 68030, introduced in 1987, continues the evolution of the 68000 family. The 68030 inherits all the key features of the 68020 including a large general-purpose register set, on-chip instruction cache, pipelining, bit manipulation, and virtual machine capability. The 68030 also maintains complete compatibility with previous 68000-family processors.

A Closer Look at the 68030

In order to perform a computation, a microprocessor requires data and instructions. Data is the raw information that the processor manipulates; instructions are the elementary commands, issued by computer programs, that tell the processor what to do with the data. A typical instruction might move a data "word" from location X to location Y or add one datum to another. Millions of such tiny steps may be required to accomplish an ordinary computing task.

Conventionally, instructions and data words are fed to the processor one at a time from external storage devices such as random access memories (RAMs). The processor's execution unit (the hardware that actually carries out the calculation) receives first an in-

The IIcx base system, which has a suggested list price of $4,669, comes with 1 MB RAM (expandable to 8 MB) and 256K of ROM. The ROM features software, such as the Hierarchical File System and Color QuickDraw and drivers for Macintosh hard disk drives, the NuBus expansion slots, the Apple Desktop Bus (ADB), the 68882 coprocessor, SCSI (Small Computer Systems Interface) devices, and the AppleTalk network.

Also included with the base system is a 1.4-MB, 3.5-inch floppy-disk drive that Apple calls a SuperDrive. The drive gets this moniker from its ability to read and write MS-DOS, OS/2 and Apple II (ProDos) files when used with the Apple File Exchange program. (As you'll see later on in this article, the Commodore Amiga offers more complete compatibility with MS-DOS computers.)

Other standard features are a mouse, two RS-232/422 ports, two ADB ports (for keyboard and mouse or other devices such as a graphics tablet), SCSI, stereo audio port, and an external floppy disk drive port. Oddly enough, the keyboard is not a standard feature and must be purchased separately. (There are two types, the Apple Keyboard and the Apple Extended Keyboard.)

As far as software goes, the Mac IIcx come with System Software V. 6.0.3, which includes Apple File Exchange, and HyperCard. (System 7.0, a much more advanced Mac operating system that appears to be Apple's answer to IBM's OS/2 while retaining compatibility with earlier Mac systems, is expected soon.)

The IIcx SCSI port supports such peripherals as hard disks and Apple's struction and then a data word from memory, does a computation, and then awaits its next instruction and data.

This sequential, or "serial," loading of instructions and data constitutes a fundamental bottleneck in the computing process. No matter how fast a microprocessor becomes internally, it is still limited by the rate at which information can be piped in from external memory. The limitation is known as the "von Neumann bottleneck," named after computer pioneer John von Neumann, who first described this type of serial computer architecture.

For a number of years, advanced mainframe computer designs have been attempting to alleviate the von Neumann bottleneck, both by moving more functions onto the processor chip itself and by increasing the parallelism of computing—that is, the number of things a processor can do at once.

The 68030 employs both strategies. The chip is the first general-purpose microprocessor to feature built-in cache memories for instructions and data. Caches are small, fast memory arrays that give processors rapid access to frequently-used information. By placing these devices on the processor chip, the 68030 puts the data and instructions within easy reach of its execution unit.

Not only can the 68030 get instructions and data from its own built-in memory, but it can do so in parallel. Whereas conventional processors use a single pathway (bus) for all data and instructions, the 68030's caches are connected to the execution unit by separate buses. Rather than retrieving first an instruction then a datum one after the other, the 68030 can fetch both simultaneously. The 68030 is the first general-purpose microprocessor to employ an on-chip dual bus structure, known as Harvard-style architecture. Harvard architectures have been traditionally confined to special-purpose processors, mainframes and supercomputers.

A cache can only hold so much information and, as the 68030 progresses through a program, its caches must be periodically replenished with new blocks of data and instructions. These are loaded in from off-chip "main" memory devices, such as dynamic RAMs. The 68030 is able to refill its caches very rapidly by virtue of a new capability called Burst Fill. Burst Fill allows the 68030 to load a cache with four 32-bit data or instruction words in rapid succession, much faster than information is retrieved by ordinary processors. Overall, Burst Fill doubles the 68030's memory bandwidth (the rate at which information can be transmitted from external memories).

The 68030 also features a complete memory-management unit (MMU), which provides the software protection and virtual memory functions critical to many applications. Protection is necessary, for example, in multi-user, multitasking systems, where it keeps the various tasks from interfering with one another. Virtual memory is a scheme that enables the microprocessor to efficiently handle program and data structures larger than the main memory of the system. Programs and data are instead kept in secondary storage (such as hard or floppy disks) and portions of them are swapped into main memory (usually RAM) as needed.

Memory management hardware, under the control of the computer's operating system, manages the swapping and keeps track of the location of information in main and secondary memory. The 68030 uses a swapping method called paging. The 68030's MMU incorporates the basic features of Motorola's MC68851, a standard single-chip memory management chip used in conjunction with the 68020 microprocessor. (A block diagram of the 68030 is shown in the accompanying illustration.)

The Motorola 68000 family is widely used in computers outside the IBM and compatible machine world, including the Apple Macintosh, Sun Apollo and many other machines. Sun's powerful Model 3/470 workstation, for example, uses a 68030 rated at 33 MHz.

Laser-Writer IIsc, Scanner, and AppleCD SC CD-ROM drive. The SCSI port provides data transfer rates of up to 1 megabyte per second.

The model contains a custom digital sound chip that provides 8-bit stereo sampling at 44.1 kHz, and includes four-voice wave-table synthesis. The chip is capable of driving stereo headphones or other stereo equipment through the sound jack. Most of the systems described in this article come with custom sound chips, which you don't find in IBM and compatible computers.

The Macintosh IIcx can be expanded with more memory and either a 40- or 80-MB 3.5-in. hard disk drive. A IIcx system with 4 MB of RAM and an 80-MB hard-disk drive has a suggested retail price of $7,552.

One choice you must make with the IIcx is the type of monitor you will use. Apple manufactures several models, including the Apple High-Resolution Monochrome Monitor, AppleColor High-Resolution RGB Monitor, Apple Two-Page Monochrome Monitor, and Apple Macintosh Portrait Display. However, you may also choose a monitor manufactured by a third-party vendor. Keep in mind that whichever Apple monitor you choose, you must purchase a separate video display adapter card.

The Macintosh IIx is very similar to the Macintosh IIcx technically, but is 50 percent wider (see box). The main differences between the two models are in the number of expansion slots: the IIx has six, while the IIcx has three; and the size of the power supply: the IIx has 230 watts, while the IIcx has 90 watts.

Both the Macintosh IIcx and IIx

evolved from the Macintosh II, which used the older 68020 microprocessor running at 16 MHz and the 68881 math coprocessor. The 68020 processor lacks an on-chip PMMU, and instead works with a separate 68851 PMMU chip, which is an optional feature of the Mac II.

A computer that retains the elegant design of the original Macintosh is the Macintosh SE/30. The SE/30, like the IIcx and IIx computers, uses Motorola's 68030 microprocessor and 68882 math coprocessor, both running at 16 MHz. The base system, which contains 1 MB RAM and a 1.44-MB SuperDrive has a suggested list price of $4,369. An SE/30 with an added 40-MB internal hard disk drive sells for $4,869. Again, the keyboard is sold separately.

The major difference between a Macintosh SE/30 and either the IIx or IIcx is the lack of NuBus expansion slots. Instead, the SE/30 has a slot called an 030 direct slot. This slot supports expansion options such as video cards that support large grayscale and color monitors, and communications cards like Ethernet and Token Ring cards. The slot is accessed through an opening in the back of the computer rather than by removing the cover.

Standard features of the SE/30 include an integral high-resolution (512 by 342 pixels) 9-inch monochrome screen. This screen, made famous by the original Macintosh, is black-and-white monochrome. Other features are the Apple Sound Chip, 256K ROM, and seven built-in ports. System Software 6.0.3, MultiFinder, HyperCard and a mouse are also included with the system.

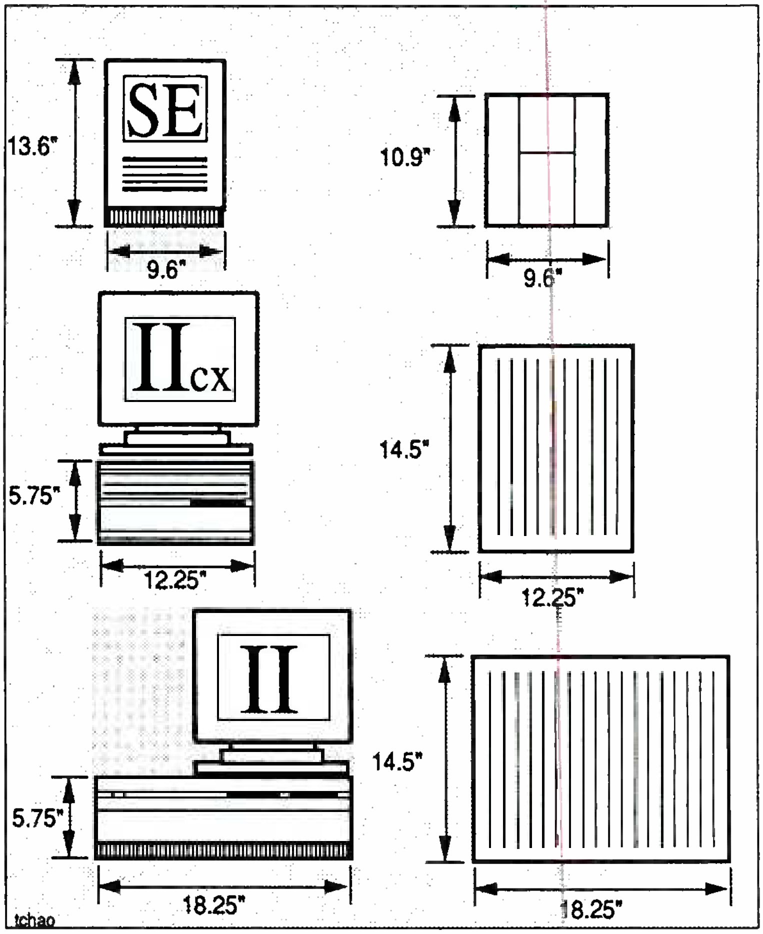
The SE/30 is the successor to the Macintosh SE, which uses a 68000 microprocessor running at 8 MHz. Like the SE/30, the SE has an expansion slot, but it isn't the equivalent of the SE/30's 030 direct slot. The latest SE model has 1.44-MB SuperDrives, permitting it to work with files from

Honey, They Shrunk the Mac II

When Apple Computer introduced the Macintosh personal computer back in 1984, one of its key features was its size. Much was made of the fact that the Mac's footprint was about the size of a standard 8½ × 11-inch sheet of paper. This was in sharp contrast to the IBM AT, whose footprint could engulf a good part of a desktop. Of course, with the AT's great size came the advantage of expandability through eight expansion slots and optional video displays (including color).

As the Macintosh increased in power and newer models were introduced, the unique style and size of the Macintosh was retained for a while. However, Apple broke with tradition when it introduced the Macintosh II. This Mac was the same size as an IBM AT! And similar to the AT, the Mac II could easily be expanded—it had six NuBus slots.

But the Macintosh II for all its expandability simply did not look like a Mac. Sure it acted like one once you turned it on, but there's no getting



Dimensions details for Macintosh series of Apple computers.

around the fact that it now looked like a typical IBM or compatible computer. Maybe that didn't sit well with Mac enthusiasts, and Apple heard about it, or maybe it is just a coincidence, but the latest Macintosh II computer, the IIcx, has been cut down to size—Macintosh size (see drawing). The Mac IIcx may lack the elegant style of the Mac SE/30, but it comes closer to its size while retaining advances such as color capability. It can be placed on its side, too, to fit a variety of work environments. And it still can be expanded—it has three NuBus expansion slots. Now at least, people won't confuse the Mac II with that bad old AT, even though the modular models can display color.

A NuBus Primer

The NuBus architecture used in the Macintosh II series of computers was created at the Massachusetts Institute of Technology and further developed by Texas Instruments. Thanks to its 32-bit architecture, the NuBus offers high performance; however, it is simple enough for manufacturers to design relatively inexpensive plug-in boards for it.

Plug-in boards for Mac II computers are similar to boards for IBM's PC AT—about 4 by 13 inches. A single 96-pin Eurocard Type-C connector is used for signal connection between the motherboard and plug-in boards.

NuBus devices are generally categorized as bus masters or slaves (see Fig. 1). NuBus masters can take control of the bus and initiate transactions with other devices. Examples are processors and DMA controllers. NuBus slaves cannot initiate transactions; instead, they respond to transactions initiated by NuBus masters. Examples are memory boards and simple I/O devices. Reads and writes are the only transactions that take place between NuBus devices.

Each expansion slot of the Macintosh IIcx, IIx, or II can hold both master and slave NuBus devices. An interrupt line in each slot can interrupt the host processor. Curiously enough, the motherboard, which contains the host processor and other chips (such as main memory), is itself a NuBus device capable of both master and slave functions. Thus the motherboard can be a NuBus master and control plug-in boards, or it can be a NuBus slave when plug-in boards function as bus masters to access main memory directly. The concept of the motherboard acting as a standard device on the NuBus is an important aspect of Macintosh-II-series architecture.

The NuBus is a synchronous bus—all transitions and signal samplings are synchronized to a central (10 MHz) system clock.

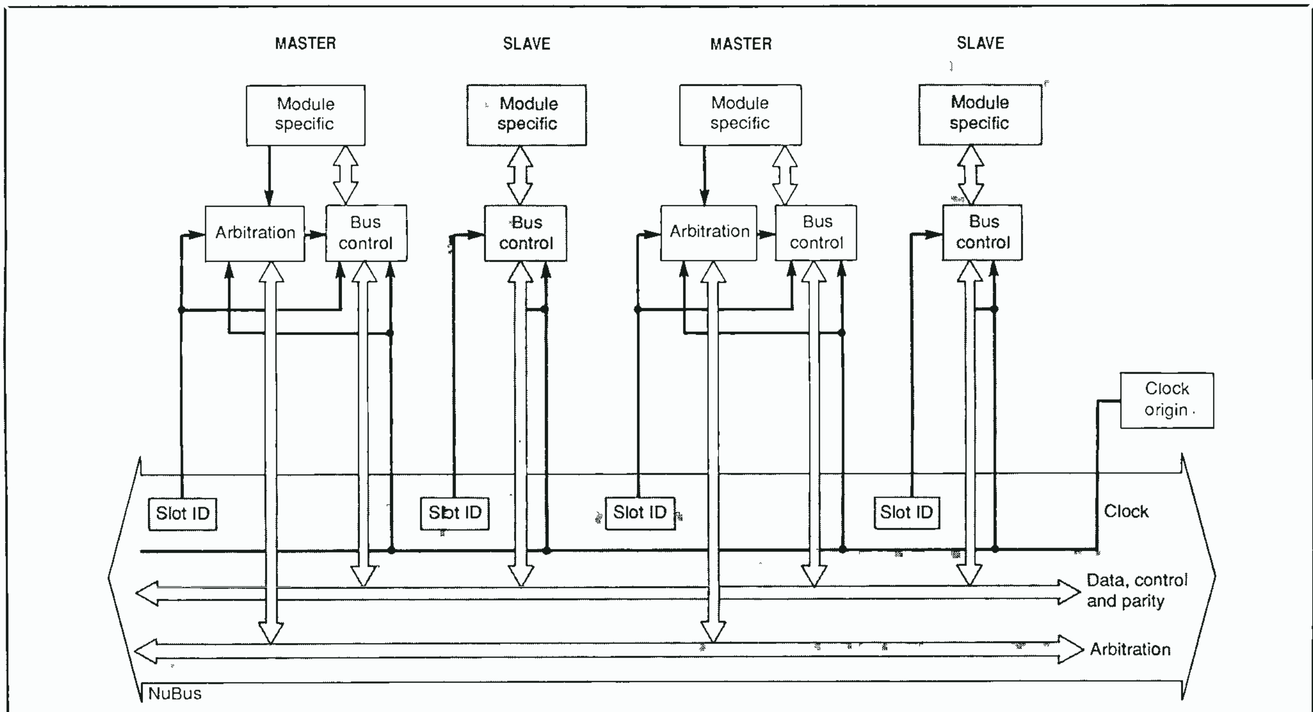
Data and address lines on the NuBus share the same signal lines. By multiplexing the signals only 51 signals, plus power and ground lines, are needed for a full 32-bit implementation.

According to NuBus arbitration protocol, any NuBus master device can request and obtain ownership of the bus to initiate data transfers with other devices. The arbitration is simple, fair, and distributed to each device in parallel. Therefore, when an arbitration conflict arises, it can be resolved while the current bus master is performing transactions. The next bus master then begins its operation right after the current bus master completes its transaction.

This scheme uses bus bandwidth in a highly efficient way. It allows full-speed data transfer between hardware subsystems even when those transfers are initiated by numerous independent bus masters.

Other multiprocessor features of NuBus are bus locking and resource locking. Using bus locking, a NuBus master can perform several successive data transfers without interruption from another NuBus master. A more sophisticated feature is resource locking. Using this feature, a bus master can perform successive transactions with a particular resource without that resource's local processor interfering. For example, a NuBus master can read or write a large

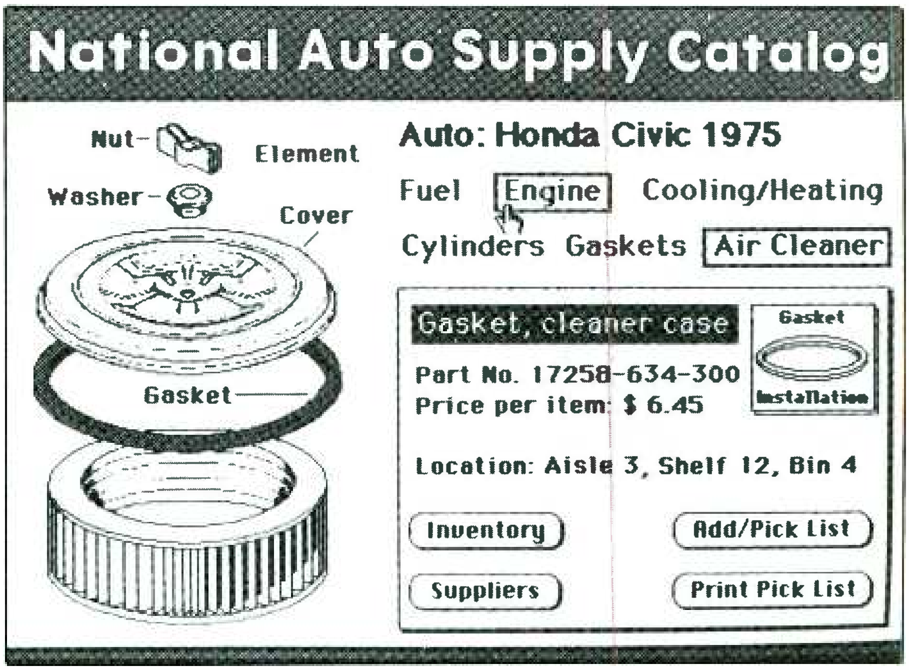
(Continued on page 82)



A NuBus system consists of masters and slaves that communicate with each other over the bus.

other operating systems, as previously cited.

Apple's entry-level model is the Macintosh Plus, a computer that very closely resembles the original Macintosh. It uses a 68000 microprocessor running at 8 MHz and contains 1 MB of RAM (expandable to 4 MB). Features include an 800K 3.5-inch floppy disk drive and an integral 9-inch high-resolution monochrome display. It has two RS-422 serial ports, an SCSI port, a mouse port, and a disk-drive port. Both mouse and keyboard come standard with the machine. The Mac Plus has four-voice sound with 8-bit digital/analog conversion using 22-kilohertz sampling rate. There is an audio jack on the rear panel of the computer.



This auto supply display screen illustrates complete integration of text and graphics featured in one of Apple's HyperCard information applications for Macintosh computers.

Pros and Cons Of the Macintosh

All Macintosh computers are excellent general-purpose computers. However, they are particularly good for applications such as desktop publishing. Since all Macintosh applications use a graphics interface (and there is an abundance of these applications), Mac users need as much power as they can get (or afford). The Macintosh II line offers power and NuBus expandability. The Macintosh SE line offers just as much power and an elegant design, but expandability is limited. If you just want to get your Macintosh feet wet, the Macintosh Plus is a fine choice.

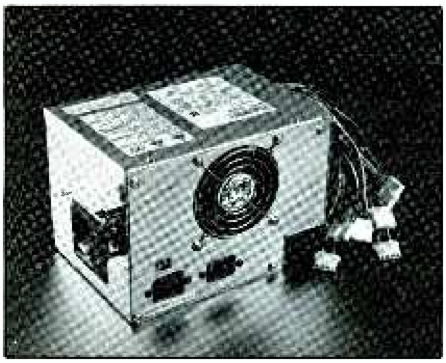
One of the best reasons for buying any Macintosh computer is the abundance of software applications and hardware peripherals that work with it. Software programs such as Microsoft's Excel and Word are very powerful spreadsheet and word processing programs. Pagemaker from Aldus is a top-notch desktop publishing program. Peripherals such as large-screen monitors, scanners and PostScript laser printers enhance the power of the Macintosh.

On the down side, the Macintosh is not the standard for business computing—IBM and compatible computers own that distinction. If all the computers in a particular company follow the IBM standard, the Mac will not be software or hardware compatible. The best you can hope for is file compatibility—if you have a Macintosh with a SuperDrive. You should think about the compatibility problem, too, if you are considering a home purchase because of work you do in the office. It doesn't make too much sense to buy a Macintosh for home use if you're using an IBM or compatible computer in the office.

Coming Next Month

This concludes the second of the three installments that make up this series. Next month, we will finish up with offerings from Atari and Commodore and Apple's 6500-microprocessor series series. **ME**

NEW PRODUCTS • • • *(from page 14)*

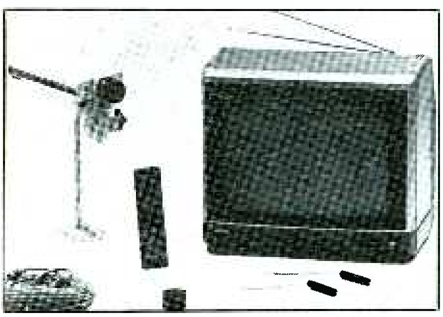


FC 5300 delivers the same currents at +5, −5 and −12 volts as the Model FC 5250 but ups current delivery at +12 volts to 12 amperes. The Model FC 5375 delivers 25 amperes maximum at +5 volts, 20 amperes at +12 volts and 0.5 ampere each at −5 and −12 volts.

CIRCLE 77 ON FREE INFORMATION CARD

Video Rear-View "Mirror"

Philips Consumer Electronics Co., under its Magnavox brand name, has developed electronic rear-view "mirrors" for owners of motor homes and boats. The Model MC4049RV01 combines a 152-channel, cable-ready 13" color TV receiver/monitor with



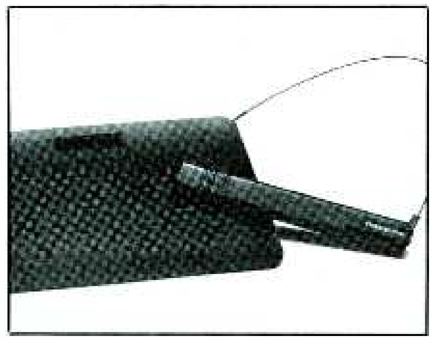
the microprocessor-controlled ability to switch automatically from television operation to rear-view observation, via a color video camera, of the vehicle in which it is installed.

The color camera provided with the system has a built-in microphone and can be used in low-light (3-lux) situations, including moonlight. A 4.8-mm lens and 57-foot coaxial cable are also included. The TV receiver/monitor features an 18-button infrared remote-control transmitter. The system retails for $949.95. A less-expensive system (the Model MC3613RV01, $449.95) offers a 5" black-and-white monitor and camera, the latter also usable down to 3 lux, and 57 feet of coaxial cable. With this system, the buyer has a choice of 4.8- or 8-mm lens for the camera.

CIRCLE 76 ON FREE INFORMATION CARD

(Continued on page 79)

Counterfeit Bill Checkers



With a growing number of bogus currency bills in circulation (over $1-billion a year is reported to be fraudulently printed), merchants and even consumers need some means to tell the real from the counterfeit. Two electronic products that have recently come on the market may be the answer to this problem.

One such product is the Visatector Counterfeit Currency Detector from Visatect Enterprises, Inc. (New York, NY). This device uses a simple two-step test to detect the magnetic particles that are embedded on the front of all legitimate U.S. paper currency. It's said to also detect counterfeiting of travelers checks and most foreign currencies

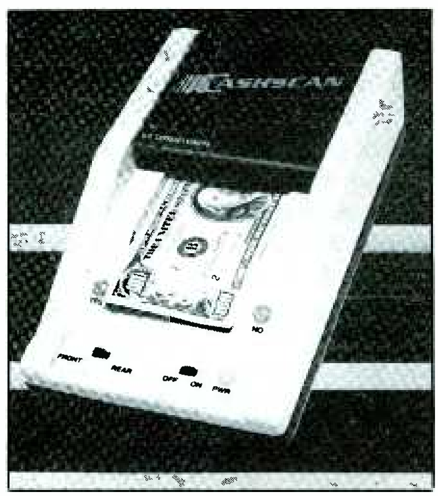
To use the Visatector, one just places the bill in question on a soft padded surface or an optional Visatector Security Pad. The head of the pencil-like scanning unit is then rapidly rubbed back and forth on portions of the bill while the user is pressing the thumb button on the unit. In the first test, the area under the portrait is rubbed, while in the second test the section on which the seal is printed is rubbed. Indicators at the top of the scanning unit and a tone signify whether a bill is genuine or counterfeit.

The Visatector is small enough to clip into a pocket. The optional Visatector Security Pad has a padded surface and includes a flexible steel security cord that easily attaches to the clip on the scanning unit. The Security Pad area measures 7" × 5". $99.99 for Detector; $19.95 for Pad.

CIRCLE 79 ON FREE INFORMATION CARD

"Cashscan" is the name of the other counterfeit bill detector. This one is from Edwin Products (Bayside, NY) and its operation is automated. Cashscan is an automatic detection system that can detect even sophisticated forgeries that the Visatector might miss.

In operation, Cashscan tells the user with a flash of a red or green indicator and by audible tone whether a bill is genuine or not. Cashscan has a built-in microprocessor that intelligently manages the detection and indication functions. It can be operated on either battery or 117/220 volts ac and comes with an ac adapter. $240.

