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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

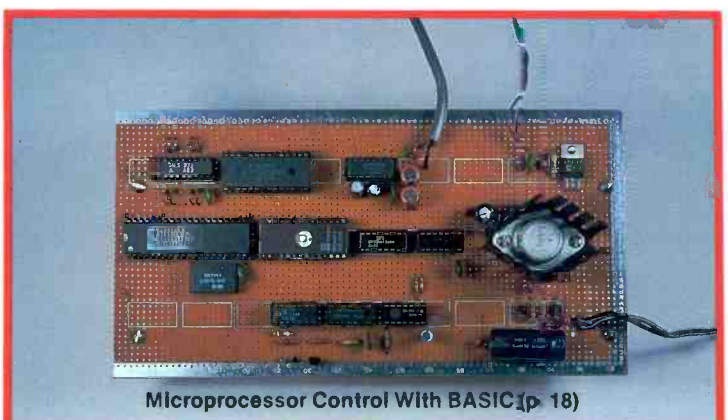
The Computer/Electronics Connection

- Enhancing Electronic Projects with Microprocessor Controllers
- The MIDI (Music Instrument Digital Interface) Revolution
- Creating Virtual Instruments From Personal Computers

A 10-Hz to 2.2-GHz Handheld Frequency Counter (p. 46)

Also In This Issue:

- Electronics Troubleshooting with Sweep Frequencies
- Play a VCR on Many TV Sets Without Wire Connections!
- Build a 10-Hz to 2.2-GHz Handheld Frequency Counter



Microprocessor Control With BASIC (p. 18)

Wireless VCR Distribution System (p. 38)

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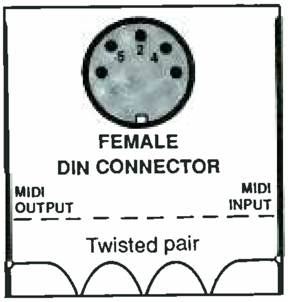
MODERN ELECTRONICS

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

APRIL 1989 **VOLUME 6, NUMBER 4**



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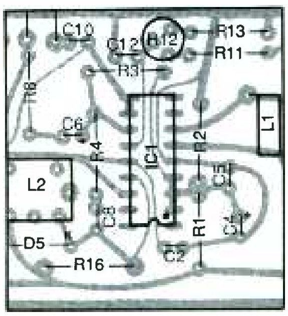

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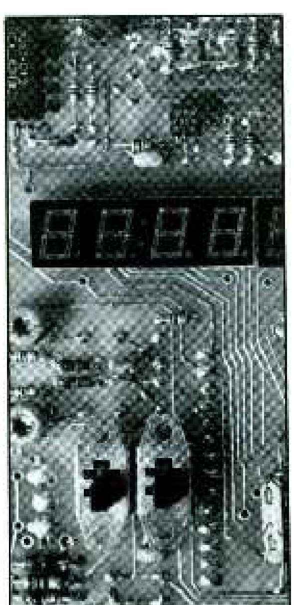

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Offices: 76 North Broadway, Hicksville, NY 11801. Telephone: (516) 681-2922. FAX (516) 681-2926. Modern Electronics (ISSN 0748-9889) is published monthly by CQ Communications, Inc. Subscription prices (payable in US Dollars only): Domestic—one year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

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CIRCLE 41 ON FREE INFORMATION CARD

EDITORIAL

The Alternatives

Buying electronics and computer products can be hard on one's psyche. There's always the latest and greatest just out, with lesser models behind them. What to do?

What's "in?" What's "out?" Which benefit is worth a whole lot of extra bucks? Will the newest twist be supported by satisfying operating and application programs? Will the company remain in business long enough to live up to a warranty? And on and on.

We're used to buying automobiles, where the old clinker can be traded in or sold privately. For most electronic equipment, the older models are either passed down to a child, to another room, to the closet or basement, or just junked.

We've got throw-away wristwatches, of course. But now even VCRs are considered to be junkable when they break down. The reason is simple: repair costs are very high and new minimal-frill VCR models are modestly priced. In some cases, the prices can be equal. There are VOMs and even digital multimeters that are priced low enough to be considered as throw-aways, too, if the problem is more than just batteries that ran out of juice.

It's easier to junk a broken-down product if it's out of style or missing important functions that were introduced after you bought your model many years ago. For example, LED wristwatches have been out of style due to their high battery drain for many, many years. Digital wristwatches are not considered "in" any longer, either. Today it's analog ones that are viewed once again as being stylish, though driven by electronic quartz means.

Videocassette recorders with remote controls that have to be plugged into the main unit's body are out, naturally. Wireless is in. Record turntables and phono cartridges are out; compact disc players are in (unless you're past 50 years old and built up a huge collection of LP records or you're a fanatical audiophile). Video game machines are in again, especially Nintendo machines. The 3½" disk drives and disks are in, while the 5¼" ones are declining if not out. CB radio, if not in, is showing signs of life, but it's cellular phones that are making greater inroads. Telephone answering machines with remote beeperless capabilities are in, as are automatic time and date stamping by digitized voice. (My home answering machine still requires me to carry around a little beeper for remote contact and my taped message still pleads with the caller to tell me the time he/she phoned. But when it requires major repair . . .).