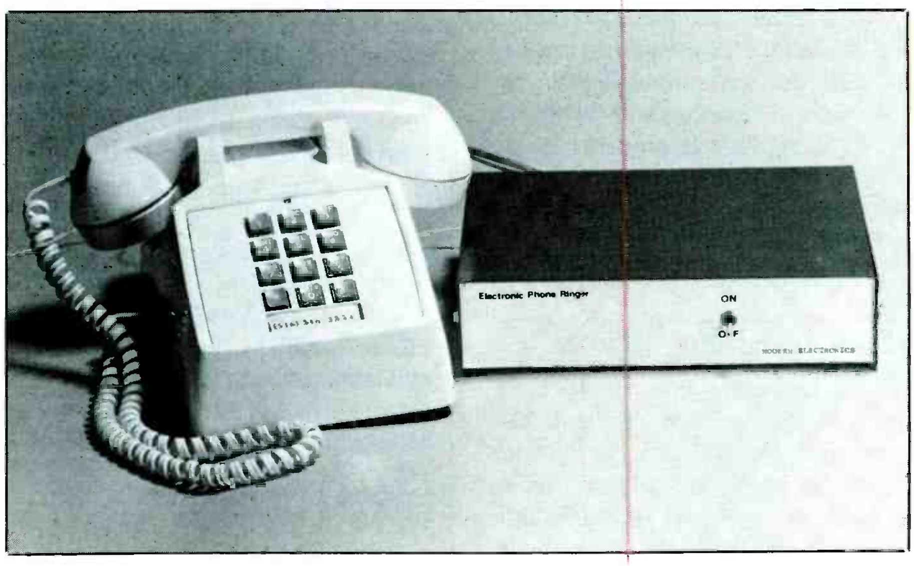


CIRCLE 78 ON FREE INFORMATION CARD

A High-Tech Telephone Ringer

Accessory sounds a more attention-getting, yet pleasant-sounding British-style phone signaling sequence to alert you to an incoming call

By Steve Sokolowski



To get one's immediate attention, telephone instrument makers build into their products electromechanical bells or transducers that sound like a "chirping-bird". Though effective attention-getter devices, these can often be irritating to the ear. A more-pleasant and just as effective attention getter is the warble tone that is generated by the High Tech Telephone Ringer described here. In addition to providing a less-irritating tone, this incorporates the distinctive characteristics of the British-style signaling system. Thus, instead of generating the 2 seconds of ringing followed by 3 seconds of silence in the standard pattern used in this country, our Ringer generates two short ring bursts followed by 4 seconds of silence.

This project is relatively low in cost to build. When built as described, it conforms to existing FCC Rules and Regulations regarding customer-installed telephone accessories. The only modification required for the instrument with which the Ringer is used is to defeat whatever audible alerting device is used inside it.

About the Circuit

Shown in Fig. 1 is a block diagram of the High-Tech Telephone Ringer circuitry. As you can see, the circuit is built around just five integrated circuits and two optical isolators (*IC4* and *IC5*). The complete schematic of the circuitry is shown in Fig. 2.

When power is supplied to to the circuit from a 12-volt dc wall transformer (*T1* in Fig. 2), separate sections of *IC1*, wired in three free-running oscillator configurations, go into oscillation. Inverters *IC1C* and *IC1D* make up a low-frequency generator that operates at approximately 12 Hz. Similarly, the *IC1F/IC1E* and *IC1A/IC1B* inverter pairs make up oscillators that operate at 287 and 335 Hz, respectively. Regardless of whether or not the telephone instrument is being used, these three oscillators will continuously develop the three signals described.

The secret of producing pleasant-sounding audio tones lies in the manner in which the three basic oscillator frequencies are digitally mixed by quad two-input Schmitt-trigger NAND gate *IC2*. Once combined, the now-continuous warble tone is present at pin 11 of *IC2C*.

To shape the Ringer's output signal into the desired form, three of the four elements inside bilateral switch *IC3* are wired in series with each other. With the combined audio signal from pin 11 of *IC2C* connected to pin 1 of *IC3*, you can very easily shape and control the output signal at pin 11 of *IC3* to drive crystal transducer *XTAL*.

To create the British-style telephone ring signal, a low-frequency "clock" is needed to generate a series of positive-going pulses. By using diodes, you can extract pulses capable of producing the required control signal at pin 12 of *IC3*. This clock signal is obtained at pin 6 of *IC1C*. This signal is not usable as is because, at 12 pulses per second (pps), the frequen-

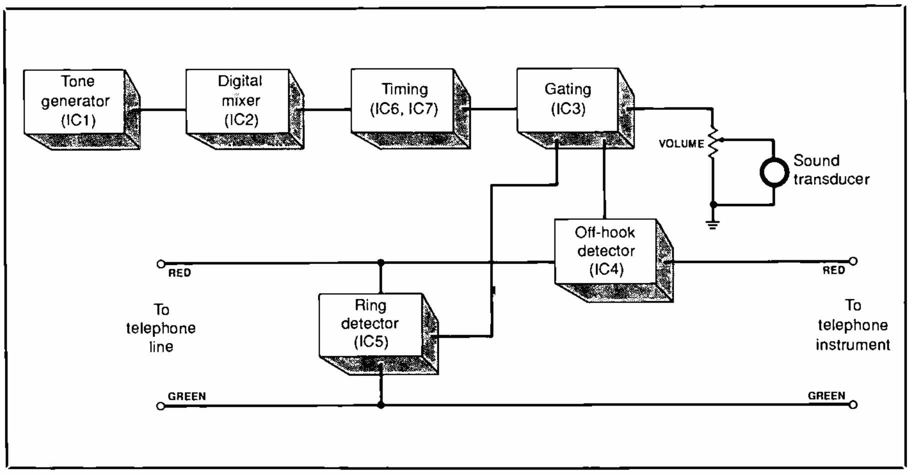


Fig. 1. Block diagram of circuitry used in the High-Tech Telephone Ringer. Five ICs and two optical isolators (IC4 and IC5) are the main elements in this circuit.

cy is too high. Therefore, it is passed through 12-stage binary ripple counter *IC6* to create a more desirable timing signal with a repetition rate of 3 pps. This 3-pps signal can be viewed with an oscilloscope by touching the input probe to pin 3 of *IC6*.

Having obtained a 3-pps clock signal, it must be converted into positive-going single voltage outputs. This task is accomplished with *IC7*, a divide-by-10 counter with a 1-of-10 positive output. Thus, for every clock pulse delivered to input pin 14 of *IC7* from output pin 7 of *IC6*, *IC7* outputs one positive pulse at one of its 10 output pins. This occurs until the tenth pulse is received, at which time the process repeats.

By connecting diodes *D3* and *D4* to pins 2 and 7, respectively, of *IC7* as shown, the British-style telephone ring signal is simulated by allowing the clock pulse to deliver a positive-going pulse to control pin 12 of one of the solid-state switches in *IC3*. This positive pulse instructs *IC3* to "close" the switch located between pins 10 and 11. Whatever signal is present on input pin 10 will then flow to output pin 11.

For illustration purposes only, let us assume that the two additional switches located between pins 1 and 2 and pins 3 and 4 of *IC3* are not connected at this time.

With the second clock pulse delivered to the input of *IC7*, this 4017 chip returns pin 2, which had the positive control signal on it, to ground potential. With the control signal now on pin 4, the signal that was previously delivered to pin 14 of *IC3* is gone. Without this pulse, the warble tone is prevented from passing to the output of the switch and on to the crystal transducer. This will be the case only until the third pulse is received.

Upon being received, the third pulse causes a positive signal to appear at pin 7 of *IC7*. The voltage is now delivered through *D4* to the same control pin of *IC3*. This instructs the internal switch to close until the fourth pulse is received. Seeing no other connections are made to pin 12 of *IC3*, the fourth through tenth pulses will generate no audio output from the project. In effect, the ringer is turned on for the duration of these clock pulses.

The above remains so until the eleventh pulse arrives. When it does, *IC7* cycles back to its starting condition, where a positive pulse is delivered to pin 2 of *IC7*. The switching process repeats continuously.

Figure 3 illustrates the gating pulse that appears during the timing procedure. With every peak shown, a warble tone is delivered to output pin 11 of *IC3*. The pulse train illustrated here is for the British-style ringer.

For the project to operate properly, a second control signal must be developed to deliver a positive-going pulse to pin 5 of *IC3* every time an incoming call is being received. This is easily accomplished with *IC5*. This optical isolator detects the ring signal that appears on the telephone line to signal an incoming call. It maintains maximum isolation between the telephone line and circuitry that makes up the High-Tech Telephone Ringer to satisfy the requirements of existing FCC Rules and Regulations regarding customer-installed telephone apparatus.

The voltage delivered by the central office of the telephone company to activate a device to signal an incoming call is about 90 volts ac at a frequency of 20 or 30 Hz. This voltage is applied across pins 1 and 2 of the LED contained inside *IC5*. Capacitor *C6* permits passage of only ac signals and blocks dc components. If this capacitor were not present, the dc voltage on the telephone line would keep the LED inside the opto-isolator on all the time and would render the project useless.

Resistor *R12* reduces the 90-volt ac ring signal to a level that can easily be handled by the LED inside *IC5*. Across pins 4 and 5 of this optical isolator is a light-sensitive transistor that operates as an electronic switch. The transistor conducts a current when the LED is on. When the transistor does conduct, it brings the voltage that was previously present on pin 5 of *IC5* to ground level. This ground signal is then applied to input pins 8 and 9 of Schmitt-trigger NAND gate *IC2D*.

Use of a Schmitt-trigger device that has snap-action operation for *IC2D* is needed to prevent the slow discharge voltage of *C7* from enter-

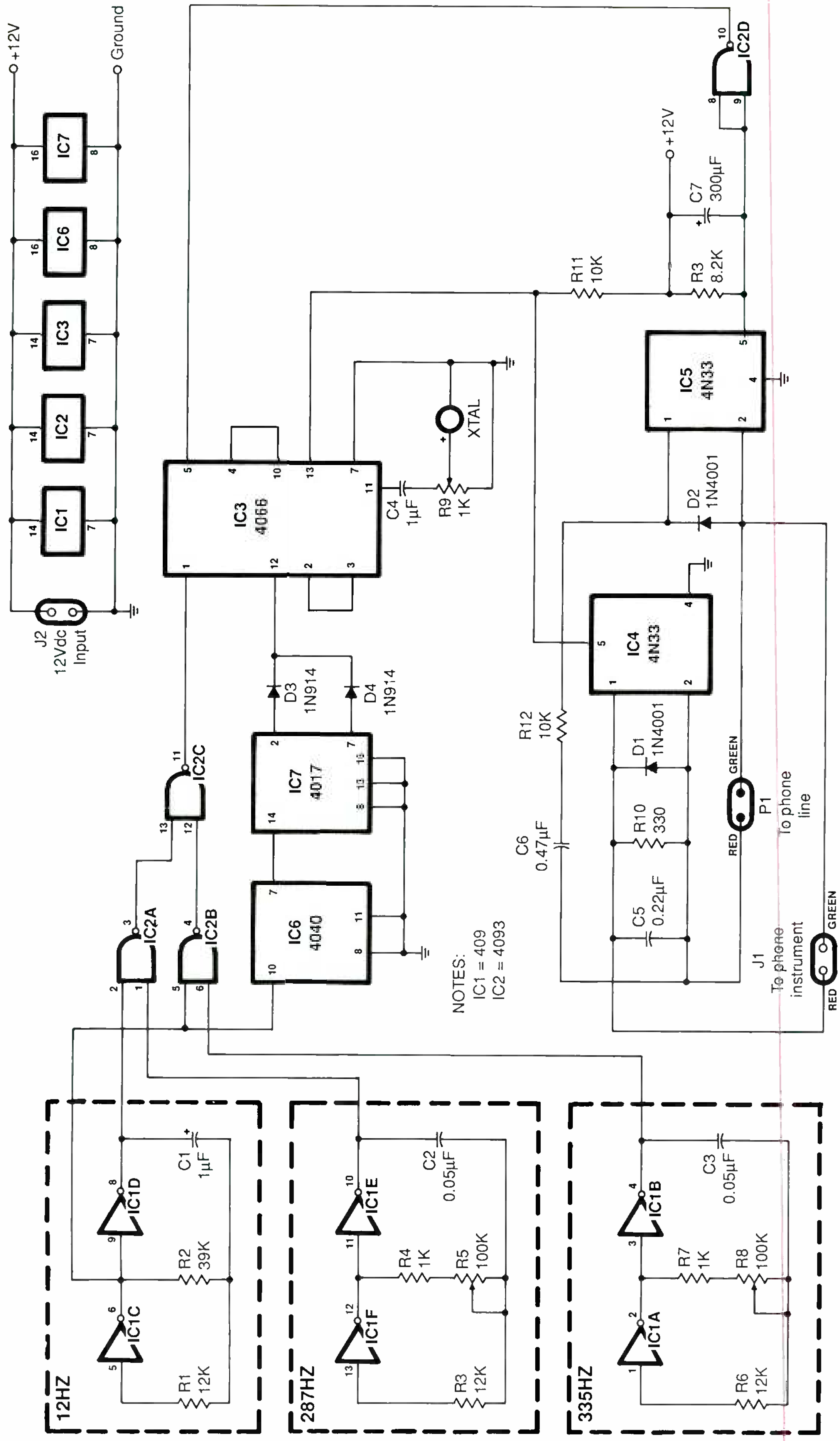


Fig. 2. Complete schematic diagram of the basic circuitry. All that need be added to this circuit is a commonly available plug-in wall-type dc power supply.

PARTS LIST

Semiconductors

D1,D2—1N4001 or similar silicon rectifier diode

D3,D4—1N914 or similar silicon switching diode

IC1—CD4069 hex inverter

IC2—CD4093 quad 2-input Schmitt-Trigger NAND gate

IC3—CD4066 quad bilateral switch

IC4,IC5—4N33 optical isolator

IC6—CD4040 12-stage binary ripple counter

IC7—CD4017 divide-by-10 counter with 1-of-10 outputs

Capacitors

C1—1-μF, 16-volt electrolytic with radial leads

C2,C3—0.05-μF ceramic disc

C4—1-μF, 50-volt electrolytic with radial leads

C5—0.22-μF, 100-volt ceramic disc

C6—0.47-μF, 250-volt tubular with axial leads

C7—330-μF, 16-volt electrolytic with radial leads

Resistors (¼-watt, 5% tolerance)

R1,R3,R6—12,000 ohms

R2—39,000 ohms

R4,R7—1,000 ohms

R10—330 ohms

R11,R12—10,000 ohms

R13—8,200 ohms

R5,R8—100,000-ohm, pc-mount trimmer potentiometer (Digi-Key Cat. No. K4A15 or similar)

R9—1,000-ohm, panel-mount, audio-taper potentiometer

Miscellaneous

J1—Telephone jack (see text)

J2—Jack to match plug-in wall-type power supply

P1—Telephone plug (see text)

XTAL—High-impedance crystal transducer (see text)

Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware; suitable enclosure (see text); telephone cord (see text); control knob for R9; machine hardware; hookup wire; solder; etc.

Note: The following items are available from Del-Phone Industries, P.O. Box 5835, Spring Hill, FL 34606: Printed-circuit board, $12; crystal sound element, $1.50; 6-ft., 6-conductor telephone line cord with spade lugs, $1.75. Add $2.50 P&H. Florida residents, please add state sales tax.

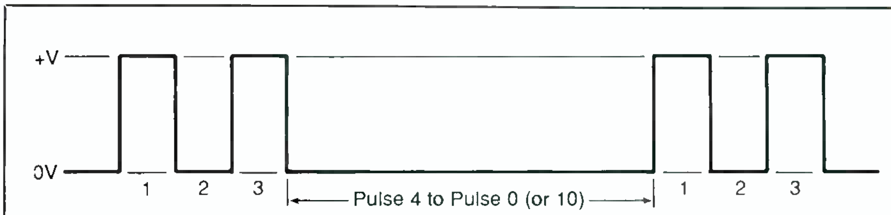


Fig. 3. Gating pulse that appears during timing period. Every peak represents a warble tone generated.

ing *IC3*. Otherwise, this discharging voltage will adversely affect operation of the circuit by allowing the tone output to be loud when the capacitor is first charged and then slowly decrease in volume during the off cycle of the incoming signal.

Even with the problems caused by using *C7*, this capacitor is still needed. It keeps the output of *IC5* low while the ring signal across the telephone line is in its 3-second-off cycle. That is, the capacitor produces, with the help of Schmitt-trigger NAND gate *IC2D*, a positive-going control signal from the time the first incoming ring signal is detected until the call is answered or terminated. This signal is then applied to pin 5 of *IC3*.

When the signal is applied to pin 5 of *IC3*, a British-style ring is being controlled at *IC3* and a positive voltage is being generated every time a call is incoming. With these two control signals, there remains one small problem. That is, when a call is coming in, *C7* charges up, the action for which develops a control signal that is being applied to *IC3*. At this time, if the telephone handset is lifted, the Ringer will still generate an audio signal until *C7* discharges sufficiently to overcome the snap action of *IC2D*, which may take 4 to 5 seconds.

To compensate for the shutoff delay, another optical isolator, *IC4*, is used as an off-hook detector. When the phone is taken off-hook, the LED inside *IC4* lights and sends the internal transistor into conduction. This causes pin 13 of *IC3* to go to ground level. When this control pin is grounded by lifting the handset off the hook, the electronic switch between pins 1 and 2 of *IC3* ceases to conduct and disconnects the Ringer circuitry from the crystal transducer.

Replacing the handset on-hook causes the LED inside *IC4* to extinguish and, thus, the internal transistor to cut off. When this occurs, the ground potential that was previously on pin 5 of *IC4* goes high. With a positive signal at this point, control pin 13 of *IC3* instructs the chip to close its associated switch.

With the switch located between pins 1 and 2 of *IC4* closed, all that remains is to have a positive signal applied to pin 5 of *IC3* from *IC5* for the project to operate as desired.

Power consumption of the circuitry is modest at only 100 milliamperes. A standard 12-volt dc, 200-milliampere plug-in wall power supply makes an ideal power source for the project.

Construction

There is nothing critical about component layout and lead routing. Therefore, you can use any method of wiring that pleases you. You can fabricate a printed-circuit board using the actual-size etching-and-drilling guide shown in Fig. 4 or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. Alternatively, you can mount the components on perforated board that has holes on 0.1-inch centers using Wire Wrap or soldering hardware and the point-to-point wiring technique. Whichever way you go, though, it is a good idea to use sockets for the DIP ICs.

From here on, we will assume you are assembling your project on a printed-circuit board. Place the ready-to-wire board in front of you oriented as shown in Fig. 5. Begin wiring it by installing and soldering into place the IC sockets. Do *not* install the sockets until after you have checked out the project and are certain that is correctly wired. Install and solder into place the two jumpers shown, using insulated hookup wire.

After the sockets are in place, install and solder into place the resistors and pc-mount trimmer controls. Then follow with the capacitors and diodes. Make sure the electrolytic capacitors and diodes are properly oriented before soldering any of their leads to the copper pads on the bottom of the board.

Strip ¼ inch of insulation from both ends of four 5-inch-long hookup wires. If you are using stranded hookup wire, tightly twist together the fine conductors at all ends and sparingly tin with solder. Plug one end of these wires into the holes labeled R9, +12V and GROUND and solder them into place.

Carefully check the top of the circuit-board assembly to make sure all components are mounted in their correct locations and and those that are polarity sensitive are properly oriented. Turn over the assembly and check all soldering. Solder any connections you missed and reflow the solder on any that appear to be suspicious. If you locate any solder bridges, especially between the closely spaced IC socket pads, clear them with desoldering braid or a vacuum-type desoldering tool.

Now prepare the enclosure in which the project will be housed. You can use any type of enclosure that will accommodate the circuit-board assembly, VOLUME control *R9* and various jacks. Machine the enclosure by drilling mounting holes for all components and exit holes for the sound from the crystal transducer. All holes, except those for mounting the circuit-board assembly, should be drilled or cut in the rear panel of the selected enclosure.

You have two choices for the connections between the telephone line and project and project and telephone instrument(s) with which it is to be used. One is to mount modular jacks on the rear panel of the enclosure and use separate cables terminated in appropriate connectors for the two connections. The alternative is to cut in half a single 12-foot or longer telephone cable with a modular plug on one end and fitted with a modular jack adapter on the other end and wire the cable halves directly to the circuit-board assembly.

Should you decide to go the latter route, drill separate entry holes for the two cables through the rear panel. If you are using a metal enclosure, deburr the holes and line them with rubber grommets. Then feed the cut ends of the cable through their

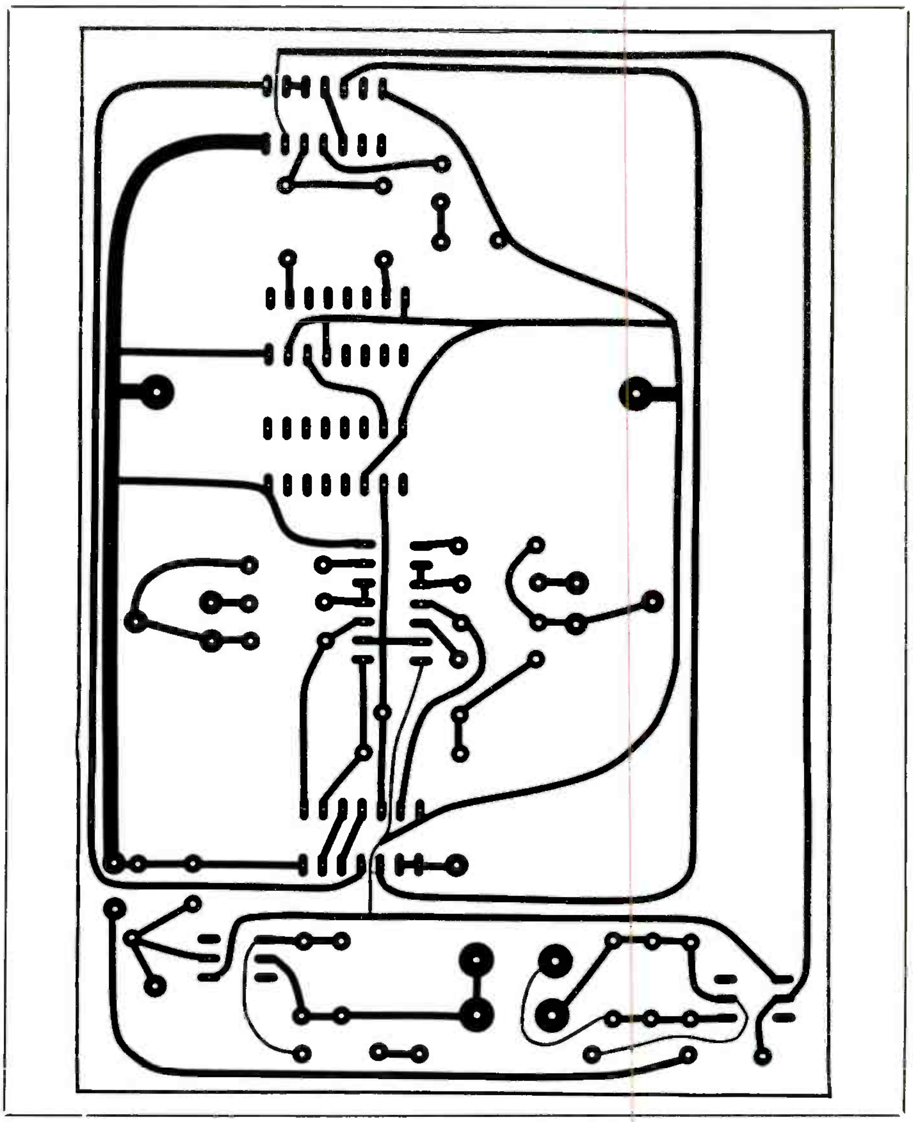


Fig. 4. Actual-size etching-and-drilling guide for fabricating project's single-sided printed-circuit board.

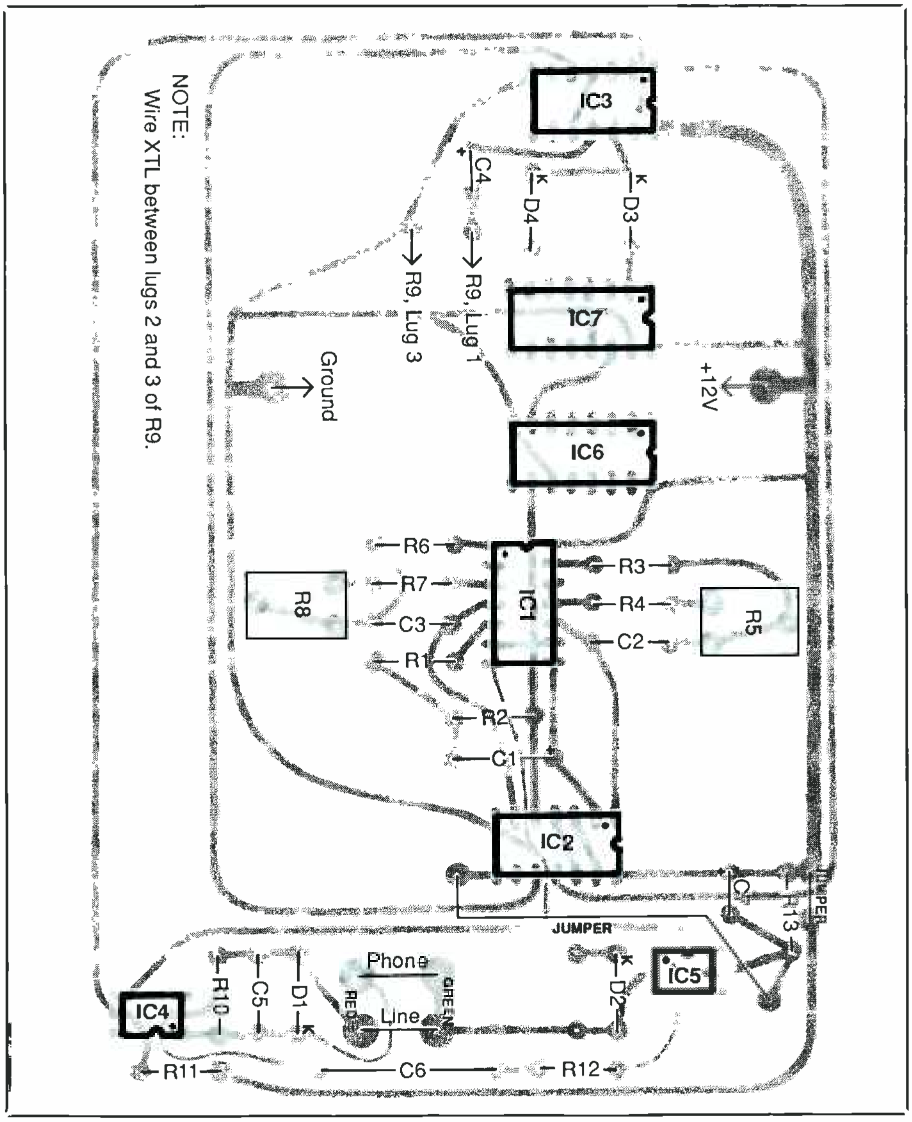


Fig. 5. Wiring guide for pc board. Use this as rough guide for positioning components when wiring on perforated board.

separate holes, and tie a strain-relieving knot in each about 5 inches from the end inside the enclosure.

Carefully remove 1½ inch of outer plastic jacket from both cables and strip ¼ inch of insulation from the two exposed conductors. (Note: If there are more than two conductors in the cable, strip the insulation from only those with red and green insulation on them and clip the remaining conductors back to the cut-off plastic jacket. Tightly twist together the fine wires in each conductor and sparingly tin with solder.)