In business, facsimile machines are fashionable. You can even hook them up to car cellular phones for high-fashion high tech. Portability has been extended to powerful laptop computer models, which are now decidedly in. There'll soon be an Apple Macintosh portable model, we understand. Small computers have taken major twists and turns in a few short years.

The old 8088 microprocessor-based personal computer is out, while 80286 CPU designs are in for some people, especially the fast-clock ones that run at 20 MHz. What's expected to really be in in '89, though, is the 80386 chip even though it's still in its childhood. And why not, with an 80486 being sampled by computer makers? Old standbys have long (a few years) disappeared from favor. Remember CGA and EGA color monitors? Well, VGA and SuperVGA are in, friend. But you'll need the proper hardware and software to go along with them.

Companies themselves are doing corporate somersaults in name or in business trials and tribulations. The leading Leading Edge Computer Product Inc. suddenly left the computer machine business, for example, with sale of its OEM contract rights with a Korean company (Daewoo) to another U.S. company. IBM changed its bus structure to MCA and walked away from the old one that's been cloned left and right, while a group of computer companies say they're going to use their own bus, the EISA, which is not yet finalized. Which one will you take an option on for yourself or for your company? Or will you sit tight with what you've got until the smoke clears, perhaps losing out by spending much more money in software for less quality in the overall end?

I don't think that the smoke will ever fully clear. Just as you decide to move in one direction, a new growth spurt in another area will pull at you, such as the new computer workstations that are carving out a separate niche for themselves in the computer world. In time, it's expected that they will replace plain old personal computers for serious business or professional work. Look for companies like Sun and Apollo to enter your consciousness.

The alternative choices we all have to weigh continue to be exciting, if confusing. Being technically hip depends on where you're coming from and where you're going. There's nothing wrong with a single-user, 8088-microprocessor computer with 640K of RAM and a 20-meg hard disk drive if all you do with it is write short articles. But this is more like a fancy typewriter now when compared to what the power users will be buying this year.

Art Salsberg

LETTERS

Negative-Logic Booster

• "Understanding Negative Logic" in the October 1988 issue of *Modern Electronics* was interesting in general, but Mr. Horn's closing sentence was most astute. It is *very easy* to confuse positive and negative logic. As a digital designer, I find it better to stick with one approach and then solve the logic problem with Boolean algebra. For example, it the article's first truth table, eight combinations of A,B,C,D yield an output of "1." Using the simple rules of Boolean algebra, these terms are combines or reduced to the expression AD + BC + BD, which is read "A and D or B and C or B and D." This expression can be further factored to BC + D(A + B), arriving at the logic circuit shown in Fig. 2(B)—which, by the way, is the positive logic diagram. Boolean algebra is fun and easy to work with.

Bill Holsinger
National Institutes of Health
Bethesda, MD

MODERN ELECTRONICS NEWS

CELLULAR PHONE GROWTH. More and more consumers are using cellular telephones. A NYNEX Veep in the New York-New Jersey area predicts that there'll be 2.5- to 3-million cellular subscribers nationwide by the end of the year. The subscriber base reached 1.7 million in '88, which was more than double the number in '87. A recent NYNEX customer survey revealed that 62% of cellular phone subscribers use their phones for personal reasons at least half the time, and that women account for more than 20% of its subscribers. To grab a bigger cellular share, Tandy has moved its merchandising efforts beyond its Radio Shack stores into car dealerships, and the company is said to be considering private labeling of phones.

U.S. ELECTRONICS SHARE SHRINKS. Using statistics compiled by the Electronic Industries Association of Japan, the American Electronics Association notes that U.S. share of world's electronic production dropped from 50.4% in 1984 to 39.7% in in 1987. At the same time, Japan's world market share rose from 21.3% to 27.1%, Western Europe from 23.5% to 26.4%, and other Pacific Ri9m countries (Korea, Taiwan, etc.) from 4.9% to 6.8%.

In dollars, U.S. production actually rose 8% in that period from $168.9-billion to $182.7-billion,while Japan's nearly 75% rise moved its production from $21.3-billion to $125.1-billion. Nevertheless, the U.S.'s shrinking share of the world market in a leading-edge segment of the U.S. economy is worrisome.

SHURE'S V-15 AT 25 YEARS. Shure Brothers' Model V15 phonograph cartridge was introduced a quarter century ago, succeeding the company's highly popular Model M3D. Its name derived from its 15-degree vertical tracking angle, which the technology represented as necessary to obtain optimal stylus tracking in a record groove. The new cartridge also featured the first elliptical diamond stylus. The V15 continued to evolve over the years, upgrading models to V15 Type II, Type II Improved, Type III, etc. Today it's latest version is the V15 Type V-MR. So it's a silver anniversary for the high-performance cartridge whose world is being compressed by compact discs that use laser beams instead of its breed. However, there are still millions of LPs sold every year, and billions of LPs to be played.

HIGH RESOLUTION COLOR LCD. Sharp Electronics' Microelectronics Division has introduced two hi-res color LCD modules that reportedly provide picture resolution rivaling high-performance CRT monitors. A four-inch module produces a high-definition picture with 115,200 pixels, while a three-inch version offers 92,160 pixel resolution. The division's marketing people feel that the new modules will fuel new products that weren't conceivable in the past, such as behind-the-seat video monitors. Sampling starts in the first quarter. Call 201-529-8757 for more information.