Plug the prepared conductors into the holes for them in the circuit-board assembly (observe color coding according to which cable is to go where) and solder into place. Then place on the other end of the cable that is to go to the telephone instrument(s) with which the project is to be used a male-to-female adapter.

If you are using the panel-mount connectors, simply mount the connectors in their respective cutouts and wire them to the circuit-board assembly. Again, make certain you observe proper color coding, and label the connectors with the legends TO TELEPHONE LINE and TO TELEPHONE INSTRUMENT accordingly.

Mount the circuit-board assembly in place with ½-inch spacers and 4-40 × ¾-inch machine screws, nuts and lockwashers. Mount the power jacks and potentiometer in their respective holes in the rear panel. Run a bead of fast-setting epoxy cement or silicone adhesive around the perimeter of the crystal sound transducer (this can be salvaged from an old telephone instrument or purchased from a surplus-parts outlet) and press this into place on the enclosure panel through which the holes for allowing the sound to escape were drilled. Allow the cement or adhesive to fully set.

Viewing the rear-panel-mounted VOLUME control from the rear, crimp and solder one lead from the crystal transducer to the center lug and crimp but do not solder the other lead to the lug on the right. Locate the wires coming from the R9 holes in the circuit-board assembly. Crimp and solder the free end of the wire coming from the lower hole to the right lug of the VOLUME control and solder the three-way connection. Then crimp and solder the other wire to the left lug of the control.

Taking care to observe proper polarity, crimp and solder the free ends of the wires coming from the +12V and GROUND holes to the lugs of the power jack. Except for installation of the integrated circuits in their sockets, this completes construction of the High-Tech Telephone Ringer. You can now proceed to checkout.

Checkout & Installation

Before you plug any ICs into the sockets, connect the 12-volt dc plug-in wall power supply to the project via its jack on the rear panel. Clip the common lead of a dc voltmeter or multimeter set to the dc-volts function to a convenient circuit-ground point, such as the right lug of *R9*. Plug the power supply into an ac outlet and touch the "hot" probe of the meter to pin 14 of the *IC1*, *IC2* and *IC3* sockets and pin 16 of the *IC6* and *IC7* sockets. In all cases, you should obtain a reading of approximately +12 volts.

If you do not obtain the proper reading at any one or more of these points on the circuit-board assembly, use the meter to ascertain that the power supply is wired into the circuit in the correct polarity. If so, remove power from the project and rectify the problem before proceeding.

Once you are certain that the project has been wired correctly, power it down and install the ICs and optical isolators in their respective sockets. Make certain that the proper IC goes into each socket and that it is properly oriented. As you push each IC and optoisolator home, make certain that no pins overhang the socket or fold under between IC and socket.

To provide an audio output from your High-Tech Telephone Ringer for testing and adjustment purposes, place a temporary jumper between pins 4 and 5 of *IC5* and power up the project. If everything is okay, you will hear some sort of tone from the crystal sound transducer.

If a frequency counter is available, clip its common or ground lead to the right lug of the VOLUME control and touch its "signal" lead to pin 10 of *IC1*. You should obtain a reading of approximately 287 Hz at this point. If not, use a small screwdriver to adjust trimmer control *R5* until the displayed frequency is 287 Hz.

Move the "signal" lead of the counter to pin 4 of *IC1* and observe the display. If you do not obtain a reading of 335 Hz, adjust the setting of trimmer control *R8* until you do obtain this reading. Note that the final oscillator, which uses *IC1C* and *IC1D* operates at a fixed 12 Hz and has no frequency-adjust control.

If no frequency counter is available, adjustment of the two oscillator frequency controls can be attempted. All you do under this condition is to adjust both trimmer controls until you hear the most pleasing tone from the crystal sound transducer.

After you have tuned the oscillators, power down the project and remove and discard the temporary wire jumper.

Now decide upon which telephone instrument to which you will connect your High-Tech Telephone Ringer. This instrument can have either a rotary or a tone dial. It can be a premium ITT model or a low-cost import. The only internal wiring that must be made is to an ITT or similar make phone. These premium instruments contain a single- or double-gong type bell, while imports contain an inexpensive tone-type ringer. The modification to be explained prevents the bells or tone generators inside the telephone instrument from sounding when an incoming call is signaled.

Imported and other low-cost telephone instruments generally have built in switches that permit the user to switch in and out the "ringer." For these instruments, all you need do is set the switch to its "off" position. Once this is done, you can simply connect the project between your telephone instrument and the incoming line from the telephone company.

With more expensive ITT and AT&T telephone instruments, the modification is more involved. The first thing you must do is remove the housing from the instrument. If you are working on a desktop phone, turn over the instrument and locate and back off on the two screws that secure the housing to the base plate.

With the housing removed, locate the mechanical telephone ringer. This ringer can have either two or four wires connected to the coil of the bells. Color coding for four-wire ringers is red, black, slate/red and slate/black, as in Fig. 6(A). A two-wire bell, such as the 148BA ringer found in 200 and 2200 style desk and wall phones, has the simple color coding of red and black, as in Fig.

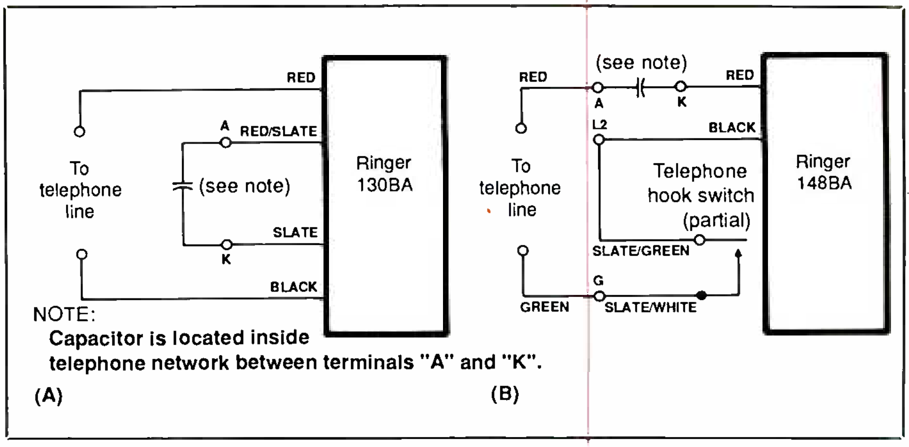


Fig. 6. Color coding for four-wire ringers (A) is red, black, slate/red and slate/black, while for two-wire ringers (B), it is simply red and black.

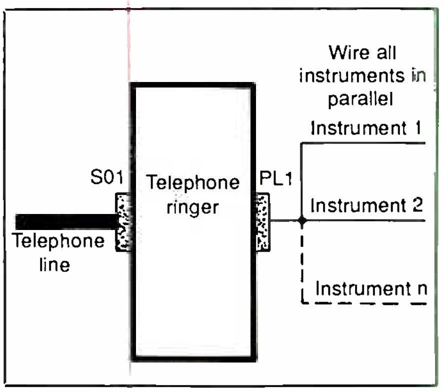


Fig. 7. Details for connecting project into multiple-instrument installations.

6(B). Do not confuse the bell's red-insulated wire for the red-insulated conductor of the telephone line; these are two completely different things.

Whether you have a two- or a four-wire telephone ringer, simply disconnect any of the bell wires (make a note of the point from which you remove it for future restoration of this function should you wish it) and use electrical tape to insulate the spade lug on the end of the wire to prevent unwanted short circuiting once the phone is reassembled.

Connect the project into your telephone system, between the incoming telephone line and your modified instrument. If you are installing this project in an older system that does not have modular connectors, substitute suitable adapter cables for the standard modular types where needed. Then plug the power supply into a conveniently located ac receptacle.

Should you wish to use the High-Tech Telephone Ringer in a system containing two or more telephone instruments, you can do so. As Fig. 7 illustrates, all you need do is wire all instruments in parallel with each other and plug them into the TO TELEPHONE INSTRUMENT jack or cable. When performing the wiring for this type of installation, make sure you observe proper color coding.

The final step in installation is to try out the project under real operating conditions. To do this, have a relative or friend call you. When the call comes in, you should hear the warble tone from the crystal sound transducer in the project. At this time, adjust the VOLUME control on the rear panel for a comfortable but attention-getting listening level.

Lifting the receiver off the hook should immediately silence the warble tone. At this point, you can conduct normal conversation over the telephone network. When you complete your call, simply hang up the handset. The High-Tech Telephone Ringer automatically rearms itself to wait for the next incoming call. ME

ELECTRONICS NOTEBOOK

More on How to Detect Ultraviolet, Visible Light and Infrared

By Forrest M. Mims III

This is the second of two columns on the detection of ultraviolet, visible and infrared radiation. Last month, I described various kinds of thermal detectors for these wavelengths of the electromagnetic spectrum. This month, we'll be looking at the most important kinds of photodetectors.

Photodetectors

Thermal detectors detect light indirectly by the temperature increase that is produced when the detector is illuminated. Photodetectors detect light directly by the photoelectric effect. Therefore, most photodetectors are more sensitive and have faster response times than most thermal detectors.

There are three major classes of photodetectors: photoemissive, photovoltaic and photoconductive. Photoemissive detectors include phototubes and photomultiplier tubes. Photovoltaic and photoconductive detectors are semiconductor devices. While semiconductor detectors are by far the most common, you should be aware of the basic operating principles of photoemissive detectors.

Photoemissive Detectors

If you know what a phototube or photomultiplier tube is, then you know what a photoemissive detector is. These detectors consist of an evacuated or gas-filled glass envelope that contains a light-sensitive *photocathode* and an electron-collecting anode. The photocathode is a metal electrode that is coated with a thin layer of material that emits electrons when it is exposed to light.

Two common photocathode materials for the visible spectrum are silver-oxygen-cesium and cesium-antimony. Cesium-telluride and other materials are used for detection of ultraviolet energy.

Some of the more commonly used photocathode materials have been assigned "S" numbers for convenient identification. Figure 1 is a graph that shows the sensitivities of several important S surfaces across the ultraviolet, visible-light and near-infrared spectra.

The simplest phototube detectors have only two electrodes—a photocathode and an anode. A phototube can be made by coating a wire electrode with a photocathode material and enclosing the wire, along with a similar uncoated wire, in a thin glass tube. Larger photocathodes are usually used since they provide more light-collection area. For example, the photocathode of the miniature phototube shown in Fig. 2 is formed by coating the inside half of a cylinder with cesium-telluride. This particular drawing of a phototube is of a Hamamatsu (P.O. Box 6910, Bridgewater, NJ 08807-0910) Model R1826 that I am using to measure the ultraviolet radiation from the sun.

Photomultiplier tubes provide hundreds of times more sensitivity than do ordinary phototubes. The photomultiplier tube, or PMT, contains a series of electrodes called "dynodes." Each dynode is maintained at a potential that is slightly greater than that on the previous dynode. Light stimulates the photocathode of the PMT to release electrons, which strike the first dynode.

In a process called "secondary emission," the dynode emits about five electrons for each one it collects. The secondary electrons strike the second dynode, and the multiplication process is repeated. Since a typical PMT has as many as 10 dynodes, eventually hundreds or even thousands of electrons for each original electron strike the anode of the tube.

Photomultipliers are so sensitive that they can detect the arrival of a single photon. But this sensitivity comes at the price of high operating voltage, which is typically 1,000 to 2,500 volts. And since each dynode requires a different voltage, a low-current voltage divider made from a string of resistors is required. Finally, for

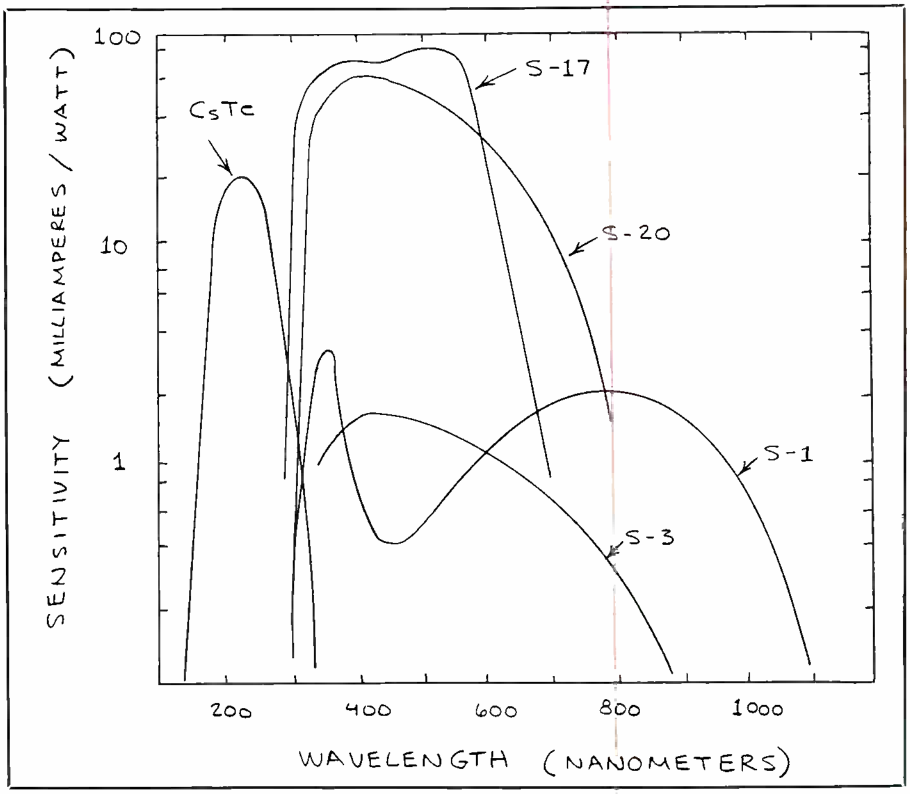


Fig. 1. Spectral responses of several photoemissive surfaces.

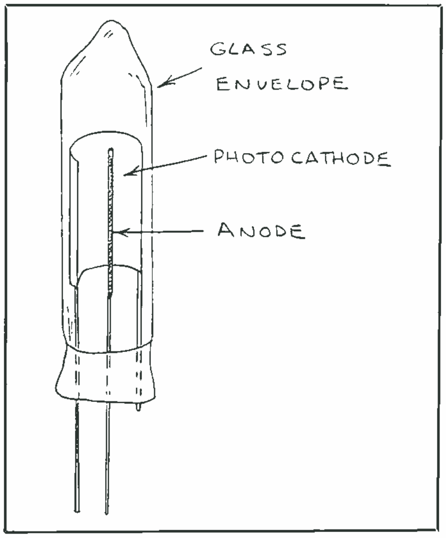


Fig. 2. Internal details of Hamamatsu R1826 ultraviolet phototube.

ultra-low noise operation, the PMT should be cooled.

Photoemissive Detector Applications

Semiconductor photodetectors have taken over in many applications where photoemissive detectors were once used. Nevertheless, phototubes and PMTs still have important uses. The various spectral sensitivities that are available make phototubes and PMTs especially useful for detecting specific bands of light.

As an example of the above, ultra-sensitive photodiodes are much more sensitive to red light than to ultraviolet radiation. This poses a difficult problem because interference filters designed to pass UV wavelengths tend to also pass some red light as well. This can be solved by using a phototube or PMT with a cesium-telluride photocathode that responds to only ultraviolet wavelengths.

PMTs are especially useful for detecting very-low light levels. That's why both amateur and professional astronomers use them to measure the light coming from faint stars. PMTs are also used to detect the flashes of light produced when radiation passes through certain plastics and crystals.

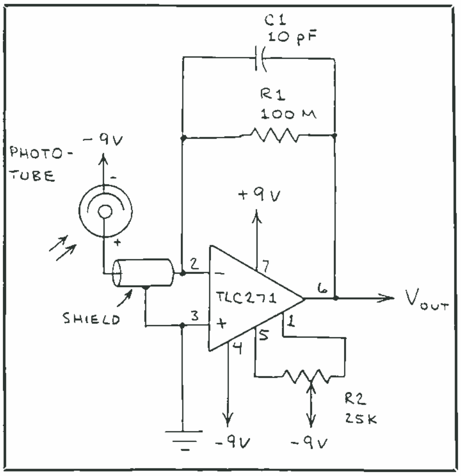


Fig. 3. Schematic diagram of a high-gain phototube amplifier.

Experimenting With Photoemissive Detectors

Shown in Fig. 3 is the schematic diagram of a circuit I've used to enable the R1826 phototube described above to detect ultraviolet energy from the sky and sun. The TLC271 CMOS op amp provides the extremely high input impedance required for this circuit to perform properly. However, you can substitute any other CMOS or FET-input op amp for the TLC271, making any pin changes that might be needed. Use a shielded cable between the phototube and op amp if the distance between the two exceeds several inches.

In the Fig. 3 circuit, *R2* controls the offset voltage in the circuit. The output can go to a digital voltmeter or, perhaps, a comparator that switches when the light on the phototube exceeds or drops below a preset threshold.

This circuit has plenty of gain. Its output is at a level of about 1 volt or so when the tube is exposed to blue sky on a clear day. The tube should *not* be exposed to direct sunlight. Otherwise, its performance and sensitivity may suffer degradation. Instead, first place the tube behind a UV filter, such as Schott UG-11 glass.

You can further reduce the intensity of direct sunlight with a diffuser made from quartz, silica or some material that is transparent to ultraviolet wavelengths. One or both surfaces of the diffuser should be ground to a rough finish.

You will also want to consider a photomultiplier tube if your application calls for detection of the light from a faint star, a firefly or a crystal that flashes when it is exposed to radioactivity. There are many kinds of PMTs available, each with a specific set of power-supply requirements.

Shown in Fig. 4 is a generalized connection diagram for a typical PMT. This circuit shows the voltage divider that delivers progressively greater voltages to the dynodes in the PMT. It is important that you use good wiring practices and properly insulated sockets when using PMTs. Manufacturers of photomultiplier tubes can supply specific connection and circuit information for their PMTs.

Semiconductor Photodetectors

The most common detectors of ultraviolet, visible-light and infrared radiation

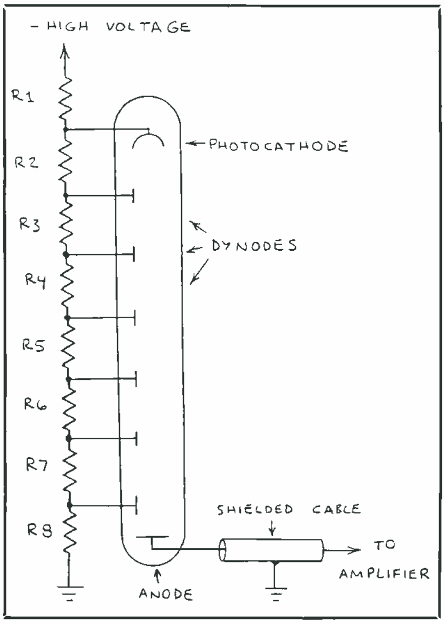


Fig. 4. Generalized connection circuit for a photomultiplier tube.

ELECTRONICS NOTEBOOK...

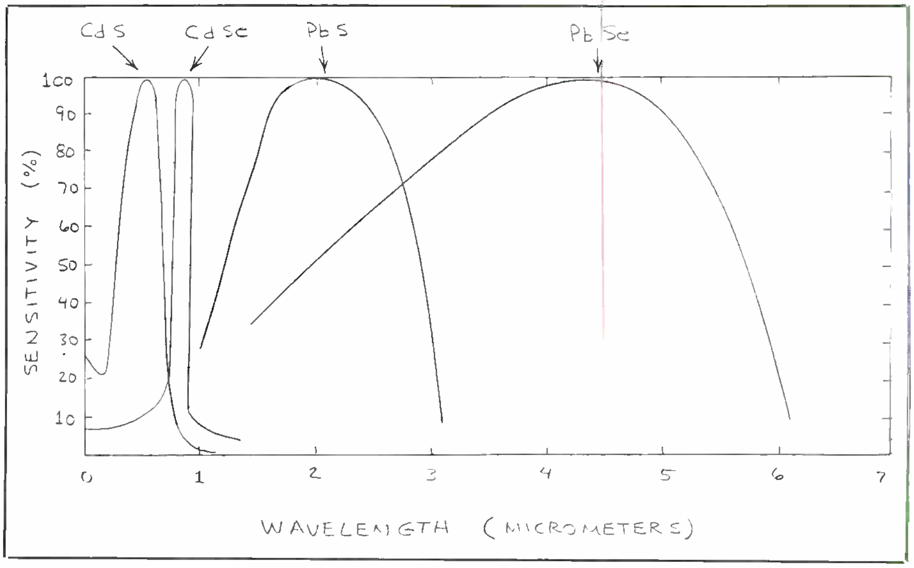


Fig. 5. Spectral sensitivites of several photoresistors.

are semiconductor photodetectors. These can be pn-junction devices like photodiodes and phototransistors, or they can be bulk devices like photoresistors. In either case, semiconductor photodetectors are physically smaller and more durable than photoemissive detectors.

• *Photoresistors.* Photoresistors are also known as light-dependent resistors (LDRs) and photocells (PCs). Since their resistance varies with the intensity of the light they intercept, photoresistors are "photoconductive" detectors. The resistance of a photoresistor is much higher when the device is dark than when it is being illuminated.

Photoresistors are made by applying electrodes to a thin film of photoresistive material. The electrodes are usually applied in a spiral or zig-zag pattern to increase the exposure of light-sensitive material.

The most common light-sensitive materials used in photoresistors are cadmium-sulfide (CdS) and cadmium-selenide (CdSe). The peak spectral response of some formulations of CdS closely matches that of the human eye—in the 550-to-555-nanometer range. The peak spectral response of CdSe ranges from 720 to 780 nanometers in the far red portion of the visible spectrum.

Lead-sulfide (PbS) and lead-selenide (PbSe) are used to make infrared-sensitive photoresistors. Cooling these detectors greatly increases their sensitivity. Figure 5 compares the spectral sensitivities of some of the most important photoresistor materials.

Photoresistors are easy to use and ex-

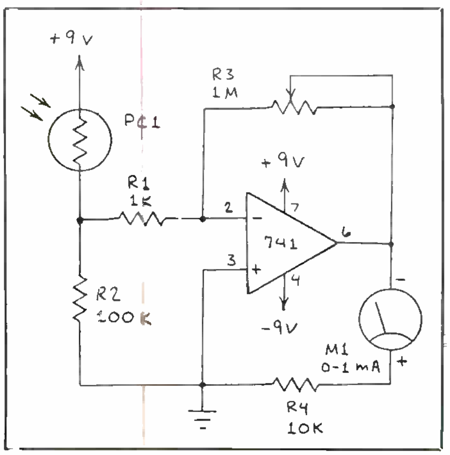


Fig. 6. Circuit details of a photoresistive light meter with gain stage.

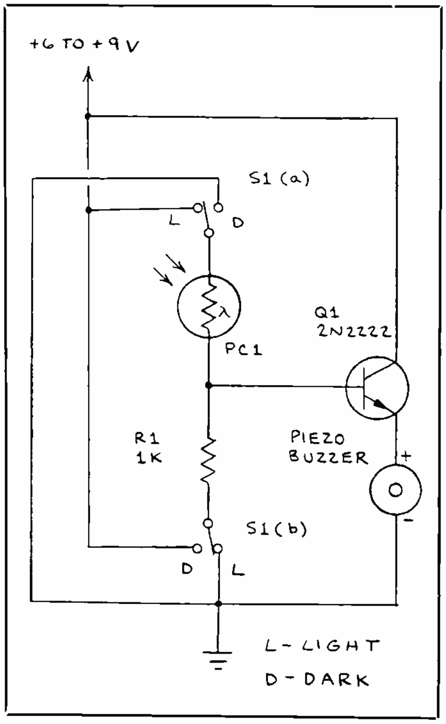


Fig. 7. Schematic diagram of a light/dark buzzer circuit.

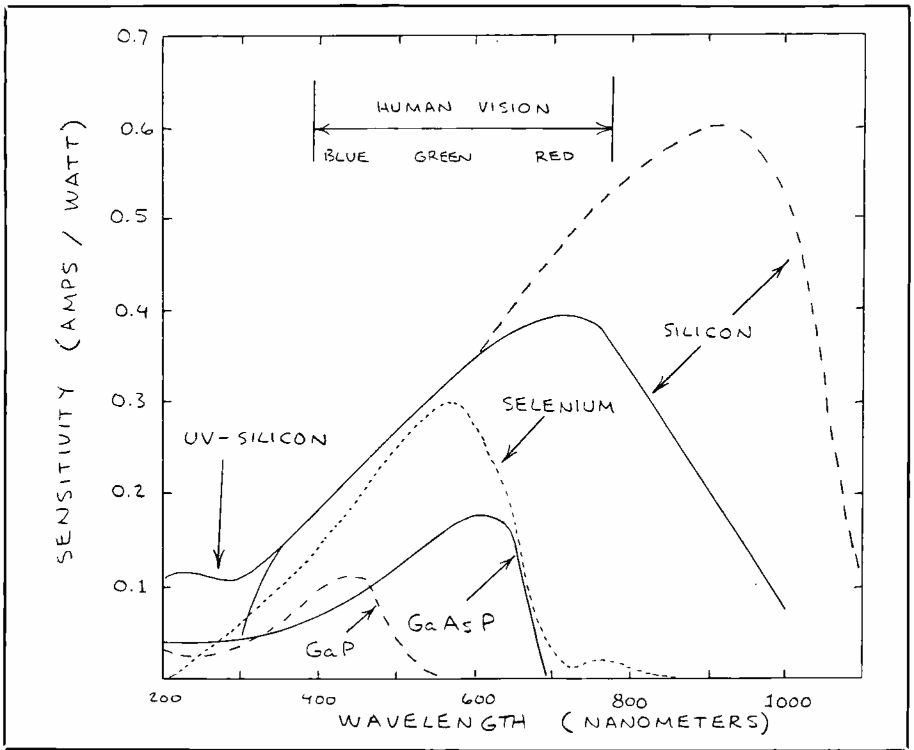


Fig. 8. Spectral responses of several photodiode materials.

ceptionally sensitive to light. However, their response time is much slower than that of junction semiconductor detectors. Also, photoresistors are subject to the "light history effect" in which the resistance of the device is dependent for a time upon the previous light level received by the detector.

You can make a sensitive light meter by connecting a photoresistor in series with a battery and milliammeter, as shown in Fig. 6. This circuit also shows how to increase the sensitivity of such a meter by adding a single op-amp gain stage. While the 741 op amp shown in the Fig. 6 schematic diagram will work, better-quality op amps with less offset voltage will work even better. A good choice is the OP-07 op amp.

Shown in Fig. 7 is the schematic diagram of a simple circuit that doubles as both a light and a dark detector. The circuit can be used to wake you when the sun comes up or warn you when your refrigerator door is ajar.

If you would like to know more about photoresistors, I refer you to my September 1988 "Electronics Notebook" column, in which I described these and several other applications. I also discussed in that column the operation of CdS and CdSe photoresistors in some detail.

• *Pn-Junction Detectors.* Virtually any semiconductor pn junction is sensitive to visible or infrared radiation. Bell Laboratories found this out when they encapsulated some of their early transistors in transparent plastic. Even light-emitting diodes can be used as light detectors.

Many kinds of semiconductor photodetectors are in common use, and many others have been developed by research laboratories. Some of them have a very small active surface area to make them suitable for detecting very fast optical pulses. Others are divided into two halves or four quadrants for use in position-sensing applications.