Learn to troubleshoot and service today's computer systems as you build a fully XT-compatible micro, complete with 512K RAM and powerful 20 meg hard drive

Train the NRI Way— and Earn Good Money Servicing Any Brand of Computer

Jobs for computer service technicians will almost double in the next 10 years according to Department of Labor statistics, making computer service one of the top 10 growth fields in the nation.

Now you can cash in on this exciting opportunity—either as a full-time industry technician or in a computer service business of your own—once you've mastered electronics and computers the NRI way.

NRI's practical combination of "reason-why" theory and hands-on building skills starts you with the fundamentals of electronics, then guides you through more sophisticated circuitry all the way up to the latest advances in computer technology. You even learn to program in BASIC and machine language, the essential language for trouble-shooting and repair.

Train With a Powerful XT-Compatible – Now With 20 Meg Hard Drive!

To give you hands-on training with the absolute in state-of-the-art computer technology, NRI includes the powerful new Packard Bell VX88 computer as the centerpiece of your training. As you assemble this fully IBM XT-compatible micro from the keyboard up, you actually see for yourself how every section of your computer works.

You build this powerful Packard Bell VX88 computer, all the while gaining a true mastery of computer electronics. Best of all, it's yours to keep for all your professional and personal computing needs.

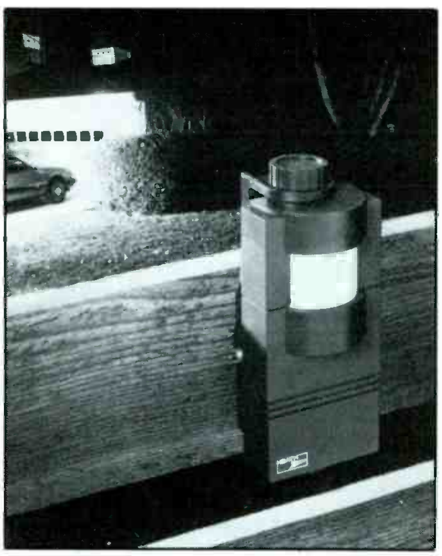
You assemble and test your computer's "intelligent" keyboard, install the power supply and 5¼" disk drive, then interface the high-resolution monitor. But that's not all.

Your hands-on training continues as you install a powerful 20 megabyte hard disk drive—today's most-wanted computer peripheral—now included in your course to dramatically increase

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.

Wireless Motion Sensor

Homeowners who have inside and outside lights located in difficult-to-reach places will appreciate a new wireless motion-sensor activating device from the Heath Company. The Model SL5420 retrofit controller can be mounted on any surface, including a lamp post, wall or fence without



requiring ac power. It is housed inside a dark-colored case that is virtually invisible under nighttime conditions.

The wireless light-control unit consists of a battery-powered motion sensor and a receiver that replaces any existing switch that controls the lighting fixture with which the product is used. The motion sensor can be located up to 150 feet away from the receiver and can be adjusted in any direction to cover a specific area. Also, multiple lights can be controlled simply by adding extra receivers to the basic system.

Employing pulse-count technology, the new Heath light controller is said to be less prone to false alarms than competitive units. Other key features include variable shut-off time, which allows the user to set the duration that the controlled lights remain on, and an adjustable photocell for changing the times lights turn on at night. The Heath Zenith wireless motion sensor light controller is also compatible with the company's wireless security systems. $100.

CIRCLE NO. 101 ON FREE INFORMATION CARD

Electronically Controlled Soldering Station

New from Elenco Electronics is a soldering station that uses an electronic circuit that permits the user to change tip temperature from 300°F (150°C) to 900°F (480°C) without having to change either tip or heating element. Once a temperature is dialed in at the tool's front panel, the station is claimed to maintain it within 10°F of the preset temperature. A unique temperature sensor located near the soldering tip provides rapid response and little temperature variation.

For safety purposes, the soldering tip is isolated from the ac line by a transformer, which delivers low-voltage (24 volts) power to the heat-

ing element. Totally electronic switching protects voltage- and current-sensitive components against transient spikes that are sometimes caused by mechanical switching elements in other station designs. A linear LED array displays soldering tip temperature. Other features include a sponge-type tip cleaning pad and an iron holder as standard accessories. $169.

CIRCLE NO. 102 ON FREE INFORMATION CARD

Multi-Band Radio

Panasonic's Model RF-B65 compact multi-band radio receiver is ready to receive the new single-sideband broadcasts that are currently being tested by shortwave stations. The radio receives on the FM, LW, MW and SW bands. It features a microprocessor-controlled PLL quartz frequency synthesizer and a double-

heterodyne receiving system. The design provides two i-fs to help lessen the first and second image interference characteristics, while image rejection is lessened by raising the initial i-f to 55.845 MHz.

A six-way tuning system offers a full range of tuning options. Included is 36-station preset tuning that allows the user to program that many stations for instant recall. Direct-access tuning is accomplished from the numeric keypad on the front panel. If the band but not exact frequency of a desired station is known, the user can key in the lowest frequency of the band and then use electronic rotary, up/down manual or automatic scan to zero in on the exact frequency.