Position-sensitive detectors can also be made from single detector elements. These use what is called the "lateral effect" to detect the position of a light spot on the surface of the detector.

The spectral sensitivities of various pn-junction photodetectors are dependent on the semiconductor material from which they are manufactured. Figure 8 shows the spectral sensitivities of some of the semiconductor materials used to make junction photodetectors. Of course, silicon is the most common photodetector material currently in use.

The peak spectral response of silicon matches the peak emission wavelength of several kinds of light-emitting diodes. For applications in which infrared sensitivity is not desired, filters can be placed in front of a silicon detector, or a gallium-phosphide (GaP) photodiode can be used for ultraviolet and visible-blue wavelengths. Gallium-arsenide-phosphide (GaAsP) can be used for the UV through visible red wavelengths.

Any semiconductor pn-junction photodetector is, by definition, a photodiode. Therefore, even silicon photocells are photodiodes. The most important characteristic of photodiodes is that they produce an output current that is linear with respect to the light that strikes their active surfaces. Depending on the semiconductor material from which the photodiode is manufactured, linearity can range from around four to as many as ten decades of light-intensity variation.

Pn-junction detectors can be used in either a photovoltaic or photoconductive mode. Self-generating photodetectors, such as silicon photodiodes and solar cells, are commonly used in the photovoltaic mode. The detector is simply connected directly to the input of an operational amplifier, as shown in Fig. 9. The op amp then functions as a current-to-voltage (also known as transimpedance or transresistance) amplifier that boosts the detector's photocurrent.

Figure 10 shows two ways in which a junction detector can be connected in the photoconductive mode. In both methods, the detector connects to an external current source in the reverse direction. Light striking the active surface of the detector increases the current flow (photocurrent, or I_p) through the device.

The voltage-amplifier connection transforms the photocurrent into a voltage that is then amplified. In the current-amplifier (transresistance or transimpedance) mode, the photocurrent is boosted by an op amp and connected to a voltage-to-current amplifier.

The voltage-amplifier connection provides a convenient way of increasing the photodiode's sensitivity. Simply increase the resistance of load resistor R_L to increase sensitivity. The down side of this is that the resistor contributes noise and a bias current is required. Also, the response speed of the circuit is inversely proportional to the resistance of the series resistor. In other words, increasing the sensitivity by increasing the resistance of the load resistor slows down response time. This happens because R_L determines the time required for the internal capacitance of the photodiode to be discharged.

The transresistance or transimpedance arrangement has no load resistor to contribute noise or slow down response time.

The avalanche photodiode is the solid-state analog of the photomultiplier tube. These photodiodes are designed to be operated at a relatively high reverse-bias voltage that is just below the breakdown or avalanche potential of the diode. Incoming photons generate free electrons that permit a much greater current to flow than in a conventional photodiode. Gains of up to several hundred are possible.

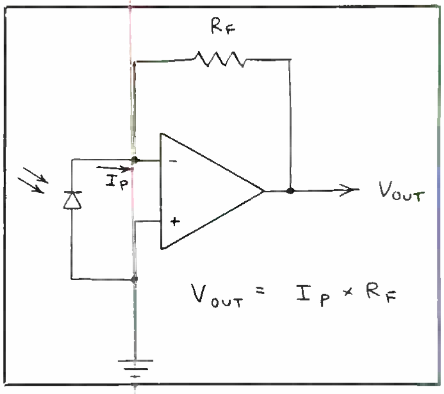


Fig. 9. Circuit details of photovoltaic operation of a photodiode.

While avalanche photodiodes provide exceptionally high sensitivity, they require a carefully regulated high-voltage power supply. They are also expensive.

Now that we've covered some photodiode basics, let's look at those photodetectors that are most important to electronics experimenters.

• *Selenium Cells.* selenium cells are large-area photodiodes with several important advantages and features. Their spectral response closely matches that of the human eye, they can be used as low-power solar photovoltaic cells, and they have good sensitivity in the blue and near-ultraviolet regions of the spectrum. It's easy to make selenium cells in various shapes and with holes. They can even be made in the shape of a cylinder.

These advantages and features have for many years made selenium cells the most important light detectors available. Perhaps their most important use was as detectors in light meters used by photographers and illumination engineers. These light meters consisted of a self-gen-

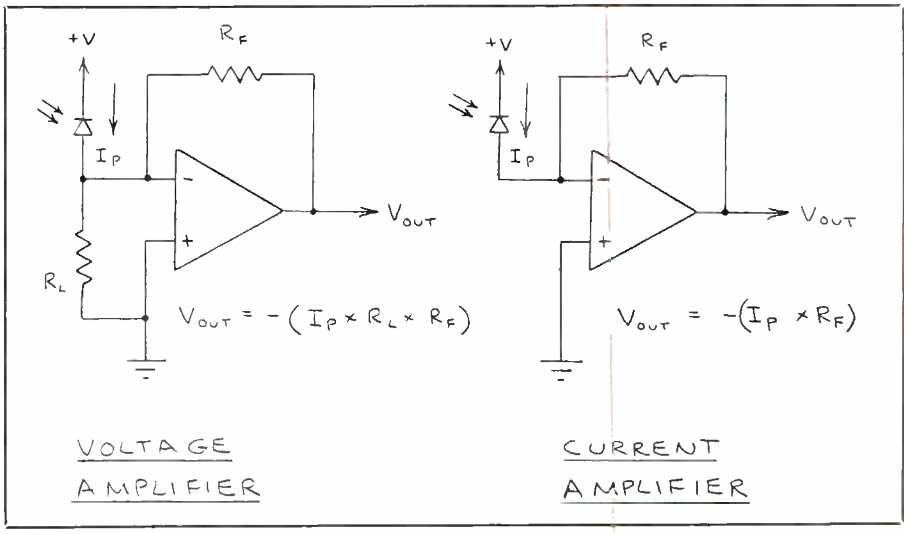


Fig. 10. Details of photoconductive operation of a photodiode.

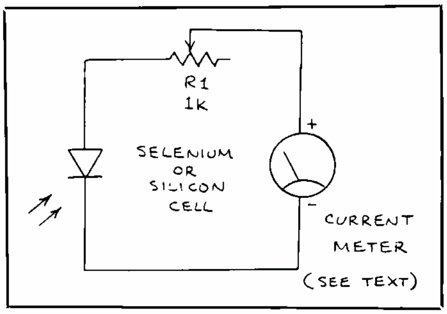


Fig. 11. Schematic diagram for a self-powered light meter.

erating selenium cell connected across a microammeter. Another common use for selenium cells was in light-activated relay applications.

From the late 1950s to the mid-1960s, International Rectifier sold its famous B2M selenium "sun battery" for $2.50. During those years, silicon solar cells cost at least $20. Therefore, a B2M played a major role in introducing many experimenters around the world, including yours truly, to solar-powered projects.

Today, selenium solar cells have been replaced almost entirely by silicon photodiodes. One of the few remaining manufacturers of selenium cells is EG&G Vactec (10900 Page Blvd., St. Louis, MO 63132). Sometimes, selenium cells are available on the surplus market.

• *Silicon Solar Cells.* Silicon solar cells can convert into electricity up to 10 percent or more of the light that strikes them. The forward voltage of a silicon solar cell is around 0.6 volt. Current output varies linearly with light exposure. In full sunlight, a 1-square-inch cell can deliver as much as 100 milliamperes of current. Large circular cells will deliver a full ampere or more.

While silicon solar cells are generally considered to be "sun batteries," they also make highly effective light sensors. Their main advantage as sensors is their large active-surface area. This means that they can detect very-low light levels without the use of a light-collecting reflector or lens.

Aside from recharging batteries on a homemade xenon strobe light I take on bicycle trips, my favorite applications for solar cells are as detectors for lightwave communication receivers and lightning detection. Their large surface area gives silicon solar cells too much capacitance for them to detect fast-risetime pulses.

Shown in Fig. 11 is the schematic diagram of a simple but effective light meter that you can make with a selenium cell or a silicon solar cell and a microammmeter. A silicon cell provides considerably more sensitivity in this application, while a selenium cell provides a spectral response that resembles that of the human eye.

If the Fig. 11 meter is too sensitive, you can place a light-limiting aperture over the detector. Alternatively, you can insert a current-limiting potentiometer between the detector element and meter movement.

You can make a simple light-powered, light-activated relay by connecting a series-array of selenium cells or silicon solar cells to a low-voltage relay. You'll have to experiment to determine how many cells of either type are needed to energize the relay. For example, a 5-volt dc relay will require approximately 10 silicon solar cells. The cells must be able to deliver sufficient current to actuate the relay, of course.

Small-area silicon photodiodes are ideal for use as detectors in lightwave communication systems. Figure 12 shows a basic circuit you can use to receive an intensity- or pulse-modulated visible or near-infrared signal. Note that *C1* is included in the circuit so that only the fluctuating (ac) signal and not the steady (dc) background is not amplified.

You can greatly increase the receiving range of the Fig. 12 circuit by placing the detector behind a lens. The circuit will work much better in daylight if you use a filter that passes only the wavelength of the signal. Interference filters work best, but they're expensive. A cheap substitute for near-infrared wavelengths is developed color film. Photodiodes encapsulated in infrared-transmitting plastic are another good choice.

Photodiodes are well-suited for use in sensitive light meters, and radiometers. The schematic diagram shown in Fig. 13 is for the circuit of a radiometer that will detect very-low light levels. Virtually any photodiode can be used in this circuit, including a solar cell. Many different operational amplifiers can be used, too. For best results, though, be sure to use an op amp that has a high input impedance, such as the OP-07. CMOS op amps might

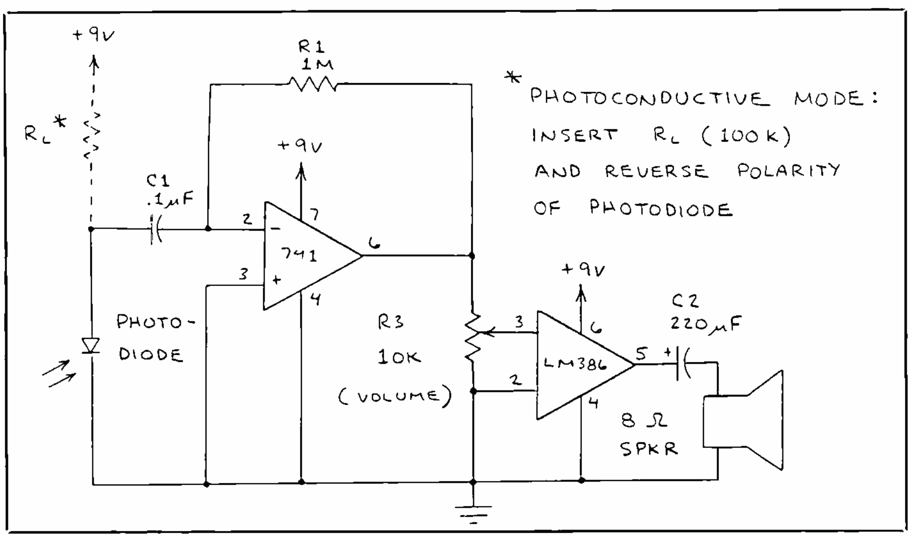


Fig. 12. Schematic diagram of a photoreceiver for audio-frequency signals.

work even better. If necessary, be sure to modify the pin connection scheme to the offset adjust.

Capacitors *C1* through *C5* serve as feedback elements that keep the response of the circuit uniform across the frequency-response (f) range of the op amp. The value of feedback capacitance needed is calculated using the formula $1/(2\pi \times f \times R_f)$. These capacitors can be eliminated if steady-state light sources are being measured.

• *Phototransistors.* A phototransistor is a transistor in which the base region has been enlarged. Light striking the base region has the same effect as a current applied to the base of a standard transistor. When the transistor is dark, only a small leakage current flows between the collector and emitter. When light strikes the base area, a collector current flows. The level of collector current that flows depends on the the intensity of the light and the current gain of the transistor.

Photodarlingtons are phototransistors that include an integral output transistor stage connected in a Darlington configuration. This arrangement provides more current gain and, hence, much greater sensitivity than a phototransistor alone.

Because of their inherent gain, phototransistors do not provide the same degree of linear response as photodiodes. When the detected light exceeds a certain level, the transistor simply saturates, or switches fully on. This means that phototransistors usually cannot be used in daylight because they will be "swamped out" by ambient light long before they detect any signal you aim at them.

Phototransistors are easy to use and provide a very simple approach to many optoelectronics applications. In Fig.

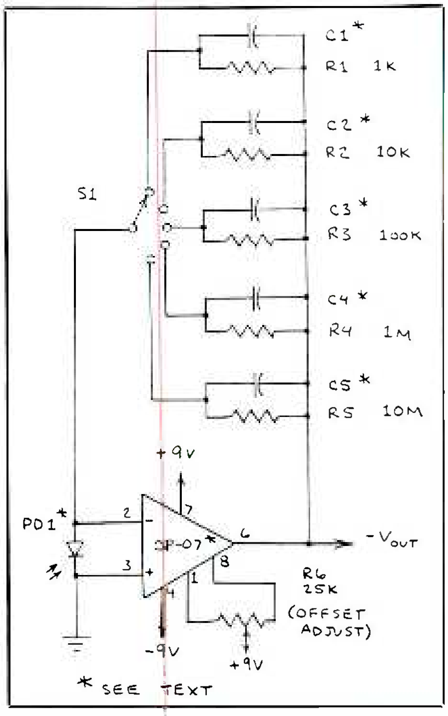


Fig. 13. Schematic diagram of a photodiode radiometer with range control.

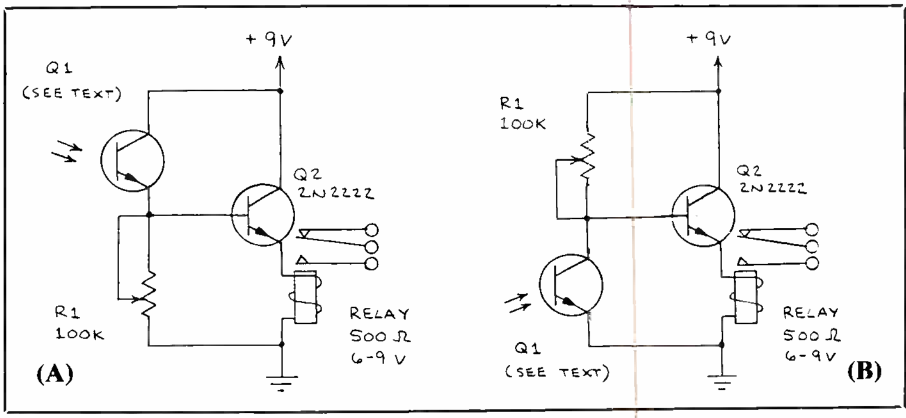


Fig. 14. Light-activated (A) and dark-activated (B) phototransistor relay circuits.

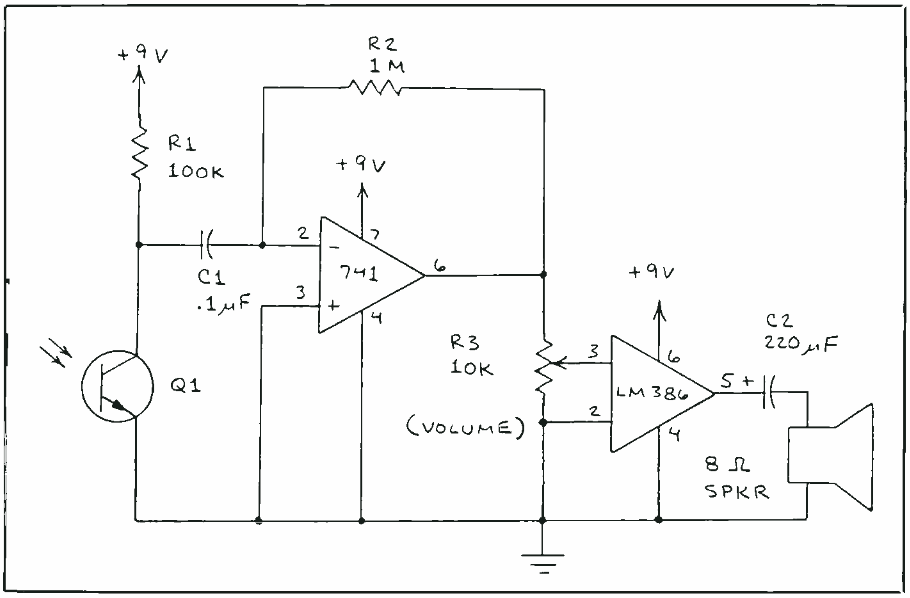


Fig. 15. Schematic diagram of a phototransistor receiver circuit for audio signals.

14(A), for example, a simple light-activated relay is made up of only four components. The sensitivity of the circuit is controlled by *R1*. Figure 14(B) shows how the position of the phototransistor and *R1* in Fig. 14(A) can be reversed to make up a dark-activated relay.

Any npn phototransistor should work well in either Fig. 14 circuit. If either circuit triggers erratically or prematurely, the phototransistor is probably receiving ambient light. In this event, either remove the external light source or place a piece of black heat-shrinkable tubing over the phototransistor to form a collimator.

Shown in Fig. 15 is the schematic diagram of a simple phototransistor receiver circuit you can assemble and use to detect a modulated light beam. This circuit is well-suited for use with many different kinds of audio-frequency lightwave-communication systems.

When experimenting with these and other phototransistor circuits, you may notice that the phototransistor is more sensitive to the signal it is supposed to detect when the phototransistor receives a small amount of ambient illumination. I noticed this many years ago when I was testing a portable lightwave receiver set up 1,000 feet away from a transmitter. While checking the receiver with a small penlight, the volume of the signal emitted from the receiver's speaker suddenly increased in amplitude. Depending on where I pointed the penlight, it was possible to increase the output signal by several times.

You might want to experiment with this technique of increasing the sensitivity of phototransistors that don't have a base lead. You can alter the gain of phototransistors with a base lead by using traditional biasing techniques.

Going Further

Even though I've devoted two columns to discussing the devices and techniques for detecting ultraviolet, visible-light and infrared radiation, there's much that I haven't touched upon. If you want to find out more about the general subject of light detectors, visit a good technical library. Many books on optoelectronics include detailed chapters on various kinds of detectors.

If you want more information about circuits for various kinds of light detectors, there's no better source than the brochures and data sheets published by the manufacturers of the detectors. Particularly good brochures are published by EG&G (25 Congress St., Salem, MA 01970); United Detector Technology (12525 Chadron Ave., Hawthorne, CA 90250); Centronic, Inc. (1829-B DeHaviland Dr., Newbury Park, CA 91320-1702); Silicon Detector Corp. (855 Lawrence Dr., Newbury Park, CA 91320); and both Hamamatsu and EG&G Vactec (addresses given earlier).

Finally, I included an elementary introduction to light detectors in my *Engineer's Mini-Notebook: Optoelectronics* (Radio Shack, 1986). I've also included considerable information about detecting light in *The Forrest Mims Circuit Scrapbook* (McGraw-Hill, 1983) and *Forrest Mims' Circuit Scrapbook II* (Howard W. Sams, 1987). ME

Electronic Organizers

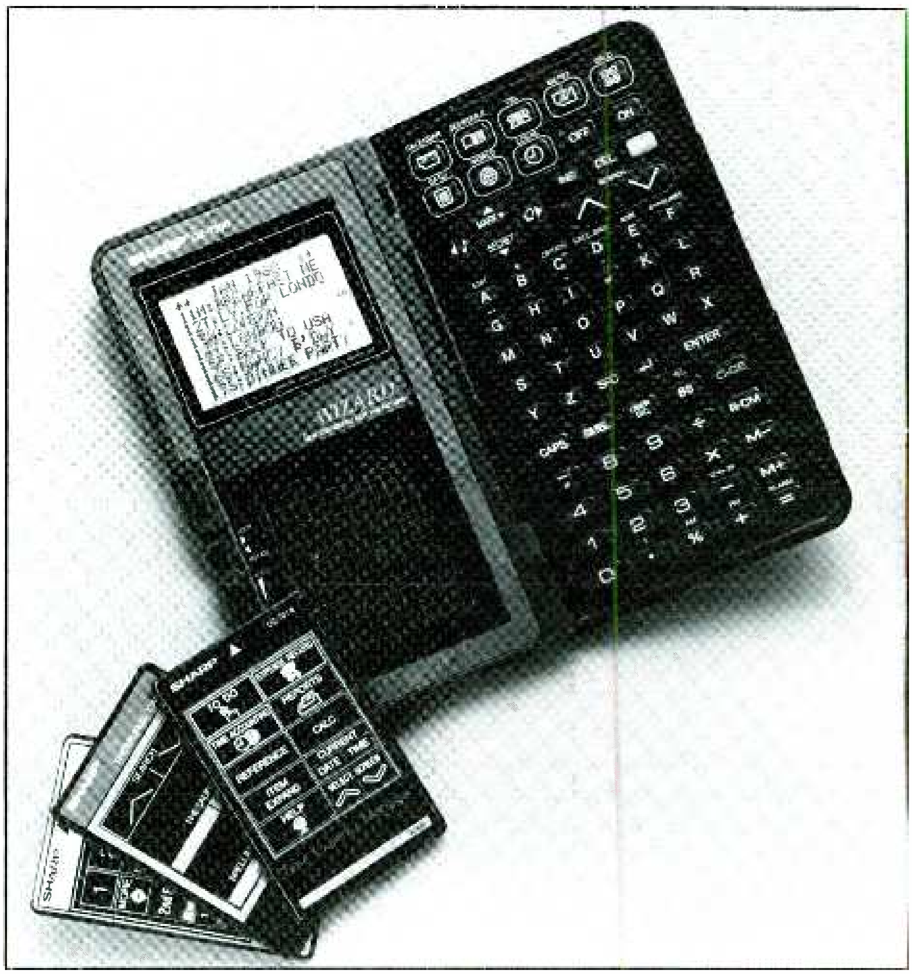
By Curt Phillips

It is one of the hazards of the modern world that we all have too much to do, too many things to remember and too little time. Those of us who take advantage of electronic helpers have an advantage, but it seems that there can never been enough assistance.

By now, we tend to take the number crunching and information processing capability of our computers and programmable scientific calculators for granted. But the widespread availability of all this computational power has also helped to flood us with innumerable phone numbers, account numbers, access numbers, addresses and other incidental data that we have to keep track of just to function in the "information age."

A few years ago, someone decided that if you had a portable calculator with multiple memories, you could as easily use these memories to store phone numbers as anything else. Then calculators appeared with memories *and* alphanumeric capabilities, and from this combination arose a specialty "calculator" known as electronic organizers.

Recently, our Japanese friends at Sharp and Casio introduced two new, powerful and expensive contenders in the electronic organizer battle. If anyone needs organization, (electronic or otherwise), I do; so I decided to see what these gadgets had to offer.



Sharp's "Wizard" Model OZ-7000 electronic organizer.

The "WIZARD" & the "B.O.S.S."

Sharp's entry is the much heralded "Wizard" Model OZ-7000 (I suspect the alphabetic prefix to the model number is no accident). The Wizard boasts seven major functions included in the standard model: calendar, schedule, telephone book, memo pad, world and local time, and calculator.

Casio has a whole new family of electronic organizers called the B.O.S.S. series (Business Organizer Scheduling System). The most powerful of the group is the SF-8000, which I had a chance to examine. It features virtually all of the functions as the Wizard, but it comes with 64K RAM standard, whereas the Wizard has "only" 32K standard.

In an early discussion about these units, *ME* Editor Art Salsberg did not think I was sufficiently impressed with this amount of memory in such small packages. He was right. I guess I've become so jaded with 640K PCs and '286 and '386 machines with multi-megabytes of memory that it is hard to remember when a 16K Apple II was a thing of awe. People used to stop by to behold my "monster" 64K CP/M machine (with *two* 315K disk drives!), which is now ignored in an unused corner of the office. The Wizard's 32K RAM can be expanded to 96K with an add-in card, which puts it ahead of even the original IBM PCs, which were shipped with only 64K RAM.

User Interface

Both units have an alphanumeric keyboard for data entry and an LCD display that isn't backlit. The Sharp display is approximate $2\frac{1}{4}$″ wide by $1\frac{1}{2}$″ high and can be set to display either 8 lines of 16 characters or 4 lines of 12 characters. The $3\frac{3}{4}$″ wide by $1\frac{1}{4}$″ high Casio screen displays 6 lines of 32 characters. The print size of both displays is easily readable, within the limitations of lighting and angle of view typical of LCD displays.

Keyboards on both units are small, as you would expect. The Casio keyboard is in the "QWERTY" format of a typewriter so that, despite its size, anyone versed in touch-typing can still enter data with reasonable speed. The top-of-the-line B.O.S.S. SF-8000 has raised buttons for the keys, but all of the lesser Casio units use membrane keyboards that have poor tactile response.

The raised buttons on the Wizard give a better tactile feel than even those on the SF-8000, but are arranged in "ABC" order. Non-touch typists are slow on a "QWERTY" keyboard, but, *everybody* is slow on an "ABC" keyboard. On both keyboards, shifting case is sufficiently tedious to encourage you to type in all caps.

The Wizard opens "backward" for right-handed people, but this is a minor inconvenience and will no doubt endear Sharp to lefties. The Casio flips up in micro-clamshell style and can be locked after opening approximately 135 degrees to provide a convenient desktop display or it can open 180 degrees to be placed flat.

The Functions

Both units can display any month from 1901 to 2099. This range is interesting to play with, but is really meaningless since these units will be obsolete before 1999 and will be relegated to museums long before 2099. The B.O.S.S. can display two months simultaneously. The Wizard only displays one month, but also lists the number of the week (1 through 52) and the number of the day in the year (1 through 365) as well as the number of days remaining in the year.

Both units can display schedules and both provide an alarm function that can be programmed to beep the user as a reminder. I have often used the alarms on my watch to remind me of meetings, but there are *only* three alarms on my watch and they can only be set for up to 24 hours ahead. With the time/date functions on these electronic organizers, you can program an alarm for a meeting several weeks away and I could find no information in either operation manual regarding a limit on the number of alarms that could be set.

The Wizard also has a scheduling function to specially denote anniversary dates and flag them for ensuing years.

Casio's SF-8000 Business Organizer Scheduling System (B.O.S.S.).

Other than use of the alarm function, the main advantage of these electronic organizers' scheduling function over a paper datebook is their ability to conduct a keyword search. On both units, if you want to see all the meetings scheduled with "XYZ Corp." the units will search and list all scheduled items that include the letters "XYZ Corp." The search mode of both models is case sensitive ("XYZ Corp" does not equal "XYZ CORP") which provides yet another incentive to stick with all caps.

Both units have a telephone directory function. The Wizard allows for three different directory files under different names so you can keep "Business," "Personal" and "Other" telephone listings separate. The Casio does not offer directory segregation per-se but I found this feature of limited use anyway. If you have a business acquaintance who is also a friend, you have to list him twice (and waste memory) or arbitrarily choose a category. Casio does have a "Business Card" category that's completely separate from the telephone directory, although it can contain phone numbers. This area has more data fields for information like company name, position, etc. than the telephone directory.