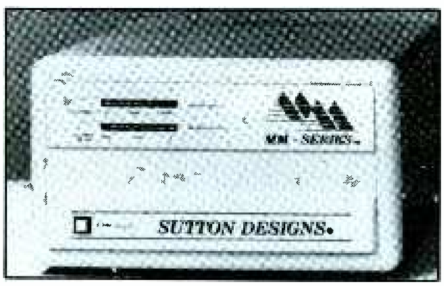
An LCD display shows all functions selected and simultaneously keeps time in two separate time zones. A sleep function automatically shuts off the unit after 60 minutes, and a standby function permits the user to set the radio to turn on automatically.

Other features include: 10-key direct time setting; hold switch; 1-kHz-step fine tuning on LW, MW and SW; volume control; external antenna, dc input and earphone jacks; carrying case; external wire antenna for SW; and earphone. Six AA cells (not included) are required, four for powering the radio and two for the clock memory. $280.

CIRCLE NO. 103 ON FREE INFORMATION CARD

"Smart" UPS

Sutton Designs (Ithaca, NY) has five new uninterruptible power supplies that allow integration with virtually every LAN configuration and multiuser operating system now on the market. Called the MM-Series Plus UPS, the new units incorporate the company's Netlinks Intelligent Circuit and new Netsavers Software Interface Package. These turn the MM-Series Plus UPS into an interactive part of a user's computer system. The UPS knows when and how



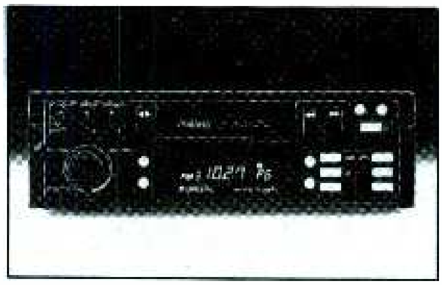
to inform the network server or multi-user host to log users off and to shut itself down in the event of a prolonged power outage. This series also writes to the server's operating system to keep an accurate log of its own activity and remaining battery capacity at all times, even during a prolonged power outage. When ac line power is restored to normal, it tells the server or host computer how long the UPS must be running on ac power before it is up to full hold-up capacity. The UPS operates as a background process and, therefore, uses no processing power.

The MM-Series Plus line includes 375-, 750-, 1,200-, 1,500- and 2,000-VA models. All are claimed to provide pure synchronized sine-wave outputs, and all feature extra large battery capacities. $599, $899, $1,299, $1,599 and $1,999, respectively.

CIRCLE NO. 105 ON FREE INFORMATION CARD

Car Audio Cassette/Tuner

Last-source memory and a CD input are only two of the features offered by Yamaha's flagship Model YCT-605 car audio cassette/tuner. Another is this DIN-sized unit's theft-proof removable chassis that is supplied as standard equipment. Last-source memory automatically returns the unit to the last source or program being played before shut-off.



Among the other features of this unit are start/stop for the CD player being used with it. The tuner section features improved MR-II circuitry, 18 FM and 6 AM presets, auto-store memory, preset scan, up/down seek tuning, five-mode agc circuitry, and a dual-gate MOSFET design. The precision load tape transport features automatic pinch-roller release on shut-off, double azimuth control for proper alignment of the hard permalloy tape head in either direction, and a dc servo motor. Included are Yamaha Music Search and Dolby B noise reduction, illuminated bass and treble controls, bi-level preamplifier fader, four output jacks, and a continuously variable loudness control.

Technical specifications: FM tuner—usable sensitivity, 16.3 dBf (1.8 μV) at 75 ohms; 50-dB quieting sensitivity, 18.3 dBf (2.2 μV); alternate-channel selectivity, 75 dB; image-response ratio, 65 dB; capture ratio, 2.5 dB; S/N mono/stereo, 70/65 dB; harmonic distortion mono/stereo, 0.3%/0.5%; separation, 40 dB at 1 kHz; frequency response, 50 Hz to 15 kHz ± 3 dB. AM tuner—usable sensitivity, 25 μV; selectivity, 33 dB. Tape section—frequency response 40 Hz to 16 kHz ± 3 dB (to 17 kHz metal); S/N ratio Dolby off/on, 58/67 dB (54/63 dB metal). Audio section—preamp output level/impedance, 1.5 volts/1k ohm; CD input level, 2 volts at 1.5-volt preamp output; tone control range, ± 10 dB at 100 Hz bass and 10 kHz treble. Dimensions: $7\frac{1}{8}'' \times 6\frac{1}{8}'' \times 1\frac{1}{16}''$. Weight: 3 lbs. 15 ozs. $399.

CIRCLE NO. 106 ON FREE INFORMATION CARD

Intelligent Multimeter

Daetron (Missisauga, Ontario, Canada) has a new "intelligent" digital multimeter that is capable of measuring and displaying four voltages simultaneously in four $3\frac{1}{2}$-decade display areas or two voltages at the same time in two $4\frac{1}{4}$-decade display areas. The Model MM100 multimeter can also show various combinations of current, resistance and voltage simultaneously in its two-line, 16-decade display window.

Each of the two or four display areas is individually programmable for hold, relative reference and comparative modes. The last permit the user to program the MM100 to audibly alert him with a "beep" when a current, resistance or voltage exceeds a certain preset value, falls below that value or is between any two preprogrammed values. In analog bargraph mode, the top line of the display contains a single 4-1/2-decade numeric window and the lower line is occupied by the bargraph display.