If you have the time and patience to enter a lot of phone numbers in these electronic organizers, their keyword search function can help in finding the right number, but the Wizard will only search within a directory and the B.O.S.S. won't search both telephone and business card areas simultaneously. If you search for "Jack Kennedy" mistakenly under the "Personal" directory, the Wizard won't tell you that he is actually listed under the "Business" directory. Likewise, if you search mistakenly under the telephone area of the B.O.S.S. So much for the usefulness of multiple directories.

Both units offer memo functions to those who can tolerate their keypads. Again, keyword search capability makes using the memo function almost worthwhile, since the memos can be formed into a quasi-database.

The local time function they provide would be ho-hum were it not for the alarm function that it allows. Setting alarms as reminders for meetings allows you to concentrate on the task at hand without constantly having to worry about forgetting the appointment. Of course, the alarm on the Wizard, my watch and almost every other electronic device I've used is sufficiently loud for an office/automobile environment, but will not attract attention on a factory floor or other noisy place where engineers and some managers occasionally find themselves. I find these alarms to be very useful, but their limitations must be recognized. Of course, if the alarms were loud enough for a factory floor, they would be inappropriately loud for an office setting. Perhaps someone will build an electronic alarming device with a noise meter included, such that it causes the alarm volume to always be louder that the ambient noise level.

World Clock

I really had great expectations of the Wizard's World Clock function. At the time I received the Wizard, there was quite a bit of action going on in Bejing, China, and I intended to use the Wizard at my shortwave listening post to help me keep track of the time there and other hot spots of the world. After all, the Wizard keeps time on 212 cities internationally.

I had hoped to set the Wizard to read Bejing time continuously and set it up by my UTC (Universal Coordinated Time) clock but, as I discovered, it only displays the time for about two seconds after the button is released. I suppose only a very small number of the target audience for this product would care for it to display continuously, but this would nonetheless be a nice additional feature. It does have a feature that remembers the last six cities accessed, so that frequently checked cities are easier to recall.

The B.O.S.S. (which I got later), will continuously display the chosen time zone, at least for six minutes until the auto power-off feature turns it off. The B.O.S.S. keeps time for *only* 127 cities internationally. North Carolinians will notice that Charlotte didn't make the shorter Casio list, as Australians will notice the missing Alice Springs, Australia and Canadians (Saskatchewanians?) will have to live without Regina time included.

They both feature four-function calculators with square root keys, which I guess you'd expect, but is hardly exciting. The Wizard displays 10 digits in the calculator mode, while the B.O.S.S. displays 12 digits, but the Wizard has a typical calculator keyboard. The B.O.S.S. makes you use the numbers located above the QWERTY keyboard and what was an asset for alphabetic data entry becomes a liability for numeric data entry. If you expect to do much number crunching with an electronic organizer, the Wizard's keyboard is definitely the better.

Both the Sharp and the Casio units are large. The Sharp Wizard is 4" wide by 6½" long and over ¾" thick closed; after much searching I finally found a shirt whose pocket it would fit, so I guess it technically is shirt pocket sized. The Casio SF-8000 folds to approximately 3" by 6¼" and is about ¾" thick also. This fits a bit more easily into a shirt pocket, though no more inconspicuously.

Tipping the scales at over ten and a half ounces, the Casio outweighs the Sharp by over an ounce. Either is sufficiently heavy that you don't have to be very fashion conscious to notice their tug even in a suit coat pocket, though they do fit. It seems they are really meant to be carried in a brief case, although having them that inaccessible would detract from their usefulness while traveling. Perhaps some leather-smith could devise a shoulder holster for them.

Add-on Software

The Sharp Wizard has three interchangeable add-on software cards that provide functions for time management, thesaurus/dictionary and foreign language translation and each retail for a little over $100. The thesaurus/dictionary provides 500,000 synonyms and will check spelling for 87,000 words and list definitions for 45,000 words. The translator card features 13 categories of pre-stored words and phrases in eight languages. The time management software card adds features for expense reports, time-accounts and to-do lists. None of the software cards were available for review.

At this point, I'm not terribly impressed with either of these units. Although they are both nice and offer interesting features, let's face facts. When you first get one of these gizmos, the novelty of it causes you to type in all your appointments and meetings, even if it is awkward and time-consuming (and it is). The real test of usefulness comes after the novelty has worn off, if the utility of the device exceeds the time and effort required to use it. For me, these units don't qualify under that criteria.

Computer Interface

Enter the computer interface. The Wizard has an option called the Organizer-Link, which will allow for data transfer to and from the serial port of a PC compatible computer. The option for the Casio B.O.S.S. series is called PC-Link and it does the same thing. Links to the Macintosh are in the works.

With these options, data for the organizers can be typed not from a marginal to bad "calculator" keyboard, but from a full sized computer keyboard! This is an altogether different proposition.

The memo functions, which I said can form a quasi-database, now allows portable access to computer generated data sets. Both interfaces allow for translations from Sidekick-format phone lists and schedules.

Both Organizer-Link (Wizard) and PC-Link (B.O.S.S.) were written by Traveling Software, the people who brought us Lap-Link and Desk-Link, and both show their estimable heritage.

Both manuals are virtually identical, with someone at Traveling Software using "search-and-replace" word processing to change "Organizer-Link" to "PC-Link," although there are some differences. The Wizard's Organizer-Link can convert files from Sidekick and SDF (Standard Delimited Format), while the B.O.S.S. PC-Link can convert from Sidekick, SDF and ASCII. Note that this SDF is *not* dBASE's System Data Format, although dBASE does have a compatible mode that is discussed in both of the manuals.

The PC software for both is not (surprisingly) similar, and easy to use. A simple cable connects the B.O.S.S. to the PC, but the Sharp Wizard to PC connection requires an "RS-232 level converter" box with an ac power adapter. Despite this extra power source, the Sharp manual warns the user against spending too much time in the link mode because "battery drain increases *significantly*" (Sharp's emphasis). There is no such warning for the B.O.S.S. PC-Link with no external power, although it may be true.

Both software packages include telephone, memo and scheduling functions for those who don't use Sidekick, and both are as easy to use as any database-type systems. By entering telephone numbers, scheduling information and memos from the ease of a PC, the electronic organizers are reduced to primarily a data-accessing device and their keyboards are much less of a liability.

Although Sharp's Organizer-Link information mentions that the user can type memos "on-the-road" and transfer them to the computer for printing when they return to the office, this seems a bit fanciful to me. Typing (if you can call punching these ill-placed keys "typing") on the Wizard is only slightly less nerve-wracking than having your wisdom teeth pulled (without novocain). I can't think of any circumstance where using the Wizard in this fashion would be preferable to just jotting the note on paper and typing it at the computer.

Conclusions

Without the PC transfer software, I wouldn't buy either of these units. With this option, both are quite nice to use although both would profit by being smaller and lighter.

Neither of these units come cheap, with the Sharp Wizard listing for just under $300 and Casio's SF-8000 B.O.S.S. running $259.95. The link software and cable adds $179.95 to the Sharp, while the Casio option costs $109.95 and includes a 25-pin to 9-pin serial adapter.

With the price advantage combined with its few functional advantages, the Casio is easily my pick as best choice. Even discounted, I'm not sure they are really worth this kind of money, but one thing is for certain. Although they may or may not help you become more organized, depending on your discipline, they absolutely will give you the high-powered executive look.

Your comments and suggestions are welcome. You can contact me through Delphi (CURTPHIL) and CompuServe (73167,2050) or at P.O. Box 678, Garner, NC 27529. ME

CIRCLE 86 ON FREE INFORMATION CARD

High-Precision and Micropower Operational Amplifiers

By Joseph Desposito

Operational amplifiers are a favorite of engineers and hobbyists and are used in a wide variety of circuits. Choosing among the different op-amp types is usually done based on circuit design parameters such as low-noise, high precision, high speed or low power. Described below are a selection of high-precision and micropower op-amps that have appeared in the last year or so.

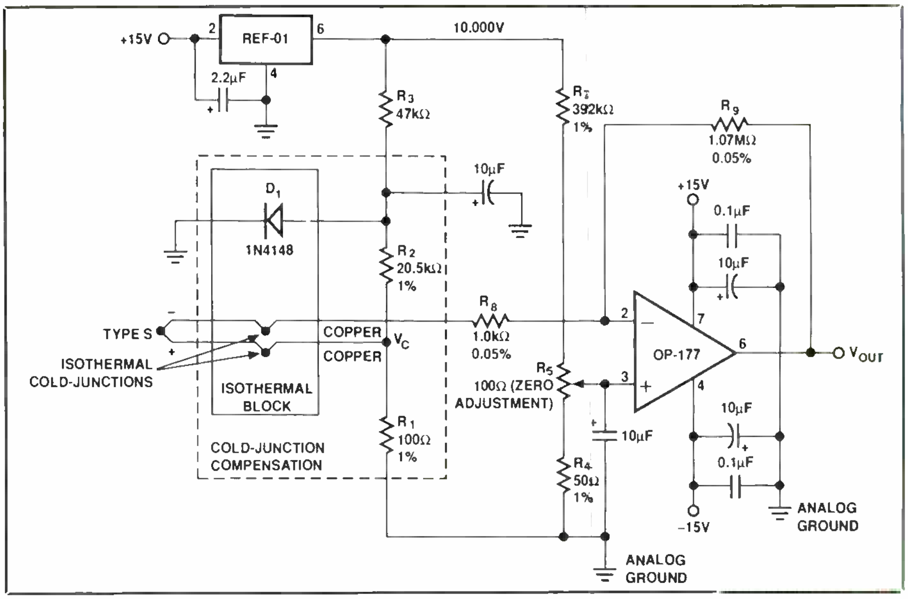


Fig. 1. In this circuit, built around Raytheon's OP-177 precision operational amplifier, an S-type thermocouple produces a 10.3-mV output at a temperature of 1,000° C.

Precision Op-Amps

Precision Monolithics, Inc. (1500 Space Park Dr., Santa Clara, CA 95052) recently introduced the OP-177. According to its specifications, the OP-177 has an offset potential of 10 V maximum at room temperature and 20 μV maximum over the full military temperature range. The low offset voltage of the OP-177 coupled with an offset voltage drift of 0.1 μV/°C maximum eliminates the need for external trimming and increases system accuracy over temperature.

The OP-177 has an open-loop gain of 12V/μV that is maintained over the full ±10 V output range. Some of the OP-177's other specifications are a common-mode rejection ratio (CMRR) of 130 dB minimum, power-supply rejection ratio (PSRR) of 120 dB minimum and maximum supply current of 2 mA. Specifications like these allow the OP-177 to produce accurate performance in high closed-loop gain applications.

The OP-177 is available in an eight-pin ceramic dual in-line (CERDIP) package for the military (−55° to +125° C) temperature range and in eight-pin CERDIP, plastic and SO packages in the extended industrial (−40° to +85° C) temperature range. The OP-177 is priced at $1.00 for plastic and SO, $1.50 for CERDIP, and $9.00 for military grades in 100-piece quantities.

Raytheon's (Semiconductor Div., 350 Ellis St., Mountain View, CA 94043) RC/RM4207 dual op-amp is designed for low-level signal conditioning and instrumentation applications. Low offset voltage of 75 μV maximum, low offset voltage drift of 1.3 μV/°C maximum, a CMRR of 100 dB minimum, and low input bias current of 5 nA maximum serve to reduce input related errors to less than 0.01% in a typical high-gain instrumentation amplifier system (Av = 1,000).

The 4207 contains two separate amplifiers with a high degree of isolation between them. Each is complete, requiring no external compensation capacitors or offset nulling potentiometers.

The RC4207, in an industry standard dual eight-lead pinout, is available in both the plastic and ceramic mini-dip packages in commercial and military temperature grades. Pricing, in 100-piece quantities, starts at $.91 for the commercial plastic package.

An example of a precision circuit is a thermocouple amplifier that must amplify very-low-level signals accurately without introducing linearity and offset errors to the circuit. In the circuit shown in Fig. 1, an S-type thermocouple produces 10.3 μV of output voltage at a temperature of 1,000° C. The amplifier produces an output voltage of 10.024 V. The circuit uses a low-cost diode to sense the temperature at the terminating junctions and, in turn, compensates for any ambient temperature change. An op-amp such as the OP-177, with its high open-loop gain, plus low offset voltage and drift, is the basis for a very precise temperature sensing circuit. A more simplified high-stability thermocouple amplifier using the 4207 is shown in Fig. 2.

Micropower Op-Amps

Linear Technology (1630 McCarthy Blvd., Milpitas, CA 95035) recently introduced the LT1178 and LT1179 precision micropower operational amplifiers with supply currents of 17 μA maximum per amplifier. The LT1178 is an eight-pin dual op-amp and the LT1179 is a 14-pin quad op-amp. Both devices are optimized for single-supply operation at 5 V.

The low supply current of the LT1178 and LT1179 is also combined with precision specifications: offset voltage is 70 μV maximum (with 0.5 μV/°C drift) and offset current is 250 picoamperes maximum. Their 1.5-picoampere peak-to-peak current noise and picoampere offset current permit the use of megohm-level source resistors without introducing serious errors. Voltage noise is 0.9 μV peak-to-peak (0.1 Hz to 10 Hz), which is very low, considering the low supply current.

Both the LT1178 and the LT1179 can be operated from a single supply (as low as one lithium cell or two nickel-cadmium cells). The input range goes below ground. The all-npn output stage swings to within a few millivolts of ground while sinking current—no power-consuming pull-down resistors are needed.

The LT1178 dual micropower precision op-amp is available in eight-pin plastic or CERDIP packages and TO-5 metal cans. The LT1179 quad micropower precision op-amp is available in 14-pin plastic or CERDIP packages. Both commercial and military versions of the op-amps are available. Pricing in quantities of 100 and up for the commercial grade, plastic DIP package is $3.00 each for the LT1178 and $3.90 each for the LT1179.

Precision Monolithics' OP-290 is a precision low-voltage micropower dual op-amp. The OP-290 draws less than 20 μA of supply current per amplifier, but it is able to drive over 5 mA per amplifier into a load. Power-supply voltage for the OP-290 ranges from + 1.6 V to + 36 V in single-supply operation and from ± 0.8 V to ± 18 V in dual-supply operation.

Input offset voltage is under 200 μV with a maximum input voltage drift of only 2 μV/°C over the military temperature range. The OP-290's gain exceeds 700,000 and its common mode rejection is better than 100 dB. The PSRR of 5.6 μV/V maximum reduces errors caused by ground noise and power-supply fluctuations of battery- or solar-powered applications. Low offset voltage and high gain of the OP-290 bring precision performance to micropower applications.

The monolithic design of the OP-290 ensures parametric matching and temperature tracking between both amplifiers. This makes the OP-290 a good choice for dual op-amp applications such as instrumentation amplifiers. The minimal voltage and current requirements of the OP-290 suit it for battery and solar powered applications, such as portable instruments, remote sensors, and satellites.

The OP-290 can be operated on a minimum supply potential of + 1.6 V, or with dual supplies of ± 0.8 V, and draws only 19 μA of supply current. In many battery-powered circuits, the OP-290 can be operated for thousands of hours before requiring battery replacement.

High-performance portable equipment and instruments frequently use lithium cells because of their long shelf life, light weight, and high energy density relative

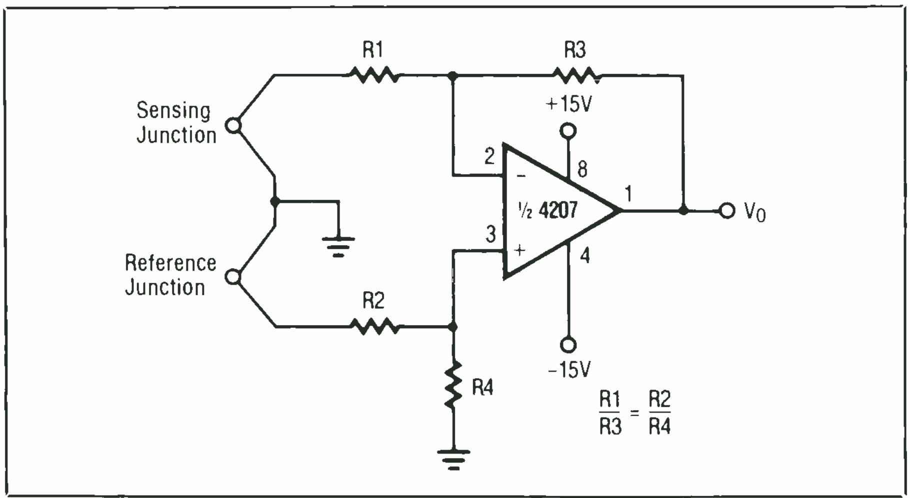


Fig. 2. This high-stability thermocouple amplifier, built around the Raytheon 4207 integrated-circuit amplifier, is much simpler than that shown in Fig. 1.

SOLID-STATE DEVICES...

to older primary cells. Most lithium cells have a nominal output of 3 V and a flat discharge characteristic.

The OP-290 conforms to the industry standard eight-pin dual op-amp pinout. It is available in the eight-pin CERDIP for the military and extended industrial temperature ranges. The OP-290 is also available in an eight-pin plastic DIP for the extended industrial temperature range. Prices in 100-piece quantities start at $2.50 for plastic, $3.40 for CERDIP, and $9.50 for military grade.

The circuit shown in Fig. 3 is a variable slew rate filter. It can be used to remove pulse noise from an input signal without limiting the response rate to a genuine signal. The non-linear filter is useful in applications where the input signal is known to have physical limitations. An example of this is a transducer output where a change of temperature or pressure can-

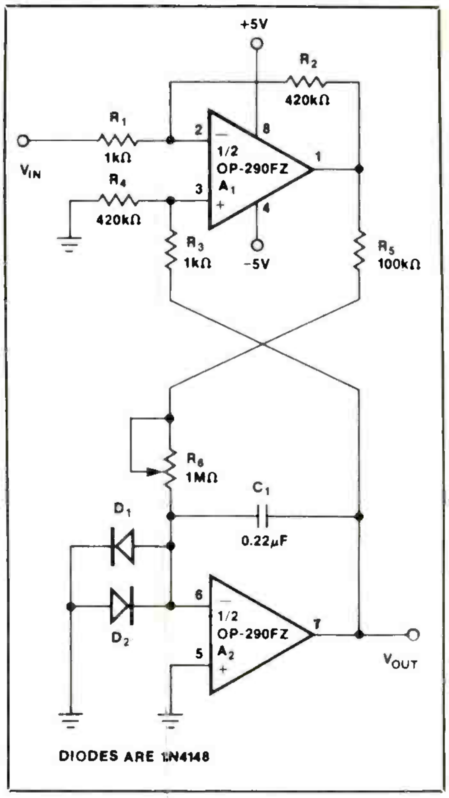


Fig. 3. Circuit details of a variable slew-rate filter built around Precision Monolithics' OP-2970FZ.

not exceed a certain rate due to physical limitations of the environment.

The filter consists of a comparator that drives an integrator. The comparator compares the input voltage to the output voltage and forces the integrator output to equal the input voltage. The closed-loop gain of *A1* is high so that with a fast slewing signal, *A1* acts as a comparator with its output high or low. Diodes *D1* and *D2* clamp the voltage across *R6* forcing a constant current to flow in or out of *C1*. Resistor *R6*, capacitor *C1* and amplifier *A2* form an integrator with the amplifier's output slewing at a maximum rate of 0.6 V/(R6 × C1).

With the values shown in Fig. 3, the maximum slew rate can vary from 2.7 V/s to 12 V/ms. For an input voltage slewing at a rate under the maximum slew rate, the output simply follows the input with *A1* operating in its linear region. ME

A New Pocket Computer

By Ted Needleman

In the more than two decades I've used computers, there have been just two systems that gave me the "knock-your-socks-off" feeling. The first was, of course, the first computer I worked with, an obsolete (even then) IBM 1401. This machine consisted of two large boxes, five feet high, a card reader/punch, and the venerable 1403 printer, a monstrously large and noisy band printer.

For all its size, the 1401 contained only 4K of ferrite core memory and no auxiliary storage such as tape or disk. It was programmed in a precursor to assembler language called AutoCoder. Memory locations could be directly altered by using a set of rotary memory address switches and nine toggle switches called "sense switches." The 1401 was manufactured before hexadecimal was widely adopted, and you needed to know a type of notation called Extended Binary Coded Decimal (which is still used in many of IBM's larger computers).

The 1401 was one of the most successful second generation (that is, all-transistor) computers. At the time I first encountered it (1968) the next generation of computers, IBM's 360, was already out and becoming very popular. But as difficult as it was to program and use, it was still my first computer, and I both loved it and was awed by it.

In the intervening years, I've used numerous other systems; IBM 360s, 370s, 3090s, System 3s, DEC PDP-11's and VAXes, and PCs ranging from Apple IIs to the 386 PC that is my main machine at the moment. Each new system offered a bit of a thrill, but until last week, that "gee-whiz" feeling was gone. The object of my affection is the new pocket-sized Portfolio computer from Atari.

I've never been particularly enthusiastic about Atari. Its Pong game was one of the first of its kind, but their computers, until recently, were more "home" machines than the business tools I generally use. This, of course, doesn't mean they were bad computers, it's just that my systems are generally used for business purposes, which has tended to bias me toward MS-DOS PCs (and CP/M computers before them).

Atari's new MS-DOS-compatible hand-held PC is about the same size of a VCR tape cartridge. It comes with word-processing software, spreadsheet, personal calendar and phone directory.

The Portfolio has eliminated my Atari prejudice. About the size of a VCR tape cartridge and weighing just under a pound, the Portfolio is the first affordable truly portable computer. Using a low-power 80C88 microprocessor running at a clock speed of 4.92 MHz, it features a 40-character by 8-line LCD display, a standard 126K of RAM that can be partitioned between a RAM disk and program memory, a true QWERTY keyboard, and ports for plug-in RAM cards that can be used to expand the memory up to another 126K, and intelligent serial and parallel cables.

The whole thing runs on three AA cells or an optional ac power supply and contains a proprietary operating system in ROM that exactly emulates MS-DOS 2.11, a 1-2-3 file-compatible spreadsheet, a stripped down word processor, a calculator, diary, and phone directory. It can even dial your phone for you by playing the tones through its built-in speaker into the phone's mouthpiece. It offers all this for a list price of $400!

Okay, I admit there have been other computers *almost* as terrific as this one. After all, the TRS-100 (and its fraternal twin, the NEC 8201) had the same size display, a QWERTY keyboard, built-in word processor; while it didn't fold and wasn't as compact, it was still light and portable. Problem with it was that it was not MS-DOS compatible, had really limited memory, and contained Ni-Cds that had to be recharged.

The Portfolio, on the other hand, is entirely MS-DOS compatible. If you download a program small enough to both run and be stored in memory, it operates on the Portfolio the same way it does on an MS-DOS PC (except for the smaller screen). And it's easier to just open the back and change the three AA cells when needed than to recharge a run-down set of Ni-Cds. The Portfolio retains its data while you do this, incidentally, so you don't have to worry about your work going to "data heaven," as often happens with battery-powered laptops when their batteries give up the ghost.

The closest thing to Atari's Portfolio is the much more powerful NEC Ultralight. The size of a paperback book when closed, it offers a full sized screen (80 characters by 25 lines), a larger keyboard, a silicon hard disk, and much more RAM (1 megabyte is standard). At $3,000, the

PC CAPERS...

NEC is 7.5 times the price of the Portfolio and more than four times the weight.

Using the Portfolio is just about the same as any other MS-DOS PC. You open the case and turn it on by depressing any of the keys. This brings you to the point where you left off. Atari's "knee-top" uses a nice windowing system for its built-in applications. The menu to select one of these applications can be displayed by typing "APP" at the DOS prompt.

Not having a power switch, the Portfolio is shut off by typing "off." The keyboard, incidentally, will give touch typists a bit of trouble. It's a standard QWERTY layout, and the keys have a good feel, but given the size of the machine, there's just no way that the keys can be spaced far enough apart so that a touch typist will feel comfortable. Unfortunately, though, that's the price you have to pay to own a PC that fits comfortably in a jacket pocket.

I've had a pre-release of the Portfolio for a week now and Atari wants it back quickly so that another reviewer can get a look at it. It came without the smart cable or an extra memory card, which severely limited what I could do with it other than use the built-in functions (spreadsheet, word processor, phone directory/dialer, and diary). Even at that, I'm going to be unhappy to see it go. I've had it just long enough to get some idea of how nice it would be to own. Atari has promised me another one on a longer loan. I'll report on whether a longer acquaintance fans the fires or cools them.

The Portfolio isn't as glamorous as the next generation of i486-based PCs. It has some limitations that are design compromises, such as the small screen (which does window into a virtual 80 character by 24 line screen), and relatively small amount of RAM (at least in these days of 640K standard memory). These compromises are minimal if your primary use for the Portfolio is for writing or speadsheeting on the go, as the built-in applications leave plenty of room for data in the standard 126K of RAM. And with the optional RAM expansion cards, there should be sufficient room to download small custom applications, turning the Portfolio into a custom inventory taker, or data capture device. With the optional 126K RAM card, you should also be able to load and run BASIC programs, some dBASE software, or even GW-BASIC or Microsoft's QuickBASIC to do programming on the go.

What makes the Portfolio exciting is that it takes us one step closer to the science-fiction vision of a portable personal computer. It's easy to become jaded when your everyday PC is a 16-MHz 386, containing 3 MB of RAM, 110 MB of disk storage, and color VGA graphics. But compared to the Epson LT laptop that I normally shlep with me on business trips, the Atari Portfolio is a wonder. It's powerful, practical, and affordable.

Clarification

Looking back at September's column, I noticed that in my attempt to simplify, I may have done Traveling Software's Lap-Link III a disservice. I described Lap-Link's ability to load a clone of itself into the target machine as being similar to a benign virus. In doing so, I probably gave the impression that this could take place without direct intervention from the user. Actually, both Traveling Software's Lap-Link, and a similar file-transfer product from Rupp Software use a feature that has been in MS-DOS since version 2.0 to accomplish this "cloning" process. And the process itself requires that a user perform a set-up process on the system that is to receive a copy of the file transfer software.

This set-up procedure requires that you use the CTTY command on the target machine. CTTY has, as I mentioned before, been available since release 2.0 of MS-DOS and, in fact, was available in CP/M, the first widely accepted microcomputer operating system. Most operating systems, whether for micros, minis, or mainframes, have a class of commands for I/O redirection. In MS-DOS 3.0 and higher, these are called pipes, but even the earlier releases allowed you to send a file to a serial port, a parallel port or to a disk file. The CTTY (standing for

Console Teletype) command is similar in concept, but what it does is transfer where the PC looks for the standard input and output device (CRT and keyboard) to an auxiliary console. This auxiliary console is most often a "dumb" terminal connected to one of the serial I/O ports (that is, COM1 or COM2).

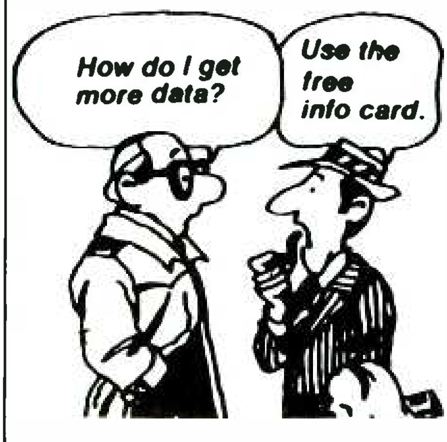
By issuing the CTTY command, you are turning over control of the PC to the device on the other side of the I/O port that you specify. The command CTTY COM1 causes the PC to look for "keyboard" input at the serial port rather than the keyboard port addresses. It also instructs the computer to send screen output to the serial I/O port, rather than the video adapter card installed in the PC. Whether you've connected a video terminal or another PC to this port is immaterial to the PC; it doesn't really look beyond the I/O port.

Both Lap-Link III and FastLynx take advantage of this situation. Once control has been handed over to the COM port (and to the software residing on the PC on the other side of that port) a series of instructions is issued that says, in essence, that the next series of "keystrokes" comprise a program that is to be stored in memory and run. This program is a copy of Lap-Link or FastLynx. When run, the "cloning" process is complete.

Aside from simulating a benign "virus," CTTY can be used for running your PC remotely. For example, if your system is located downstairs in the basement, but you'd also like to occasionally work in your upstairs bedroom, you can buy an inexpensive serial RS-232 terminal and run some cable from the downstairs PC to the upstairs bedroom. Then, by powering up the PC and issuing the CTTY COM1 command (along with some parameters that set the serial port to the same speed and word length as the terminal) you can operate the PC from your upstairs terminal.

There are some limitations to this technique. Many inexpensive terminals do not offer PC graphics, so word processing, programming, data base management, and spreadsheeting are the most appropriate applications to run remotely. Also, many RS-232 terminals are limited as to the speed they can operate at. The most frequent speed limitation is 9600 baud or 19 kilobaud. This is substantially slower than the screen and keyboard connected directly to your PC operates at, and may be distracting in some applications.

On the other hand, though, you can get a fairly decent terminal for under $300 from many mail-order companies. Moreover, serial communication can be accomplished with cable having as few as three conductors (depending on the terminal's requirements). While shielded cable is best, short runs of inexpensive telephone cable often work satisfactorily. Keep in mind, though, that with cable lengths in excess of 50 feet, serial communications begin to suffer because of line losses, so try and keep your cable runs under this length. **ME**



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BOOKS

The Book of FAX. *By Daniel Fishman & Eliot King. (Ventana Press, P.O. Box 2468, Chapel Hill, NC 17515. Soft cover. 130 pages. $12.95.)*

Facsimile communication is becoming more and more important in business and personal communication. This book can help the newcomer gain a working knowledge of the FAX technology and the person who already owns FAX equipment to obtain the most cost-effective use of it. It guides the newcomer to an intelligent buy decision based on needs, price and other important criteria. Though the book talks about not being "left behind," it also discusses whether or not a need even exists for a FAX machine in given situations. If no need exists, there is no push in the text for the reader to buy a FAX machine regardless, as so many books do.

This book's lucid text imparts technical and non-technical detail without unnecessary theory or side issues. At the outset, it discusses why one might need a FAX machine and builds from there. To set the stage, the two opening chapters familiarize the newcomer with the FAX revolution, his options, types of equipment available and advantages and pitfalls of becoming a FAX user. Later chapters are geared to people who are already users of FAX. These deal with choosing between competing FAX machines, the buy or lease decision, whether a FAX board that plugs into your computer is a better option than a stand-alone FAX machine, the FAX document as legally binding, and how to stop FAX "junk" mail. FAX "etiquette," managing FAX in a large company, and how FAX is becoming integrated with computers, copy machines and other technologies are other issues discussed. Included are checklists for determining FAX needs and which machine features to look for when making a purchase.

All in all, this is a well-rounded book on the FAX topic. Its approach is from a user's point of view, making the material it contains particularly valuable to the non-technical audience.

Encyclopedia of Electronic Circuits, Volume 2. *By Rudolf F. Graf. (Tab Books. Soft cover. 731 pages. $29.95.)*

Written to serve as a companion to an earlier volume, this massive book (it is more than 2 inches thick) contains 108 chapters that offer more than 1,400 circuit schematics not covered in Volume 1. It is a truly encyclopedic work, giving schematics that encompass virtually the entire spectrum of electronics technology from alarm to touch-switch circuits. Just about every letter of the alphabet is represented between the two.

Arranged in alphabetical order by category, this book groups together circuits that share a common function, such as amplifiers, bridge circuits, clock circuits, and so on down the line. Each schematic is fully detailed with component values and numbers. Each is also accompanied by a small Circuit Notes section that tells something about the circuit. Its source is also identified, whether from a manufacturer's applications note, a magazine or book or a private individual. If the reader wishes more information on a particular circuit, he can find it in the source from which it was obtained. (All source references are given in a section at the back of the book.)

This volume—plus its companion Volume 1—should make up a ready source to which to turn for just about any type of circuit you can imagine. In this volume alone, you will find circuits for: counters, descramblers and decoders, electronic-locks, fence chargers, gas and smoke detectors, humidity sensors, intercoms, logic amplifiers, metal detectors, oscillators, power amplifiers, radar detectors, strobes, and theremins—to name just one from each alphabetical letter represented. Many more types of circuits are schematically represented. This is a well worthwhile book to have handy if you do a lot of experimenting on your own or do not want to have to reinvent the wheel every time you are given an assignment on the job for designing a new system.

Complete Guide to RS232 and Parallel Connections. *By Martin D. Seyer. (Prentice-Hall, Inc. 633 pages. $27.95 soft cover; $42.00 hard cover.)*

This book is extraordinarily large in both page count and size (it measures 8" × 11" and is about 1" thick), considering that it focuses exclusively on making connections to serial and parallel ports. Leafing through it, however, one quickly learns why this is so: the author uses a "tutorial module" approach to analyze several dozen connections between a wide variety of equipment types and models from a host of manufacturers. Each module is written to stand on its own. Thus, with much of the text material repeated from module to module, a lot of extra space is eaten up—to good use, considering that there would be an inordinate amount of flipping back and forth otherwise.

The book is arranged into six chapters, each covering a specific type of connection. Chapters 1 and 2, for example, cover connecting printers with RS-232 and parallel interfaces. Chapters 3, 4 and 5 detail connection of modems, terminals and computers. The final chapter deals with special tools for making connections, software, hardware and cable designs. In each of the "connecting" chapters, a series of specific-equipment connections are described (the tutorial modules), such as between an HP LaserJet printer and an IBM PC/XT computer. Each of these chapters closes with a general analysis that shows the reader how to apply what was covered in the specific-equipment analyses to equipment other than that mentioned.

By completing fill-in "port profiles" and adhering to the steps and tools provided in the text, the user can successfully connect together any different number of serially and parallel-fed devices.

Appendices sprinkled throughout the book (rather than being grouped together in the back of the book) provide technical details like RS-232 circuit summary with OCITT equivalents, the Centronics standard, pinouts for serial computers and peripherals, connection symptoms and solutions, rules for cable design, etc. In all, a review of more than 300 devices is included in these appendices.

If computers and peripherals are your profession, buying this book can be one of the best investments you make. It will make you into an expert on interconnections in short order.

NEW LITERATURE

Tools/Test Equipment Supplement. Contact East is offering a 1989 supplement to its General Catalog. It lists and describes a wide range of brand-name products for testing, repairing and assembling electronic equipment. Product listings are included for analog/digital oscilloscopes, static protection, test instruments, precision hand tools and soldering supplies and workstations. Also featured are lines of tele/data communications test instruments, tool kits, wire and cable aids, electronic adhesives, and inspection equipment. For a free copy, write to: Contact East, 335 Willow St. S., Dept. ME, N. Andover, MA 01845.

Soldering Tools Catalog. A.W. Sperry's new catalog features a complete line of products, including all specifications and accessories. The 35-page catalog contains several new additions to the company's line of instruments, including a snap-on VOM, peak-hold and true-rms ac/dc digital voltmeters, photo/contact digital tachometer, no-contact microwave leakage detector, etc. For a free copy of Catalog No. MC-600 Issue C, write to: A.W. Sperry Instruments Inc., 245 Marcus Blvd., Dept. ME, Hauppauge, NY 11788.

Soldering Tools Catalog. A new catalog from Ungar describes the company's updated line of soldering and desoldering equipment for the electronics industry. The 28-page illustrated color catalog describes features and benefits of Ungar surface-mount network systems, desoldering service centers, soldering systems, soldering/desoldering irons, tips, accessories, heat guns and rechargeable cordless tools. Included are construction features, specifications, MIL-SPEC compliance information, ordering information and tip selection guidelines. For a copy of the "Soldering Tools for Electronic Production" catalog, write to: Ungar, 5620 Knott Ave., Buena Park, CA 90621.

Public-Domain PC Software Catalog. PC programs for $4 per disk are the subject of a new catalog from Sector Systems Co. Listings are for easy-to-use business, engineering and personal-use programs. The eight-page catalog contains five full pages of software listings that are broken down into such categories as spreadsheets, word processors, engineering and science, business and financial, database, communications, graphics, desktop publishing, languages and programming, utilities, and—for the home—sports and games, health and nutrition, etc. Each is briefly described. For a free copy of the catalog, write to: Sector Systems Co., Inc., 416 Ocean Ave., Marblehead, MA 01945.

The Latest WordStar Upgrade: WordStar 5.5 adds new benefits

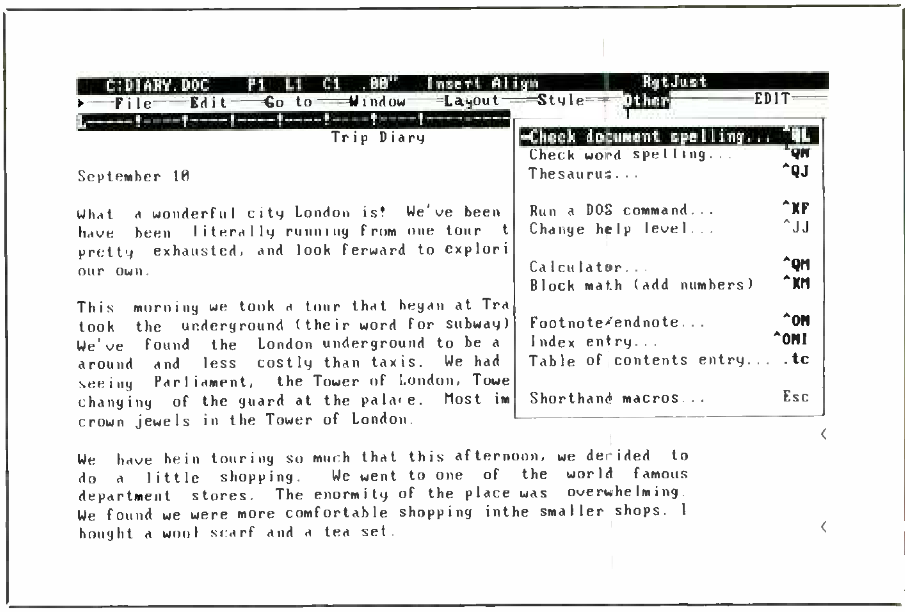
By Art Salsberg

WordStar 5.5 for IBM XT/AT/PS-2 types of computers and compatibles fills in most of the missing pieces of its major 1988 revision, 5.0. The new $495 list-priced package costs only $89 to upgrade from the previous version and $119 from any prior ones. The LAN package is $595.

The 5.5's major changes consist of adding helpful programs that were heretofore for sale separately. This includes "Star Exchange" to convert other word-processing files, including WordPerfect and Microsoft Word, to WordStar format, and "Inset" to integrate screen graphics with text.

Among other important changes is a Style library to store paragraph styles such as indentations, body fonts, titles, positioning of graphic elements, etc. Its superb Advanced Page Preview feature that lets you see just what a page looks like before printing now also integrates graphics with text.

A bevy of enhancements add further to the productivity of the latest WordStar version. Prime ones include more elaborate menus, automatic spacing between lines when fonts are changed to ones with different heights, a typewriter mode, and multi-lingual spelling and hyphenation when using optional foreign language dictionaries. Also improved is an automatic installation process. Setting up multiple columns has been made easier, too, through use of a column layout dialog box instead of using a bevy of dot commands.



An example of the new WordStar's pull-down menus.

In-Use Comments

WordStar's latest version is a nice step forward, making it fully competitive with the few other top-notch, heavyweight word-processing programs on the market. It has its competitive advantages and shortcomings, much as similar packages have.

The new version carries forward the massive changes made in the earlier one last year, as readers may recall when we reviewed it in depth (see *Modern Electronics*, December 1988). These include pull-down menus with selections made by entering an item that's highlighted (while retaining the option of using the old "classic" control- and combination-key command method), automatic paragraph reformat, an outliner, desktop publishing features (including WYSIWYG Page Preview and many more font drivers), file import/export (including direct Lotus 1-2-3 and dBASE data without the need of an intermediary conversion step), extended footnotes and headers, an extensive search/retrieve program, a telecommunications program, windows, and paragraph numbering, among other advances.

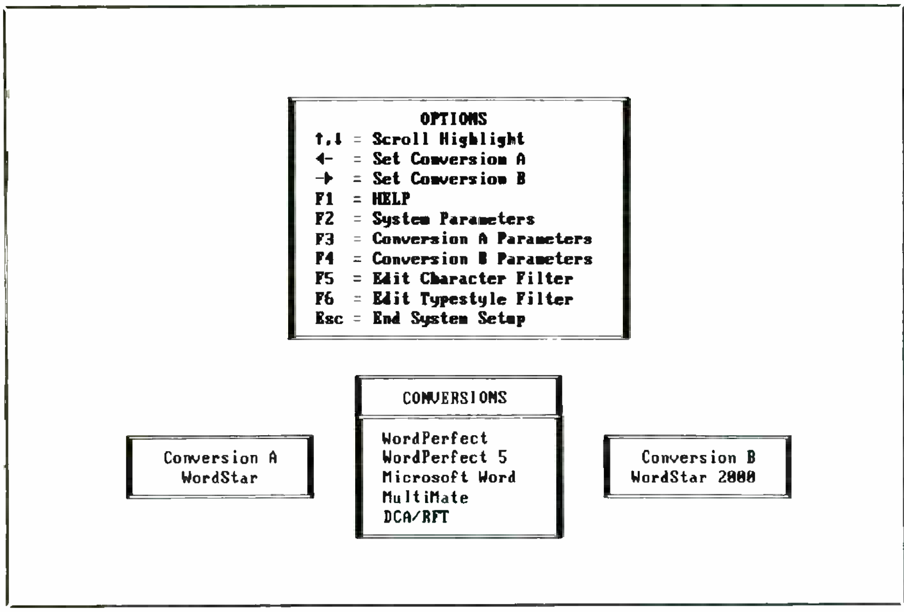
This upgrade gives us an opportunity to revisit the changes made last year with the perspective of a year's worth of experience working with them as well as examining the latest revisions.

Star Exchange, an add-on module that had to be bought separately, but is now included in Version 5.5, is most welcome. Given the enormous popularity of WordPerfect, as well as a few other word-processing packages, it is valuable if you exchange data with non-WordStar users.

The conversion program is easy to use. I had no problem converting programs from and to WordStar without even glancing at the user's manual to learn what to do. The program lists input files and as each one is converted lists the file name in an output column. The input file also displays total number of files to be converted, while the output section displays a running count of the number converted.

I discovered that it does not accept files with suffixes if it already converted one with the same prefix. Thus, in converting a file named Downeast, the program signified a duplicate program when the next one to be converted was Downeast.pre, requesting a new file name or overwrite command. I re-titled the file as Down.pre and it proceeded to do the conversion. All converted files are issued a .ws suffix, so I wound up with a Down.ws file. This information may well be noted in the user's manual, but I did not refer to it.

Converting files, which run automatically, is a little on the slow side compared to WordPerfect's similar function, but it does the job well. A 1,453-byte file re-



The Star exchange menu.

quired 20 seconds to convert, while a 1,662-byte file was clocked at a half-minute. A floppy disk filled with 65 files (258K total) of WordPerfect data consumed 1¼ hours to convert all of it to WordStar 5.5.

WordStar's new paragraph style feature simplifies things when you work with text that requires a lot of format changes since it relieves the user of constantly specifying new fonts, margins, etc. Also, leading (height of space between text lines) is automatically adjusted when new fonts are chosen.

Inset, like Star Exchange, is another program included with WordStar 5.5 that could be bought separately. With it, you can capture graphics from a program and integrate it with text. It's a memory-resident program that can be called up or removed at any time.

Text does not automatically flow around an image unless spacing provisions were made during word-processing. Previewing and the ability to edit allows the user to make any necessary adjustments before printing. Its a nice program nevertheless. Since it is limited to .PIX files, it doesn't support import of some other graphics file formats that are popular. To do this, you'd have to buy an add-on program, Hijaak. I'd guess that the next revision will include this.

The graphics program is versatile. You can modify an image, re-size it, choose a variety of colors from a palette, clip artwork (clip-art files are included with a variety of symbols), choose line widths, rectangles and circles as well as draw with dots, fill in areas, and create a signature file with a password to protect your signature. A mouse can and should be used for efficient work in some of these areas, although one can stick with the keyboard and still make do. Clearly, Inset is a big step forward for WordStar, given the growing appeal of integrating graphics with text.

Conclusions

The new version makes WordStar even more powerful than it was, which is what new versions should be all about. (The previous WordStar wasn't plagued with a lot of bugs, so the latest one wasn't brought out to address such a problem, as is the case with some programs.)

Compared to other leading word processors, WordStar still falls short in some operating speed departments, especially when moving paragraphs or going to the end of a long file. So it falls in the middle of the pack among some eight popular full-power WP packages in terms of raw performance.

In fairness, though, it beats out others in spots here and there. For example, it's got the best page preview function of all; the same goes for its import/export capability in terms of breadth. Its spelling checker and thesaurus take a back seat to none, the choice of fonts is breathtakingly deep, and its documentation is, I think, the best. On the latter, the user's manual comes in bound-text form. A ring binder with three-punch pages is available for $10.

WordStar 5.5 is laden with useful features and still retains its ability to be user-customized. In spite of the riches it now possesses, however, it fails to incorporate a few of the extra features in a seamless manner. Some, like Brown Bag's outliner, which is very good, are clearly add-on modules. That is, a different set of commands are used. This isn't the worst thing in the world, of course. But I, for one, am not enthralled by a requirement to learn more commands. One of the attractions of continuing along with WordStar is my familiarity with its workings. Consequently, the learning curve is minimal. As a result of the cited built-in clumsiness, I do not use the outliner at all.

In the plus department once again is WordStar's relative ease of learning and everyday use. I've noted this many times in the past, disagreeing with the continual commentary of other reviewers that a major shortcoming of WordStar is the difficulty newcomers face in learning how to use the program. Surprise! The latest reviews by others now rank WordStar as the easiest to learn and use among the top-rated full-power word processors, now extolling the virtues of using the control key in combination with another key to get where you want to go. This is the very method that they continually blistered. Perhaps WordStar Inter-

SOFTWARE FOCUS ...

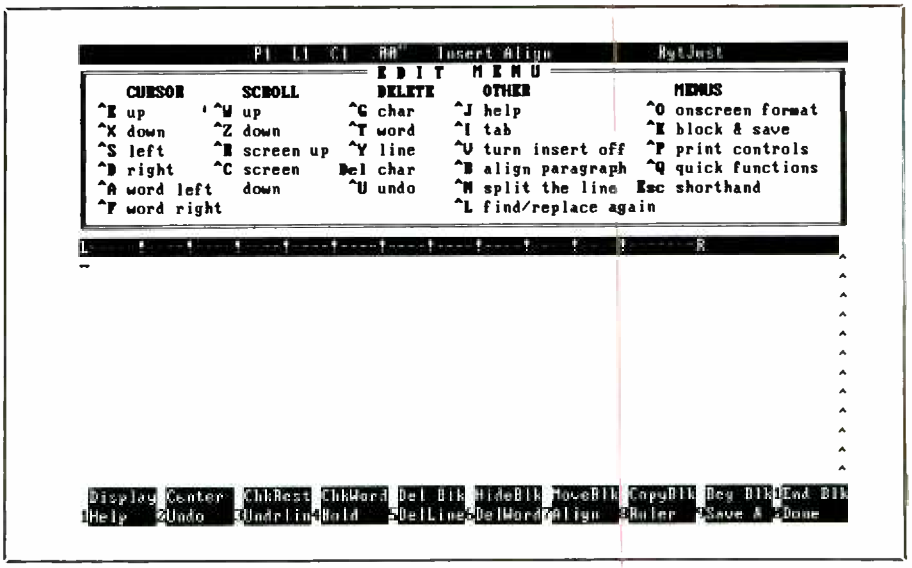
national's (the new corporate name, changed from Micropro) promotion program that WordStar is for "touch typists" brought home this point to reviewers who might have been hunt-and-peck typists all along and couldn't appreciate this potential.

Another very positive aspect of WordStar, although often unheralded, is its superlative error-handling and Help (function key F1) screens.

A criticism I can make for all the powerful word processors that gain muscle upon muscle with every succeeding version is the same one that I observed when "integrated" software first emerged: the programs that were "integrated" into the word processor are not necessarily the best ones available as separate add-ons. Moreover, all the programs are not necessarily desired in the first place. I like WordPerfect's approach to this complaint through an Executive edition that does not include supplementary programs on top of supplementary programs. The price is reduced accordingly. WordStar should do the same.

Although there is a modified version of WordStar built in as an option for users who don't have a hard disk or lots of memory, you lose out on speed and convenient operation if you use it. More than any other earlier version, WordStar 5.5 cries for a hard disk drive and 640K of user memory. The entire program, Postscript files included, requires about 6 megabytes of hard disk space! This can be reduced considerably by deleting lots of printer drivers and fonts that won't be used, but it's still a lot of space, especially when one remembers early WordStars that worked on 64K machines and a CP/M operating system. A sort of virtual memory system made it possible, switching data in and out of memory, onto and off a floppy disk. This considerably slowed down performance of the old WordStar. Later versions operate much faster; so the good old days were really not that good when you think about it.

Working with its predecessor version, 5.0, I came to appreciate its many added benefits even more as time went by. I even use the pull-down menus many times for straight writing purposes, switching to the Classic format when editing and rewriting. Using the latest version, 5.5, is essentially the same, so there's no learning pain. Furthermore, one of WordStar's early strengths, its MailList program, is more powerful than ever. Merging different information into a letter for personalization was never better. This includes invoices, with changing loans and interest calculated and printed automatically, not just switching names and addresses.



An example of the classic WordStar menu.

Version 5.5 adds a Landscape function, allowing wide printing (printing across a paper's length rather than its width). It's easy, too, to set up phone lists, print on Rolodex cards, labels, etc.

An extra in the latest package is the offer of a Bitstream type face starter kit for only $15 S&H, and an introductory subscription to CompuServe.

WordStar 5.5 still has some imperfections, as do similarly all-encompassing programs. There is no doubt that it is now up there with the handful of highly ranked powerful word processors on the market. The "street" prices of software are much less than their suggested manufacturers selling price, of course. I've seen WordStar 5.5 priced at $189, for example, down from $495, as well as WordPerfect for $215, down from $495. I think its a shame that all these manufacturers play such pricing games, but they do. So don't be scared off by "list prices."

Technical support by telephone varied from being exemplary to getting busy signals. The latter is evidently due to heavy sales increases, but promises to greatly improve due to centralizing customer service in the midwest and adding many more trained employees to serve customers without delay.

For newcomers, I heartily recommend WordStar 5.5 for serious consideration among heavyweight word processors, especially if you're a fairly capable typist and you're not locked into special needs such as widespread use of another program in your office. It comes with a fine tutorial, by the way. And if you're already familiar with WordStar typing conventions, it's an even more compelling choice. Believe me, WordStar is more a star than ever, though it doesn't shine the brightest in every single category (none does). **ME** other charge cycle. Thus, a screen sweep occurs only when the input signal falls *below* the trigger threshold set by *R24*. If this sounds backwards, it is because the signal input to the trigger comparator comes from the output of *IC1B*, which is an inverted version of the actual input signal. Thus, to initiate a sweep when the actual input signal reaches $+V_{trigger}$, comparator *IC1D* must switch states when the inverted signal drops to $-V_{trigger}$.

In practice, triggering on the inverted signal presents no difficulties. By taking the signal input to the trigger comparator from *IC1B* instead of *IC1C*, triggering operation remains independent of any dc offset that may have been added to the input signal.

The overall result of the triggered sweep is a fairly stable display of the input signal with its rising edge located in column 1 of the LED display. Notice that because the trigger level from *R24* is fed to the *inverting* input of comparator *IC1D*, the oscilloscope will always trigger on the *rising* edge of the input signal. For maximum flexibility, you can include a dpdt switch that can reverse the inputs to this comparator, which would permit triggering on both the rising and falling edges of an input signal.

Power for the Solid-State Oscilloscope is provided by a bipolar supply made up of two 9-volt batteries. A bipolar supply is needed for the vertical amplifier stages if the oscilloscope is to accept input waveforms with negative voltage portions. While leaving a lot to be desired as a source of power, use of 9-volt batteries does make the oscilloscope a truly portable instrument.

If the oscilloscope is to be used primarily at the workbench, a separate ac-operated ±12-volt, 100-milliampere regulated supply can replace the batteries. Total current drain for the oscilloscope is approximately 35 milliamperes from the V+ and −15 milliamperes from the V− supplies; so fresh 9-volt alkaline batteries should provide several hours of operation.

The drain from the V− supply is considerably less than that from V+ supply. Therefore, you can simply swap the two batteries when they begin to run low to obtain an additional few hours of service.

Construction

Though building the Solid-State Oscilloscope is not a trivial matter, there is nothing particularly difficult about building it, either. The entire project can be assembled in about a week's worth of evenings. If you purchase all new components, total project cost should be $20 to $30.

The Wire Wrap technique is ideal for this project. It makes checking each stage for proper operation as you go along a simple procedure. More importantly, because this project is also intended as an oscilloscope tutorial and trainer, Wire Wrap construction makes designing and testing of circuit modifications and improvements an easy proposition.

Begin construction by mounting and wiring the LED display array into place. In the prototype shown on the cover and in the lead photo, a couple of IEE1257R 5 × 7 LED dot-matrix displays were used because they are designed to fit side-by-side without an intervening gap. However, there is no reason why you cannot use a couple of MAN-2 5 × 7 LED displays, a series of 10-element LED bargraph-type displays, or even individual light-emitting diodes.

Whichever way you go, work carefully and take your time. Wiring the LED display is the most tedious part of the project and, thus, the part most prone to error. When you are finished wiring the display, check your work by connecting each LED in turn to a 9-volt battery through a 520-ohm series resistor, observing proper polarity.

Continue assembly by wiring the basic horizontal and vertical deflection circuits into place. These consist of the LED display, *IC3* and *IC4*. You can check you work at this stage by clocking the input at pin 12 of *IC4* with a signal from a square-wave generator and applying low-amplitude signals to the pin 5 input of *IC3*. Remember at this stage that the display scale factor is just 0.5 volt per row; so full vertical deflection will result with only a 3.5-volt input. When these stages are operating properly, continue construction by adding the input buffer and gain stages. Again, use a frequency generator to check these stages for proper operation when you finish wiring them.