All functions and ranges are selected and programming is accomplished with a membrane-type touch panel on the front of the instrument.

Supplied with the DMM are red- and black-insulated test leads and instruction manual. Additional color-coded test leads that match the coding of the jacks on the side of the meter's case are available optionally. $230.

CIRCLE NO. 107 ON FREE INFORMATION CARD

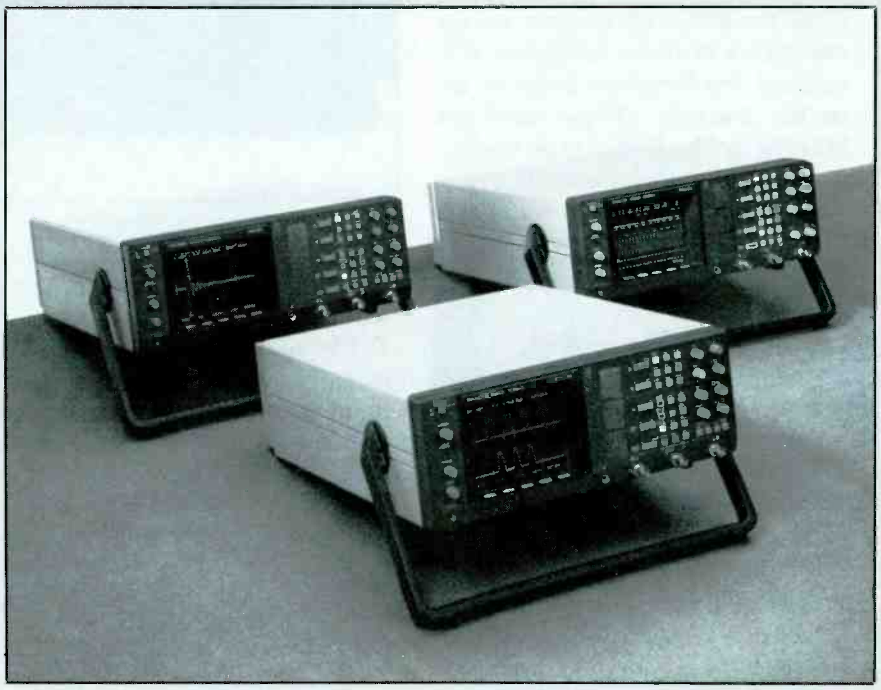
Modem/Line Driver

Telebyte Technology Inc. (Greenlawn, NY) has announced the Model 201 Auto Powered Line Driver that is claimed to be the industry's smallest short-haul modem/line driver. It incorporates dc-to-dc converters for power, built-in surge protection for the twisted-pair communication link, and both screw-type terminals and RJ-11 connector for user selection of line termination. The device has the capability of deriving all of its operating power from only the input signal to be transmitted, with the dc converters establishing the necessary voltage levels and supplying the power to operate the low-power circuitry of the modem.

This new device provides full duplex operation at data rates up to 19,200 baud and distances of 2 miles

(Continued on page 79)

Analog/Digital Storage Oscilloscope Family



Powerful cursor facilities, AUTOSET and optional GPIB/IEEE-488 interface are featured in a new three-member family of Philips analog/digital storage oscilloscopes from John Fluke Mfg. Co. The Models PM 3335, PM 3350 and PM3365 are said to combine digital storage capability with ease of use. Bandwidths range from 50 MHz to 100 MHz, sampling rates from 20 MS/s to 100 MS/s for each channel and up to 8K bytes of memory, depending on model.

Simple operation is facilitated by cursor facilities that allow for instant on-screen measurements with numeric readouts of measured and calculated values, automatically compensating for probes in use. High-speed triggering provides the ability to reliably capture fast pulses and other high-frequency phenomena. An LCD panel near the CRT display gives information on sensitivity on both channels, timebase and trigger settings, memory status, and a display magnification indicator. Another feature, AUTOSET, provides for automatic channel selection and setting of amplitude, timebase and triggering for the input signal.

The GPIB/IEEE-488 or RS-232 interface options allow the scopes to be used under computer control in automatic measuring systems. Measurements can be downloaded to the computer for storage on disk or further processing, and special instrument settings for complex test routines, user-definable softkey guidance and on-screen operator prompts can be downloaded from the controller.

The 50-MHz PM 3335 DSO provides a 20 MS/s sampling rate on both channels, an 8K memory for high-resolution acquisition and storage of signal information, 100-MHz triggering bandwidth, and 8-bit vertical resolution. $2,490.

The middle-of-the-line Model PM 3350 50-MHz analog/digital scope offers dual-channel operation, synchronous sampling, cursors, AUTOSET, 100 MS/s single-shot sampling on both channels, 100 MHz triggering and a 4K memory. Optionally available is the GPIB/IEEE-488 interface. $3,990.

The Model PM 3365 features 100 MS/s single-shot sampling on both channels, while an additional repetitive sampling mode ensures high-resolution acquisition of recurrent signals up to 100 MHz. A 4K memory, 150-MHz triggering bandwidth and dual-timebase referencing for simultaneous display of basic waveform and signal detail are also provided. $4,990.

CIRCLE NO. 111 ON FREE INFORMATION CARD

Microprocessor Control With BASIC

(Part I)

A Development System for Microprocessor-Controlled Projects

By Jan Axelson & Jim Hughes

Microprocessor control can greatly expand the capabilities of many electronic instruments. A microprocessor-controlled "smart" thermometer, for example, can do more than just measure temperature. With proper programming, it can be made to keep track of maximum and minimum temperatures and when they occurred, or perform other temperature-related functions. With microprocessor control, it is also feasible to use panels that display informative data and messages.

Designing microprocessor-controlled devices is a complex task. In addition to building the required circuitry, you have to write the software that will control the circuits. Fortunately, you do not have to start from square one in this area. With the Microsys project presented here the task is greatly simplified because the project serves as a base system for projects like the smart thermometer. The Microsys simplifies the hardware and, particularly, the software design.

This article is presented in two parts. This month, we'll describe the basis Microsys that allows you to write, run and save programs. Next month, we'll describe the Tempwatch instrument that's created by adding a few components to the Microsys and which monitors temperature and displays present temperature, time, maximum and minimum temperatures and the times these occurred, all on a 16-character dot-matrix LCD panel.

The Preliminaries

The key to implementing successful Microprocessor Control of instruments is the Intel 8052AH-BASIC microcontroller. A microcontroller is a microprocessor, or a single-chip CPU, that is optimized for use in single-purpose (dedicated) controllers or instruments. The 8052AH-BASIC has several features that make it especially easy to use, including a built-in BASIC language interpreter, serial port,and automatic programming of EPROMs. This is the microcontroller used in the Microsys. By adding real-world inputs and outputs (sensors, displays, switches, and the like) you can program the Microsys to collect and display data or to act as a controller or other intelligent device.

While you're developing a project, the serial port of the Microsys connects to the serial port of a computer terminal. Just about any type of personal computer can be used for this in terminal-emulation mode. You can then experiment by writing, running, and debugging programs on the Microsys, using the BASIC interpreter in the 8052AH-BASIC chip and the keyboard and video display of the terminal. This frees you from having to write programs in machine code or assembly language and from having to invest in assemblers, debuggers, or other costly development tools.

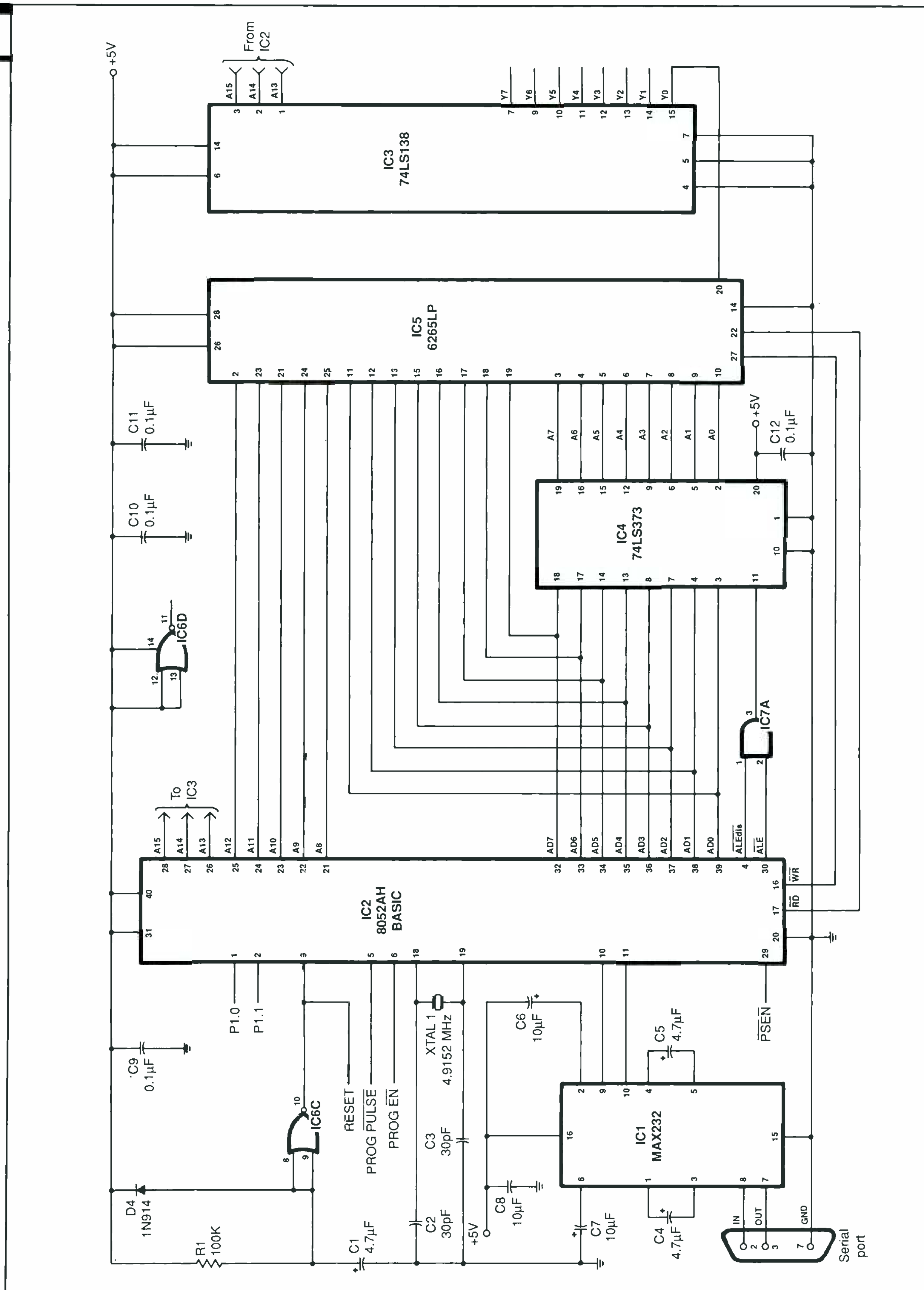
Programs you develop on the Microsys can be stored in EPROM (one command in BASIC does this automatically). When your design is completed and the EPROM is programmed, the "umbilical cord" to the serial port can be disconnected. You then have a complete, stand-alone project.