Add the trigger-sweep circuitry next. Then complete the construction by wiring the master clock section, keeping the wiring in this section short and direct. With the component values specified, clock frequencies from 1 kHz to around 1 MHz are possible (horizontal time base values of 1 millisecond to 1 microsecond per division). Poor wiring in the clock circuit, however, could slow the fastest time base by a factor of 2 or 3.

Component values are generally not critical. Even so, try to use at least 5-percent-tolerance resistors throughout to maintain some semblance of accuracy. You might want to use precision 1-percent-tolerance resistors for *R6* through *R12* in the gain section. Also, if possible, use high quality tantalum, Mylar, and silvered-mica capacitors for *C3* through *C12* in the vco clock circuit. The clock will work fine with ordinary ceramic disk capacitors, but the actual time/column for the various switch positions might deviate considerably from the desired values if such capacitors are used.

When all wiring is completed, give the oscilloscope a final visual inspection. Double-check everything, and keep an eye out for loose bits of solder and wire. If you have verified operation of the various stages as you assembled the oscilloscope, your unit should work perfectly the first time. You can give it a final checkout using a signal generator, preferably one with both sine and square wave outputs.

Apply a 60-Hz 5-volt peak-to-peak signal to the oscilloscope input (use the center-tapped output from a 6.3-volt transformer if you do not have a signal generator). Set vertical deflection for 1 volt/row and set *S4* to FREE RUN. The display will probably show a rather random pattern of illuminated LEDs. Set the time base for 1 millisecond/column and slowly adjust the setting of *R32*. As the internal clock nears 600 Hz, the 60-Hz input signal should appear and slowly parade across the display.

Use *S3* to vary the number of volts/row and observe how the signal becomes deflected over a greater or lesser number of rows. Verify that the number of rows of vertical deflection corresponds to the peak-to-peak value of the input signal voltage.

DC OFFSET control *R15* should raise and lower the signal on the screen. Raise the input signal beyond the top row of the display and verify that the OVERRANGE LEDs illuminate. Check triggering action by setting *S4* to TRIG. Adjust TRIGGER LEVEL control *R24* until the oscilloscope sweeps. Verify that the input waveform "freezes" on the screen. With the time base set to 1 millisecond/division, slightly more than one-half of a 60-Hz cycle should fit on the screen.

You can now expand or compress the waveform by changing the time base using *S5* or *R32*. Slowly increase and decrease the trigger voltage level. If you are using a sinusoidal input waveform you will observe the displayed trace begin at higher and lower LED rows. If you adjust the trigger level to a value the input signal never reaches, horizontal sweep will stop and the display will show a bright dot or vertical line in column 1.

Increase the frequency of the input signal by a factor of 2 and then advance TIME/DIV horizontal sweep switch *S5* to its next position. TRIGGER LEVEL control *R24* may need a slight readjustment, but the input signal should immediately reappear.

Continue increasing the input frequency and horizontal sweep rate until you reach the 1 μs position. Apply a 100-kHz signal to the input of the oscilloscope and adjust trimmer capacitor *C12* so that one full cycle of the input signal just fits onto the entire display. This vco is now set for 1-MHz operation.

Improvements

Working with a Solid-State Oscilloscope takes a bit of patience and practice, but you will find that this instrument really is quite flexible and informative. With only 70 LEDs making up the screen, display resolution is rather coarse. However, with a little experience you will soon have no trouble distinguishing between triangle and sine waves or catching the rising and falling portions of high-frequency square waves.

If you do much work with this project, you will find the trigger-sweep feature to be a distinct convenience. As the frequency of the input signal increases, it will become increasingly difficult to adjust the horizontal sweep via *R32* for a steady or slowly parading display. This is where the trigger-sweep feature becomes especially useful. Just flip *S4* to TRIG position and adjust the horizontal time base for a convenient number of input cycles on the display. In fact, with the 1-2-5 time base sequence, you will usually find that one of the "calibrate" values for the time base will provide a stable display without having to move *R32* from its CALIBRATE position.

If the input frequency is relatively low, the trigger circuit will spend a lot of time simply waiting for the input signal to reach the appropriate trigger voltage. This will result in a bright dot or vertical trace appearing in column 1 of the LED display, in addition to the input waveform being examined. That is, the input signal is being displayed without its time component (no horizontal sweep). At higher input frequencies, this vertical trace will become less apparent.

Finally, the Solid-State Oscilloscope is also ideal for expansion and modification. If you wish, experiment with the project by adding digital storage capability. Arrange for the screen display to be "captured" in RAM, from which it can be "recalled" at a later time. The 7489 16 × 4-bit RAM would be ideal for this purpose; you could store the contents of the lower six screen rows in 60 of its 64 memory cells.

Although the vco design used here gives very good performance to well past 1 MHz, you might want to consider using a phase-locked loop and divide-by-N counter (such as the CD4059) with a crystal timebase to build a super-accurate horizontal sweep clock that is set by BCD thumbwheel switches. This would let you read the frequency of the input signal directly from the number dialed on the BCD switches.

The display screen of this oscilloscope is wide open for expansion. With a single LM3914, the display is limited to a maximum of 10 rows, but it is fairly easy to add LM3914s and increase the vertical size of the display. The same goes for the horizontal section. A single 4017 limits the screen width to 10 columns in the basic project, but cascading 4017s broadens the display. If you do go this route, do not forget that for a given clock frequency, the effective horizontal sweep frequency is the clock frequency divided by the number of display columns!

As you can readily see, though this appears to be a very basic instrument, our Solid-State Oscilloscope is endowed with plenty of sophistication. With a little expertise and small investment in components, it can be greatly expanded to provide much of the sophistication of modern instruments, including digital storage capability. ME

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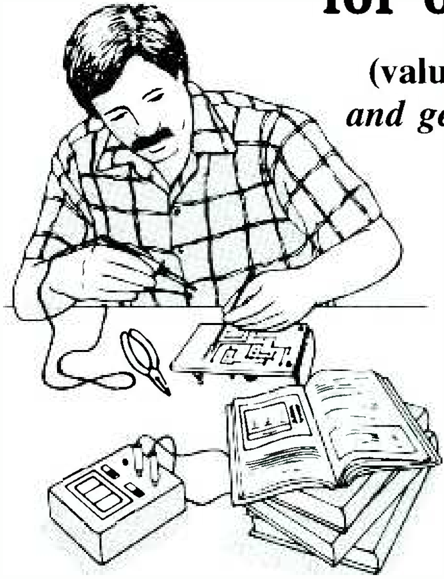

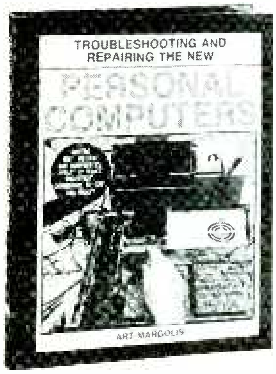

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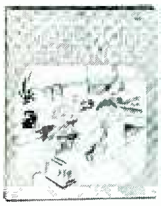
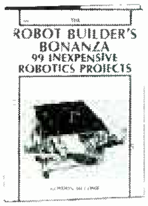


2912P $14.95

3044 $18.95



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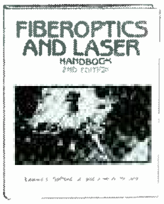

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2900P $24.95
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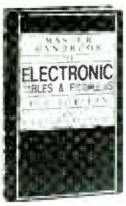
1604P $17.95



1625P $18.95

3107 $26.95
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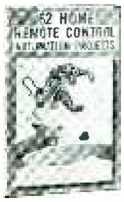

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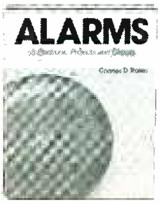
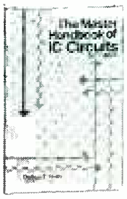
2925 $16.95



2996P $12.95



3185 $34.95
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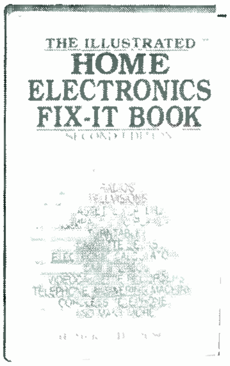

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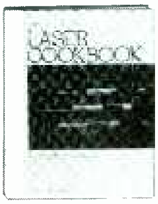

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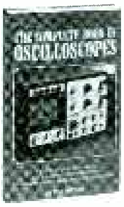

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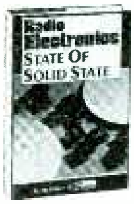

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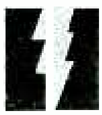

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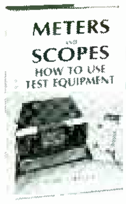

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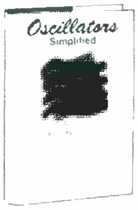

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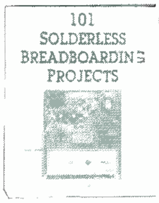

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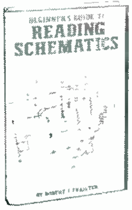

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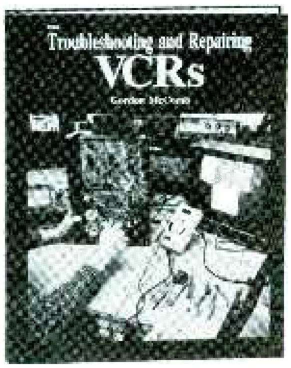

2960 $27.95
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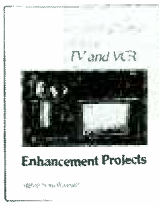

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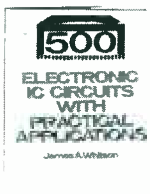

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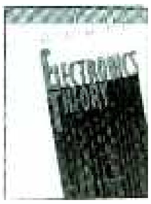

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7404N	.35
7405N	.43
7406N	.48
7407N	.48
7408N	.43
7409N	.43
7410N	.43
7414N	.50
7416N	.35
7417N	.35
7420N	.33
7426N	.35
7427N	.43
7430N	.30
7432N	.35
7437N	.40
7438N	.40
7440N	.48
7442N	.55
7445N	.98
7446AN	.98
7447AN	1.20
7450N	.42
7451N	.48
7453N	.34
7459N	.30
7460N	.34
7473N	.48
7474N	.48
7475N	.50
7476N	.48
7485N	.70
7486N	.48
7489N	7.50
7490N	.55
7493AN	.55
7495N	.63
74107N	.53
74109N	.53
74121N	.60
74123N	.58
74125N	.60
74132N	.75
74145N	1.03
74148N	1.10
74150N	1.58
74151AN	.63
74153N	.63
74154N	1.58
74155N	.60
74157N	.60
74161AN	.75
74164N	.75
74166N	.90
74173N	1.00
74174N	.63
74175N	.63
74180N	.90
74181N	2.50
74182N	1.15
74184N	3.45
74185AN	3.37
74191N	.90
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75492N	1.12
75493N	1.38
75494N	1.38

74LS00 TTL

Part	Price
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74LS03N	.32
74LS04N	.31
74LS05N	.32
74LS08N	.32
74LS09N	.32
74LS10N	.32
74LS11N	.32
74LS12N	.32
74LS14N	.45
74LS15N	.36
74LS20N	.32
74LS21N	.32
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74LS27N	.32
74LS30N	.32
74LS32N	.32
74LS37N	.33
74LS38N	.33
74LS42N	.60
74LS51N	.45
74LS55N	.38
74LS73AN	.42
74LS74AN	.42
74LS75N	.42
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74LS83AN	.66
74LS85N	.66
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81LS96AN	1.89
81LS97AN	1.89
81LS98N	1.89

74S00 TTL

Part	Price
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74S02N	.35
74S03N	.35
74S04N	.35
74S05N	.35
74S08N	.35
74S09N	.38
74S10N	.38
74S11N	.38
74S15N	.50
74S20N	.38
74S22N	.54
74S30N	.46
74S32N	.46
74S40N	.46
74S51N	.45
74S64N	.45
74S65N	.55
74S74N	.43
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74S112N	.50
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74S114N	.82
74S133N	.45
74S134N	.71
74S135N	1.12
74S138N	.88
74S139N	.85
74S140N	.58
74S151N	.85
74S153N	.85
74S157N	.85
74S158N	.85
74S161N	2.38
74S163N	2.38
74S174N	.63
74S175N	.63
74S181N	2.48
74S182N	1.75
74S188N	1.70
74S194N	1.43
74S195N	1.43
74S240N	1.63
74S241N	1.63
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74S251N	1.05
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74S258N	.90
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74S287N	2.00
74S288N	1.70
74S373N	1.75
74S374N	1.75
74S387N	1.95
74S472N	4.80
74S473N	4.80
74S474N	4.80
74S475N	4.80
74S570N	3.75
74S571N	3.75
74S572N	4.50
74S573N	5.00
74S940N	3.50
74S941N	3.50

74C00 CMOS

Part	Price
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74C02N	.45
74C04N	.45
74C08N	.45
74C10N	.45
74C14N	.33
74C20N	.45
74C30N	.45
74C32N	.48
74C42N	1.05
74C48N	1.33
74C73N	.65
74C74N	.63
74C76N	.65
74C83N	1.60
74C85N	1.60
74C86N	.53
74C89N	5.00
74C90N	1.23
74C93N	1.23
74C95N	1.50
74C107N	.85
74C150N	3.98
74C151N	2.60
74C154N	3.98
74C157N	2.60
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74C161N	.83
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74C175N	.55
74C192N	1.10
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74C221N	1.50
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74C928N	6.38
74C932N	1.23
74C941N	1.98
74C945N	11.25
74C947N	11.25
80C95N	.55
80C96N	.55
80C98N	.55
82C19N	3.98

74HC00 CMOS

Part	Price
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74HC02N	.28
74HC04N	.28
74HC08N	.28
74HC10N	.28
74HC11N	.28
74HC14N	.39
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74HC75N	.39
74HC76N	.50
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74HC86N	.45
74HC107N	.53
74HC112N	.53
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74HC125N	.48
74HC126N	.53
74HC133N	.38
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74HC151N	.55
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74HC154N	1.13
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74HC574N	1.10
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74HC4002N	.28
74HC4020N	.93
74HC4040N	.93
74HC4049N	.70
74HC4050N	.70
74HC4060N	1.10
74HC4075N	.28
74HC4078N	.30
74HC4306	1.64
74HC4514N	1.50
74HC4538N	1.05
74HC4543N	1.37

4000 CMOS

Part	Price
4001BCN	.27
4002BCN	.40
4006BCN	.63
4007CN	.28
4008BCN	.65
4009CN	.35
4010CN	.38
4011BCN	.28
4012BCN	.28
4013BCN	.30
4014BCN	.70
4015BCN	.55
4016BCN	.30
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4019BCN	.35
4020BCN	.60
4021BCN	.60
4022BCN	.55
4023BCN	.28
4024BCN	.45
4025BCN	.28
4027BCN	.33
4028BCN	.55
4029BCN	.75
4030CN	.30
4031B	.83
4034BCN	1.13
4035BCN	.75
4040BCN	.60
4041CN	.63
4042BCN	.63
4043BCN	.63
4044BCN	.63
4046BCN	.65
4047BCN	.75
4048BCN	.35
4049CN	.33
4050BCN	.33
4051BCN	.55
4052BCN	.55
4053BCN	.55
4060BCN	.58
4066BCN	.33
4071BCN	.28
4072BCN	.50
4073BCN	.28
4075BCN	.28
4081BCN	.28
4082B	.28
4089BCN	1.00
4093BCN	.30
4099BCN	.78
4503BCN	.33
4510BCN	.80
4511BCN	.80
4512BCN	.80
4514BCN	1.08
4515BCN	1.08
4516BCN	.83
4518BCN	.83
4519BCN	.48
4520BCN	.73
4522BCN	.90
4526BCN	1.03
4527BCN	.88
4528BCN	.83
4529BCN	.83
4541BCN	.80
4543BCN	.83
4723BCN	.95
4724BCN	.83

Linear

Part	Price
LF347N	1.20
LF351N	.60
LF353N	1.05
LF355N	1.20
LF356N	1.20
LF357N	1.50
LF398N	3.36
LF411CN	1.05
LF412CN	1.74
LF441CN	.90
LF444CN	1.80
LF13741N	.78
LM10CLN	2.70
LM11CLN	2.55
LM34CZ	6.00
LM35CZ	6.00
LM301AN	.57
LM307N	.75
LM308N	.90
LM311N	.54
LM317K	4.95
LM317LZ	.92
LM317MP	.86
LM317T	.99
LM318N	1.65
LM319N	1.50
LM320LZ 5.0	.72
LM320LZ 12	.60
LM320LZ 15	.72
LM320MP 5	2.25
LM320MP 12	1.90
LM320MP 15	1.95
LM322N	2.40
LM323K	8.25
LM324N	.54
LM325N	5.12
LM326N	6.00
LM327N	3.38
LM329DZ	.81
LM331N	5.25
LM334Z	1.65
LM335Z	2.10
LM336Z 2.5	1.20
LM336Z 5.0	1.20
LM337K	7.65
LM337MP	1.80
LM337T	1.95
LM338K	10.20
LM339N	.51
LM340KC 5	2.10
LM340KC 12	2.10
LM340KC 15	2.10
LM340T 5	.87
LM340T 12	.87
LM340T 15	.78
LM341P 5	.90
LM341P 12	1.00
LM341P 15	.90
LM346N	1.65
LM348N	.90
LM349N	1.35
LM350K	7.50
LM350T	4.95
LM358N	.51
LM359N	2.40
LM380N	1.50
LM380N 8	1.50
LM381N	2.61
LM382N	1.86
LM383AT	4.05
LM384N	2.55
LM386N 1	.81
LM387N	1.65
LM389N	1.38
LM390N	1.32
LM391N 60	2.00
LM391N 100	2.40
LM392N	.75
LM393N	.51
LM395P	2.40
LM395T	3.00
LM395K	10.50
LM396K	21.00
LM555CN	.75
LM556CN	.90
LM565CN	1.95
LM566CN	1.56
LM567CN	1.11
LM709CN	.75
LM723CN	.75
LM725CN	2.70
LM733CN	.84
LM741CN	.51
LM747CN	.72
LM748CN	.72
LM1458N	.54
LM1496N	1.50
LM1800N	1.95
LM1801N	1.35
LM1812N	12.30
LM1830N	2.55
LM1870N	3.00
LM1871N	2.40
LM1872N	2.55
LM1875T	5.25
LM1889N	2.16
LM2900N	1.50
LM2901N	.60
LM2902N	.60
LM2903N	.57
LM2904N	.57
LM2905N	3.90
LM2907N	1.80
LM2907N 8	2.70
LM2917N	2.25
LM2917N 8	2.25
LM2924N	2.61
LM2931Z 5.0	.66
LM2931T 5.0	.95
LM2931CT	1.65
LM3046N	1.35
LM3080N	1.26
LM3086N	.84
LM3089N	2.55
LM3146N	1.53
LM3301N	.99
LM3302N	.99
LM3401N	1.02
LM3524N	3.75
LM3900N	.69
LM3905N	1.80
LM3909N	1.50
LM3911N	2.25
LM3914N	2.85
LM3915N	2.85
LM3916N	2.85
LM78L05ACZ	.45
LM78L12ACZ	.54
LM78L15ACZ	.54
LM7905CT	.93
LM7912CT	.96
LM7915CT	.96
LM13080N	1.80
LM13600N	1.44
MF10CCN	4.20
LM7805	.75
LM7806	.75
LM7807	.75
LM7808	.75
LM7809	.75
LM7810	.75
LM7812	.75
LM7815	.75
LM7818	.75
LM7820	.75
LM78L05	.43
LM78L06	.43
LM78L07	.43
LM78L08	.43
LM78L09	.43
LM78L10	.43
LM78L12	.43
LM78L15	.43
LM78L18	.43
LM78L20	.43
LM78L24	.43
LM78M05	.63
LM78M06	.63
LM78M08	.63
LM78M09	.63
LM78M10	.63
LM78M12	.63
LM78M15	.63
LM78M18	.63
LM78M20	.63
LM78M24	.63
LM7905	.75
LM7906	.75
LM7907	.75
LM7908	.75
LM7909	.75
LM7910	.75
LM7912	.75
LM7915	.75
LM7918	.75
LM7920	.75
LM7924	.75
LM79L05	.43
LM79L06	.43
LM79L07	.43
LM79L08	.43
LM79L09	.43
LM79L10	.43
LM79L12	.43
LM79L15	.43
LM79L18	.43
LM79L20	.43
LM79L24	.43
AN79M05	.63
AN79M06	.63
AN79M07	.63
AN79M08	.63
AN79M09	.63
AN79M10	.63
AN79M12	.63
AN79M15	.63
AN79M18	.63
AN79M20	.63
AN79M24	.63

Memory

Part	Price
MM2147N	17.50
MM5257N	2.40
74C200N	9.37
74C910N	6.87
74S188N	1.70
74S189N	2.10
74S287N	2.00
74S288N	1.70
74S289N	2.10
74S387N	1.95
74S472AN	4.80
74S473AN	4.80
74S474AN	4.80
74S475AN	4.80
74S570N	3.75
74S571N	3.75
74S572N	4.50
74S573N	4.50

Micro.

Part	Price
COP402N	7.75
COP470N	4.13
COP498N	5.38
COP499N	5.38
DP8212N	3.38
DP8216N	2.75
DP8224N	3.75
DP8226N	2.25
DP8228N	6.88
DP8238N	6.88
DP8303N	6.87
DP8304BN	2.13
DP8307N	1.88
DP8308N	3.25
DP8310N	2.74
DP8311N	5.88
INS8035N 6	5.88
INS8039N 6	3.50
INS8035N 11	3.38
INS8039N 6	3.25
INS8039N 11	5.63
INS8154N	17.50
ISP 8A/652	25.00
MM58167AN	10.63
MM58174AN	10.25
NSC800N	18.25
NSC800-1	9.25
DM8334N	2.25

A/D & D/A

Part	Price
ADC0801LCN	7.38
ADC0803LCN	4.50
ADC0804LCN	5.00
ADC0808CCN	8.13
ADC0808CCN	4.75
ADC0816CCN	18.00
ADC0817CCN	11.25
ADC0833CCN	5.00
ADC1001CCJ	32.00
ADC3511CCN	8.25
ADC3711CCN	8.25
DAC0801LCN	8.88
DAC0830LCN	8.88
DAC0806LCN	1.85
DAC0807LCN	1.58
DAC0808LCN	1.65
DAC0830LCN	6.90
DAC0831LCN	3.88
DAC1020LCN	7.50
DAC1022LCN	5.75
MM53H9AAN	1.63
MM53H9LST	1.63

Interface

Part	Price
DS1488N	.85
DS1489AN	1.20
DS1488N	.85
75150N	.87
75451N	.70
75452N	.70
75453N	.70
75454N	.70
75491N	1.00
75492N	1.12
75493N	1.37
75494N	1.37

SILICON TRANSISTORS

Digi Key Part No.	Pac Price	Digi Key Part No.	Pac Price	Digi Key Part No.	Pac Price
2N3117	1.37	2N5416	2.00	MPS3393	.27
2N3055	1.47	2N5457	.60	MPS3565	.23
2N3439	1.75	2N5550	.30	MPS3638A	.23
2N3440	1.40	2N5679	2.55	MPS3563	.30
2N3700	1.00	2N5680	2.50	MPS3640	.52
2N3724	1.06	2N5681	2.60	MPS3646	.27
2N3903	.23	2N5682	2.60	MPS3704	.23
2N3904	.23	2N5769	.23	MPS5172	.65
2N3905	.14	2N5771	1.25	MPS6651	.24
2N3906	.23	2N5772	.31	MPS6514	.28
2N3962	1.16	2N5830	.65	MPS6515	.24
2N4030	1.12	2N5831	.70	MPS6520	.41
2N4032	1.12	2N5833	.75	MPSA05	.45
2N4033	1.24	2N5961	.51	MPSA06	.15
2N4036	1.40	2N6715	.35	MPSA10	.27
2N4037	1.40	2N6725	.49	MPSA12	.52
2N4123	.23	2N6727	.35	MPSA13	.52
2N4124	.23	2N718A	1.15	MPSA14	.30
2N4125	.23	2N7132A	2.04	MPSA18	.45
2N4126	.23	2N1613	.92	MPSA20	.45
2N4208	.21	2N1893	1.14	MPSA42	.45
2N4209	2.10	2N2218	.75	MPSA43	.45
2N4234	2.10	2N2218A	.95	MPSA55	.36
2N4235	2.30	2N2219	.76	MPSA56	.24
2N4236	2.30	2N2219A	.76	MPSA63	.36
2N4237	2.30	2N2221	.80	MPSA64	.23
2N4238	2.30	2N2221A	.80	MPSA92	.25
2N4239	2.30	2N2222	.60	MPSA93	.25
2N4240	2.30	2N2222A	.60	PN2222	.30
2N4401	.23	2N2369	.60	PN2222A	.23
2N4402	.23	2N2369A	.60	PN2369	.23
2N4403	.23	2N2405	1.45	PN2369A	.39
2N4410	.36	2N2484	.84	PN2907	.28
2N4896	2.90	2N2904	.95	PN2907A	.31
2N5086	.28	2N2905	.76	PN3251	.28
2N5087	.28	2N2905A	.76	PN3565	.24
2N5088	.28	2N2906	.60	PN3566	.30
2N5089	.28	2N2906A	.60	PN3567	.30
2N5210	.29	2N2907	.60	PN3569	.23
2N5223	.28	2N2907A	.60	PN3638	.23
2N5225	.23	2N3013	1.10	PN3640	.30
2N5226	.23	2N3019	1.04	PN3643	.32
2N5227	.23	2N3020	1.04	PN3644	.32
2N5320	2.30	2N3053	1.04	PN3645	.35
2N5321	2.60	2N3107	1.30	PN3646	.32
2N5322	2.30	2N3108	1.30	PN4122	.34
2N5323	1.81	MPS2907A	.23	PN4248	.34
2N5400	.31	MPS3392	.24	PN4249	.40
2N5401	.31			PN4250	.30
2N5415	1.80			PN4250A	.40
				PN4258	.29
				PN1275	.29
				PN4355	.36

Part	Price	Part	Price	Part	Price
PN4356	.37	PN5128	.26	PN5136	.27
PN4888	.56	PN5133	.27	PN5138	.24
PN4889	.70	PN5134	.26	PN5139	.35
PN4916	.36	PN5135	.35	PN5142	.27
PN4917	.36				

1 AMP SILICON RECTIFIES

Part No.	Description	Pkg.	1	10	1000	1,000
1N4001	50 PIV	DO 41		.70	5.60	49.00
1N4002	100 PIV	DO 41		.75	6.00	52.50
1N4003	200 PIV	DO-41		.80	6.40	56.00
1N4004	400 PIV	DO 41		.85	6.80	59.50
1N4005	600 PIV	DO-41		.88	7.00	61.25
1N4006	800 PIV	DO 41		.98	7.80	68.25
1N4007	1000 PIV	DO 41		1.08	8.60	75.25

5% CARBON FILM RESISTORS

Available in 1/8, 1/4 & 1/2 Watt

How To Order: Take any standard resistor value (i.e. 3.2) and add an "E" for 1/8 watt or a "Q" for 1/4 watt or an "H" for 1/2 watt (i.e. 3.2Ω for 3.2Ω 1/4 watt), this is the Digi-Key part number.