All components in the Microsys are readily available from mail-order suppliers. The extra capabilities of the 8052AH-BASIC IC do mean that it carries a premium price tag, $20 to $30 more than it costs for a "plain-vanilla" microcontroller without BASIC. Still, with careful shopping, component cost for the basic Microsys (minus the cost of the components that make up the power supply) runs only around $50.

To program the Microsys, you'll need a computer terminal, or a computer that can be configured to emulate a terminal, with a serial port and cable. Modem communication is an example of terminal emulation. If your computer has a serial port and can communicate by modem, it should be able to communicate with the Microsys.

We use an IBM XT-compatible computer running the Procomm communications software. With Procomm, we communicate with the

Fig. 1. Schematic diagram of the basic Microsys, minus the EPROM circuitry and dc power supply.


IC1 MAX232
IC2 8052AH BASIC
IC3 74LS138
IC4 74LS373
IC5 6265LP
IC6C
IC6D
IC7A
XTAL 1 4.9152 MHz
Serial port

PARTS LIST

Semiconductors
D1—1N914 silicon switching diode
D2—1N270 general-purpose germanium diode
D3 thru D6—1N4001 or similar 50-volt rectifier diode
IC1—MAX232 RS232 driver/receiver (Jameco, JDR)
IC2—8052AH-BASIC microcontroller (Jameco, JDR)
IC3—74LS138 3-to-8-line decoder
IC4—74LS373 octal D-type latch
IC5—6264LP 8,192 × 8 static RAM
IC6—4001 CMOS quad NOR gate
IC7—74LS08 quad AND gate
IC8—LM317 3-terminal adjustable regulator
IC9—2764 8,192 × 8 EPROM with 12.5-volt programming
IC10—7407 hex open-collector buffer
IC11—7805K +5-volt regulator in TO-220 package
Q1—2N4403 pnp switching transistor

Capacitors (25-WV)
C1,C4,C5—4.7-μF electrolytic
C2,C3—30-pF ceramic
C6,C7—10-μF electrolytic
C8 thru C13—0.1-μF ceramic
C14,C16,C17—1.0-μF tantalum electrolytic
C15—470-μF electrolytic
C18—100-μF electrolytic

Resistors (¼-watt, 5% tolerance)
R1—100,000 ohms
R2—2,000 ohms
R3—240 ohms
R4,R6,R8 thru R16—10,000 ohms
R5—4,700 ohms
R7—1,000 ohms

Miscellaneous
B1,B2—9-volt battery
F1—1-ampere slow-blow fuse
S1—Dpst toggle switch
T1—12.6-volt, 1-ampere power transformer
XTAL1—4.9152-Megahertz crystal
Perforated board with copper-ringed holes on 0.1" centers and interleaved power and ground buses; heat sink for TO-3 package; two 9-volt snap-type battery connectors; suitable enclosure; one set each of 2- and 3-pin interlocking connectors; panel-mount, solder-type 9-pin D-type connector; in-line fuse holder; rubber grommet; ac line cord with plug; heat-shrinkable tubing; Wire-Wrap IC sockets and hardware; machine hardware; hookup wire; solder; etc.

Addresses of Suppliers

Digi-Key Corp.
701 Brooks Ave. S.
Thief River Falls, MN 56701-0677
1-800-344-4539

Intel Literature Sales
P.O. Box 58130
Santa Clara, CA 95052-8130
1-800-548-4725

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
415-592-8097

JDR Microdevices
110 Knowles Dr.
Los Gatos, CA 95030
1-800-538-5000

Datastorm Technologies
(For Procomm communications software)
P.O. Box 1471
Colombia, MO 65205
1-800-626-2723

Sources of Information

MCS BASIC-52 User's Manual
Intel Part No. 270010-003
Essential reference to the version of the BASIC language interpreter contained in the 8052AH-BASIC microcontroller. Also contains schematics of sample system configurations.

Embedded Controller Handbook
Intel Part No. 210918 (Jameco Cat. No. 210918)
Hardware description, specifications, and timing diagrams for the 8052 microcontroller (and many others).

Microsys and can also easily print program listings, save programs to disk and load programs from disk to the Microsys. This is just one possible configuration. Many other computer/software combinations are also feasible.