Pricing	5	200	1,000
1/8 Watt	.25	6.40	25.00
1/4 Watt	.25	3.40	13.00
1/2 Watt	.25	3.50	16.00

1/8 Watt Resistor Assortments

RS112 Set of 5 each of the 73 standard 5% 1/8 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces) — $9.90

RS212 Set of 5 each of the 72 standard 5% 1/8 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces). — $9.90

1/4 Watt Resistor Assortments

RS125 Set of 5 each of the 73 standard 5% 1/4 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces) — $9.90

RS225 Set of 5 each of the 72 standard 5% 1/4 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4 etc., through 910 kilohm (360 total pieces) — $9.90

1/2 Watt Resistor Assortments

RS150 Set of 5 each of the 73 standard 5% 1/2 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohms (365 total pieces) — $9.90

RS250 Set of 5 each of the 72 standard 5% 1/2 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces). — $9.90

5% WIREWOUND REC. RESISTORS

Available in 5 & 10 Watt

How To Order: Take any standard resistor value (i.e. 7.5) and add "W5" for 5 watt, or add a "W10" for 10 watt (i.e. 7.5W5 for 7.5Ω 5 watt), this is the Digi-Key part number.

Pricing	1	10	100	500	1,000
5 Watt	.36	3.25	26.90	100.80	162.00
10 Watt	.41	3.78	31.90	118.00	212.00

5 Watt Metal Resistor Assortments

RS105 5 each of values 0.30Ω to 0.91Ω (300 total pieces) — $20.10

RS205 4 each of values 1.0Ω to 9.1Ω (384 total pieces) — $31.30

RS305 4 each of values 10Ω to 91Ω (384 total pieces) — $31.30

RS405 4 each of values 100Ω to 2.0KΩ (288 total pieces) — $31.30

10 Watt Resistor Assortments

R110 2 each of all 10 watt standard resistor values listed in the Digi Key catalog. (168 total pieces) — $58.95

5% METAL OXIDE FILM RESISTORS

Available in 1 & 2 Watt

How To Order: Take any standard resistor value (i.e. 1.5K) and add a "W1" for 1 watt, or add a "W2" for 2 watt (i.e. 1.5KW1 for 1.5KΩ 1 watt), this is the Digi-Key part number.

Pricing	1	5	100	500	1,000
1 Watt (0.47-0.91Ω)	.21	.98	12.60	56.00	101.50
1 Watt (1.0-1.0MΩ)	.15	.70	9.00	40.00	72.50
2 Watt (0.47-0.91Ω)	.23	1.06	13.15	59.40	109.40
2 Watt (1.0-1.0MΩ)	.18	.85	10.50	47.50	87.50

1 Watt Metal Resistor Assortments

RS101 5 each of values 0.47Ω to 56Ω (255 total pieces) — $26.95

RS201 5 each of values 62Ω to 7.5KΩ (255 total pieces) — $26.95

RS301 5 each of values 8.2KΩ to 1.0M (255 total pieces) — $76.95

2 Watt Resistor Assortments

RS102 5 each of values 0.47Ω to 56Ω (255 total pieces) — $29.95

RS202 5 each of values 62Ω to 7.5KΩ (255 total pieces) — $29.95

RS302 5 each of values 8.2KΩ to 1.0M (255 total pieces) — $29.95

1% METAL OXIDE FILM RESISTORS

Available in 1/4 Watt

How To Order: Take any standard resistor value (i.e. 1.69K) and add an "X" (i.e. 1.69KX), this is the Digi-Key part number.

Pricing	5	200	1,000
1/4 Watt	.50	7.80	30.00

1/4 Watt Metal Film Resistor Assortments

RS1X 5 each of values 10Ω to 97.6Ω (480 total pieces) — $29.95

RS2X 5 each of values 100Ω to 976Ω (480 total pieces) — $29.95

RS3X 5 each of values 1.00KΩ to 9.76KΩ (480 total pieces) — $29.95

RS4X 5 each of values 10.0KΩ to 97.6KΩ (480 total pieces) — $29.95

RS5X 5 each of values 100KΩ to 1.00MΩ (480 total pieces) — $29.95

PANASONIC® SU SERIES

Miniature Aluminum Electrolytic Capacitors

WV/Cap. (VDC)/(µF)	Axial Lead Digi-Key Part No.	Price 1	Radial Lead Digi-Key Part No.	Price 1
6.3/47	P6301	.25		
6.3/100	P6302	.26	P6201	.16
6.3/220	P6303	.35	P6202	.21
6.3/330	P6304	.42	P6203	.22
6.3/470	P6305	.46	P6204	.23
6.3/1,000	P6306	.64	P6205	.38
6.3/2,200	P6307	.81	P6206	.62
6.3/3,300	P6308	.95	P6207	.81
6.3/4,700	P6309	1.13	P6208	1.01
6.3/6,800	P6310	1.48	P6209	1.22
6.3/10,000	P6311	1.97	P6210	1.62
6.3/15,000	P6312	2.67	P6211	2.64
6.3/22,000	P6313	3.82		
10/22	P6314	.21		
10/33	P6315	.27	P6212	.14
10/47	P6316	.28	P6213	.14
10/100	P6317	.33	P6214	.16
10/220	P6318	.41	P6215	.22
10/330	P6319	.49	P6216	.24
10/470	P6320	.53	P6217	.33
10/1,000	P6321	.73	P6218	.42
10/2,200	P6322	.99	P6219	.75
10/3,300	P6323	1.16	P6220	.87
10/4,700	P6324	1.49	P6221	1.19
10/6,800	P6325	1.86	P6222	1.62
10/10,000	P6326	2.65	P6223	2.31
10/15,000	P6327	3.79		
10/22,000	P6328	5.10		
16/22	P6329	.27	P6224	.14
16/33	P6330	.28	P6225	.15
16/47	P6331	.33	P6226	.16
16/100	P6332	.29	P6227	.21
16/220	P6333	.47	P6228	.24
16/330	P6334	.53	P6229	.31
16/470	P6335	.63	P6230	.39
16/1,000	P6336	.82	P6231	.50
16/2,200	P6337	1.13	P6232	
16/3,300	P6338	1.49	P6233	1.24
16/4,700	P6339	1.75	P6234	1.62
16/6,800	P6340	2.14	P6235	2.31
16/10,000	P6341	4.04		
16/15,000	P6342	5.16		
25/10	P6343	.21		
25/22	P6344	.26	P6236	.15
25/33	P6345	.29	P6237	.16
25/47	P6346	.34	P6238	.20
25/100	P6347	.42	P6239	.22
25/220	P6348	.49	P6240	.33
25/330	P6349	.57	P6241	.42
25/470	P6350	.66	P6242	.50
25/1,000	P6351	.89	P6243	.82
25/2,200	P6352	1.35	P6244	1.24
25/3,300	P6353	1.71	P6245	1.74
25/4,700	P6354	2.55	P6246	2.48
25/6,800	P6355	3.79		
25/10,000	P6356	4.95		
35/4.7	P6357	.21	P6247	.14
35/10	P6358	.26	P6248	.14
35/22	P6359	.29	P6249	.20
35/33	P6360	.35	P6250	.21
35/47	P6361	.42	P6251	.23
35/100	P6362	.46	P6252	.26
35/220	P6363	.56	P6253	.42
35/330	P6364	.66	P6254	.53
35/470	P6365	.72	P6255	.65
35/1,000	P6366	1.03	P6256	.97
35/2,200	P6367	1.71	P6257	1.74
35/3,300	P6368	2.24	P6258	2.48
35/4,700	P6369	3.47		
35/6,800	P6370	4.88		
50/0.47	—	—	P6259*	.13
50/1.0	—	—	P6260*	.13
50/2.2	—	—	P6261*	.13
50/3.3	P6371	.21	P6262*	.14
50/4.7	P6372	.26	P6263*	.14
50/10	P6373	.29	P6264*	.16
50/22	P6374	.35	P6265*	.22
50/33	P6375	.41	P6266*	.23
50/47	P6376	.45	P6267*	.24
50/100	P6377	.49	P6268*	.38
50/220	P6378	.70	P6269*	.53
50/330	P6379	.79	P6270*	.77
50/470	P6380	.95	P6271*	.90
50/1,000	P6381	1.38	P6272*	1.34
50/2,200	P6382	2.52	P6273*	2.38
50/3,300	P6383	3.63		
50/4,700	P6384	4.79		
63/0.47	P6385	.21	P6274	.14
63/1.0	P6386	.21	P6275	.14
63/2.2	P6387	.21	P6276	.15
63/3.3	P6388	.26	P6277	.16
63/4.7	P6389	.29	P6278	.18
63/10	P6390	.34	P6279	.18
63/22	P6391	.42	P6280	.24
63/33	P6392	.47	P6281	.27
63/47	P6393	.47	P6282	.40
63/100	P6394	.59	P6283	.53
63/220	P6395	.78	P6284	.77
63/330	P6396	.92	P6285	.97
63/470	P6397	1.12	P6286	1.14
63/1,000	P6398	1.75	P6287	1.74
63/2,200	P6399	3.53		
63/3,300	P6400	4.83		
100/0.47	P6401	.21	P6288	.21
100/1.0	P6402	.21	P6289	.22
100/2.2	P6403	.26	P6290	.23
100/3.3	P6404	.29	P6291	.24
100/4.7	P6405	.34	P6292	.26
100/10	P6406	.42	P6293	.31
100/22	P6407	.48	P6294	.40
100/33	P6408	.54	P6295	.46
100/47	P6409	.57	P6296	.52
100/100	P6410	.82	P6297	.81
100/220	P6411	1.22	P6298	1.09
100/330	P6412	1.54	P6299	1.32
100/470	P6413	2.02	P6300	1.89
100/1,000	P6414	3.94		
160/0.47	—		P6415	.23
160/1.0	—		P6416	.24
160/2.2	—		P6417	.27
160/3.3	—		P6418	.36
160/4.7	—		P6419	.37
160/10	—		P6178	.46
160/22	—		P6179	.65
160/33	—		P6180	.85
160/47	—		P6181	1.13
160/100	—		P6182	1.25
160/220	—		P6183	2.15
250/1.0	—		P6184	.40
250/2.2	—		P6185	.42
250/3.3	—		P6186	.43
250/4.7	—		P6187	.43
250/10	—		P6188	.61
250/22	—		P6189	.87
250/33	—		P6190	.98
250/47	—		P6191	1.28
250/100	—		P6192	2.19
450/1.0	—		P6193	.47
450/2.2	—		P6194	.55
450/3.3	—		P6195	.73
450/4.7	—		P6196	.79
450/10	—		P6197	.98
450/22	—		P6198	1.57
450/33	—		P6199	2.04

DISC CAPACITORS

Part No	Cap./Volt. (pf)/(V)	Price 10	Part No	Cap./Volt.	Price 10
			P4158	10000/50	1.24
			P4159	15000/50	1.35
P4000	10/500	.71	P4160	22000/50	1.95
P4002	15/500	.64	P4100	100/500	.68
P4003	18/500	.64	P4102	150/500	.68
P4004	22/500	.64	P4103	180/500	.68
P4005	27/500	.64	P4104	220/500	.68
P4006	33/500	.64	P4105	270/500	.68
P4007	39/500	.64	P4106	330/500	.68
P4008	47/500	.64	P4107	390/500	.68
P4009	56/500	.64	P4108	470/500	.79
P4010	68/500	.71	P4109	560/500	.79
P4011	82/500	.71	P4110	680/500	.79
P4141	1000/25	.98	P4111	820/500	.79
P4142	1500/25	.98	P4112	1000/500	.94
P4143	2200/25	.98	P4114	1500/500	.94
P4144	3300/25	.98	P4116	100/1K	1.28
P4145	4700/25	1.09	P4117	120/1K	1.28
P4146	6800/25	1.09	P4118	150/1K	1.28
P4147	10000/25	1.13	P4119	180/1K	1.28
P4148	15000/25	1.20	P4120	220/1K	1.28
P4149	22000/25	1.20	P4121	270/1K	1.28
P4150	33000/25	1.76	P4122	330/1K	1.99
P4152	1000/50	1.09	P4123	390/1K	1.99
P4153	1500/50	1.09	P4124	470/1K	1.99
P4154	2200/50	1.09	P4125	560/1K	1.99
P4155	3300/50	1.09	P4126	680/1K	1.99
P4156	4700/50	1.20	P4127	820/1K	2.25
P4157	6800/50	1.24	P4128	1000/1K	2.25

DISC CAPACITORS

Part	Cap./Volt.	Price	Part	Cap./Volt.	Price
P4129	1200/1K	2.25	P4307	.047 µf/25	.79
P4130	1500/1K	2.25	P4311	.1 µf/25	1.61
P4131	1800/1K	2.25	P4418	1000/25	.75
P4132	2200/1K	2.93	P4419	1500/25	.75
P4133	2700/1K	2.93	P4420	2200/25	.75
P4134	3300/1K	2.93	P4421	3300/25	.75
P4135	3900/1K	4.46	P4422	4700/25	.75
P4136	4700/1K	5.36	P4423	6800/25	.83
P4137	5600/1K	5.36	P4424	10000/25	.83
P4138	6800/1K	8.44	P4425	15000/25	.90
P4139	8200/1K	8.44	P4426	22000/25	.94
P4140	10000/1K	8.44	P4427	33000/25	.94
P4161	10000/50	.86	P4428	47000/25	1.55
P4162	22000/50	.94	P4429	68000/25	1.73
P4163	47000/50	1.01	P4430	100000/25	1.91
P4164	100000/50	1.13	P4431	1000/50	.86
DH682	6800/50	.90	P4432	1500/50	.86
P4200	1000/100	.68	P4433	2200/50	.86
P4202	1500/100	.68	P4434	3300/50	.86
P4203	2200/100	.79	P4435	4700/50	.86
P4205	3300/100	.79	P4436	6800/50	.94
P4206	4700/100	1.09	P4437	10000/50	1.01
P4209	6800/100	.71	P4438	15000/50	1.01
P4300	.01µf/25	.56	P4439	22000/50	1.09
P4303	.022 µf/25	.64	P4440	33000/50	1.73
P4305	.033 µf/25	.64	P4441	47000/50	1.73

NPO NPO NPO NPO NPO NPO NPO NPO

Part	Cap./Volt.	Price	Part	Cap./Volt.	Price
P4400	10/500	.68	P4409	56/500	1.13
P4402	15/500	.79	P4410	68/500	1.28
P4403	18/500	.79	P4411	82/500	1.91
P4404	22/500	.79	P4412	100/500	1.91
P4405	27/500	.79	P4413	120/500	1.91
P4406	33/500	.98	P4414	150/500	2.03
P4407	39/500	.98	P4415	180/500	2.70
P4408	47/500	1.13	P4416	220/500	2.70

TANTALUM CAPACITORS

Part No.	Cap./Volt. (µF)/DC	Price 1	Part No.	Cap./Volt.	Price 1
			P2045	2.2/25	.34
			P2046	3.3/25	.42
P2011	4.7/6.3	.31	P2047	4.7/25	.54
P2012	6.8/6.3	.34	P2048	6.8/25	.65
P2013	10/6.3	.42	P2049	10/25	1.06
P2014	15/6.3	.50	P2050	15/25	1.19
P2015	22/6.3	.60	P2051	22/25	1.68
P2016	33/6.3	.72	P2052	33/25	2.36
P2017	47/6.3	.85	P2053	0.1/35	.27
P2018	68/6.3	1.18	P2054	0.15/35	.27
P2019	100/6.3	1.82	P2055	0.22/35	.27
P2020	150/6.3	3.60	P2056	0.33/35	.27
P2094	220/6.3	7.85	P2057	0.47/35	.27
P2095	330/6.3	11.65	P2058	0.68/35	.28
P2022	2.2/10	.28	P2059	1.0/35	.31
P2023	3.3/10	.31	P2060	1.5/35	.34
P2024	4.7/10	.34	P2061	2.2/35	.42
P2025	6.8/10	.42	P2062	3.3/35	.51
P2026	10/10	.50	P2063	4.7/35	.65
P2027	15/10	.60	P2064	6.8/35	.90
P2028	22/10	.72	P2065	10/35	1.19
P2029	33/10	.85	P2066	15/35	1.88
P2030	47/10	1.18	P2099	.047/35	.43
P2031	68/10	1.82	P2100	.068/35	.43
P2032	100/10	3.60	P2101	22/35	2.56
P2083	150/10	6.98	P2102	33/35	4.46
P2084	220/10	9.63	P2103	47/35	13.36
P2033	1.5/16	.23	P2067	0.1/50	.28
P2034	2.2/16	.31	P2068	0.15/50	.30
P2035	3.3/16	.33	P2069	0.22/50	.30
P2036	4.7/16	.42	P2070	0.33/50	.30
P2037	6.8/16	.50	P2071	0.47/50	.33
P2038	10/16	.60	P2072	0.68/50	.37
P2039	15/16	.74	P2073	1.0/50	.50
P2040	22/16	.88	P2074	1.5/50	.84
P2041	33/16	1.18	P2075	2.2/50	.90
P2042	47/16	1.82	P2076	3.3/50	1.48
P2043	68/16	3.60	P2077	4.7/50	1.89
P2086	150/16	9.08	P2078	6.8/50	3.90
P2096	100/16	6.98	P2104	10/50	5.40
P2044	1.5/25	.31	P2093	15/50	8.37

PANASONIC® V SERIES

Stacked Metalized Film Capacitors

Part No.	Cap./Volt. (µF)/VAC	Price 10	Part No.	Cap./Volt.	Price 10
			P4535	0.68/50	4.83
			P4536	0.82/50	5.74
P4513	0.01/50	1.23	P4537	1.0/50	6.62
P4514	0.012/50	1.26	P4713	0.01/100	1.81
P4515	0.015/50	1.28	P4714	0.012/100	1.38
P4516	0.018/50	1.32	P4715	0.015/100	1.81
P4517	0.022/50	1.35	P4716	0.018/100	1.81
P4518	0.027/50	1.38	P4717	0.022/100	1.85
P4519	0.033/50	1.41	P4718	0.027/100	1.89
P4520	0.039/50	1.44	P4719	0.033/100	1.93
P4521	0.047/50	1.47	P4720	0.039/100	1.96
P4522	0.056/50	1.54	P4721	0.047/100	2.03
P4523	0.068/50	1.63	P4722	0.056/100	2.10
P4524	0.082/50	1.73	P4723	0.068/100	2.23
P4525	0.1/50	1.69	P4724	0.082/100	2.25
P4526	0.12/50	1.88	P4725	0.1/100	2.30
P4527	0.15/50	1.95	P4726	0.12/100	2.57
P4528	0.18/50	2.01	P4727	0.15/100	2.65
P4529	0.22/50	2.10	P4728	0.18/100	2.75
P4530	0.27/50	2.45	P4729	0.22/100	2.94
P4531	0.33/50	2.79	P4730	0.27/100	3.34
P4532	0.39/50	3.10	P4731	0.33/100	3.81
P4533	0.47/50	3.45	P4732	0.39/100	4.22
P4534	0.56/50	4.14	P4733	0.47/100	4.71

PANASONIC® B SERIES

Polyester Capacitors

Part No.	Cap./Volt. (µF)/VAC	Price 10	Part No.	Cap./Volt.	Price 10
			P4556	.0027/50	1.05
			P4557	.0033/50	1.05
P4551	.001/50	1.05	P4558	.0039/50	1.05
P4552	.0012/50	1.05	P4559	.0047/50	1.05
P4553	.0015/50	1.05	P4560	.0056/50	1.05
P4554	.0018/50	1.05	P4561	.0068/50	1.05
P4555	.0022/50	1.05	P4562	.0082/50	1.05

QUARTZ CRYSTALS

Freq MHz	Digi-Key Part No.	Case	Pricing 1	10
1.000	X045	HC-33	10.08	84.00
1.0000	X066	HC-18	9.65	79.50
1.8432	X046	HC-33	3.96	33.00
1.8432	X067	HC-18	3.42	28.50
2.000	X001	HC-33	3.78	31.50
2.0000	X068	HC-18	3.24	27.00
2.4576	X047	HC-33	3.78	31.50
2.4576	X069	HC-18	3.06	25.50
2.5000	X070	HC-18	3.42	28.50
3.000	X048	HC-33	3.78	31.50
3.2768	X022	HC-18	1.73	14.40
3.579545	X005	HC-33	2.34	19.50
3.579545	X049	HC-18	1.62	13.50
3.6864	X071	HC-18	1.62	13.50
3.700	X012	HC-6/U	2.60	22.00
4.000	X006	HC-18	1.62	13.50
4.0320	X072	HC-18	1.62	13.50
4.194304	X007	HC-18	1.62	13.50
4.91520	X050	HC-18	1.62	13.50
5.000	X051	HC-18	1.62	13.50
5.0688	X052	HC-18	1.62	13.50
5.1850	X053	HC-18	1.62	13.50
5.9904	X073	HC-18	1.62	13.50
6.000	X026	HC-18	1.62	13.50
6.144	X054	HC-18	1.62	13.50
7.3728	X074	HC-18	1.62	13.50
8.000	X056	HC-18	1.62	13.50
9.2160	X075	HC-18	1.62	13.50
10.000	X057	HC-18	1.62	13.50
11.0592	X078	HC-18	1.98	16.50
12.000	X058	HC-18	1.62	13.50
15.000	X059	HC-18	1.62	13.50
16.000	X077	HC-18	1.62	13.40
18.000	X060	HC-18	1.80	15.00
18.432	X061	HC-18	1.80	15.00
20.000	X062	HC-18	1.98	16.50
22.1184	X063	HC-18	1.98	16.50
48.000	X065	HC-18	1.98	16.50

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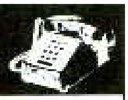

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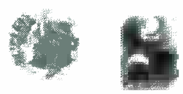

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LETTERS . . .

(from page 7)

Prentice-Hall book, *How to Read Oscilloscope Waveforms.*)

Robert G. Middleton

Some Caveats

• The "Multiple-Applications Strobe Light" project that appeared in the September 1989 issue should have carried the following caveats: (1) A fuse is *never* optional in an ac-driven project [it's a "must"]; (2) transformerless projects require special caution; (3) newcomers weaned on 5- and 12-volt devices may need to be reminded of the respect the high voltages in this project demand. Please so advise *Modern Electronics* readers.

Leslie Paul Davies
Middle Village, NY

Good points to ponder.—Ed.

Forrest Mims Booster

• I am indebted to Forrest M. Mims III for choosing *Modern Electronics* as the magazine in which to have his column appear. Mr. Mims might be interested to know that I appreciate and read carefully his *Understanding Digital Computers.* Considering that I am 65 years old and my classical educational background provided me with just a general knowledge of mathematics, I fully comprehend his writing, of which I am very grateful.

H. Curumtally
Montreal, Canada

Lend a Helping Hand

• Help! I own and love my Powered Advent Loudspeakers (manufactured circa 1975 by Advent prior to its acquisition by Jensen), but one of the two bi-amplified speakers has blown a few parts and nobody seems to be able to help me get it repaired. Specifically, I need the main circuit board (or parts from it). I'd love to buy one—in fact, I'll buy a whole speaker if I have to—or locate someone who is familiar with the product and what generic parts might work.

Don Freeman
113 Linbrook Dr.
Winston-Salem, NC 27106

If anyone can help, please contact Don directly at the above address—Ed.

NEW PRODUCTS . . .

(from page 37)

Wireless Radar Detector

Fox Marketing has an updated version of its Wireless Radar Detector. The MicroFox 2000 detector has been narrowed to fit the under-hood areas of more cars than the original unit. The unit consists of separate sensor and control modules. The latter resembles a pocket pager. Being battery powered, it can be operated from anywhere inside the car in which the detector is installed. It features an audible alerter that sounds when the driver inadvertently leaves power turned on after turning off the ignition. An earphone jack is provided so that motorcyclists can monitor the audible alarm despite background noise.

Other features found on the control module include: alarm and low-battery indicators, a power switch/volume control, and a highway/city switch. The unit's internal battery can be recharged with either the supplied power cord via the vehicle's electrical system (the module recharges while in operation) or with an optional Fox battery charger. Detection of a radar signal results in both an audible tone alarm and a lighted visual indicator, both of which respond according to the strength of the received signal. $279.95.

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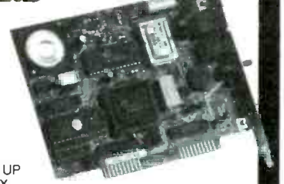

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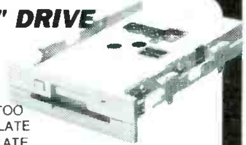

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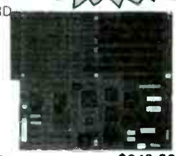

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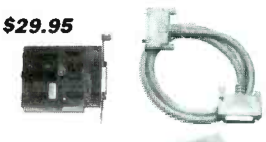

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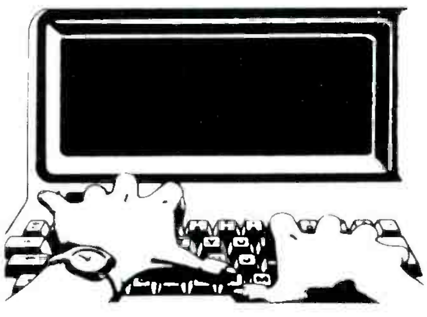

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NusBus Primer *(from page 35)*

section of RAM on another processor card and can prevent the local processor from changing any of the data until the entire operation is complete.

Unlike other personal computers, the Macintosh II series of computers does not support DMA on the bus. Rather than defining DMA as a resource supplied by the bus, NuBus board manufacturers and users can customize DMA capabilities to fit the application.

The NuBus specification allows for as many as 16 different devices or slots. A 4-gigabyte physical address space allows all NuBus masters to address all devices on the bus. Slot space is assigned to the top 256 MB of this address space. A technique called geographical addressing assigns a private 16-MB section to each of the 16 possible devices. The remaining 3.75 gigabytes of address space is allotted to the system to be used as desired.

Although the NuBus specification allows up to 16 slots, the Macintosh II and IIx have six open slots plus one device location occupied by the motherboard, and the Macintosh IIcx has three open slots plus one device location occupied by the motherboard.

Of all the NuBus features, users will appreciate geographical addressing the most. This feature eliminates the need for address jumpers or switches on the plug-in board. Instead, each board has a ROM carrying unique identifying information. Upon power up, the system automatically identifies and configures boards installed in the expansion slots. Thus a user can install boards without worrying about address conflicts with other boards.

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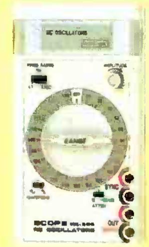

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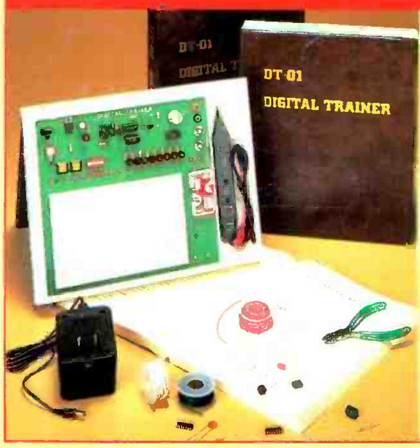

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