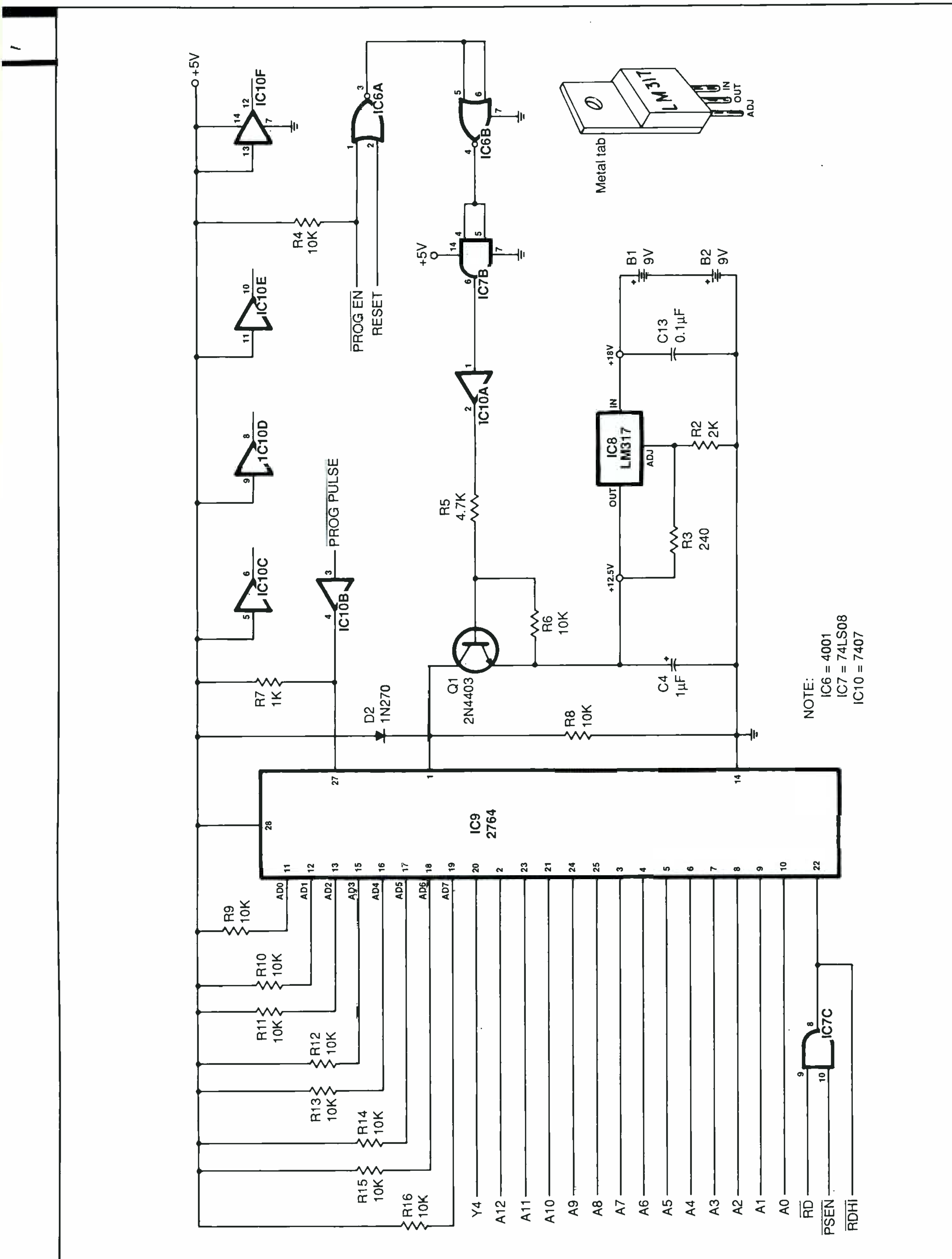
A few other capabilities and resources are highly recommended for experimenting with the Microsys. One is some familiarity with the BASIC programming language. Intel's MCS BASIC-52, which is the BASIC interpreter used in the 8052AH-BASIC, is similar to other versions of BASIC. Consequently, any BASIC experience will make programming the Microsys that much easier.

A second helpful resource is access to an EPROM eraser. This will allow you to experiment with different programs in EPROM, then erase and try new ones. EPROM erasers consist of a controlled, enclosed source of ultraviolet light, and are widely available. An EPROM eraser project appeared in the May 1987 issue of this magazine. Also, check out the *Modern Electronics* advertisers for sources of erasers.

If you're familiar with computer-relevant subjects, such as hexadecimal and binary number systems, this will also help you in understanding the Microsys. If not, the Microsys is a good place to gain some experience and practice with these and other topics related to computer hardware and software.

Finally, to experiment on your own with the Microsys, more complete documentation than can fit in this article is recommended. The user's manual for MCS BASIC-52 is a particularly important source of such documentation. This and other sources of information and components is given in the section following the Parts List.

Fig. 2. Schematic diagram of the EPROM circuitry. A battery-powered 12.5-volt dc supply provides the EPROM's programming voltage.


+5V
IC10F
IC6A
IC6B
IC7B
IC10E
IC10D
IC10C
IC10B
IC10A
R4 10K
PROG EN
RESET
PROG PULSE
R5 4.7K
R6 10K
R7 1K
R8 10K
D2 1N270
Q1 2N4403
LM317
IN
OUT
ADJ
Metal tab
B1 9V
B2 9V
C13 0.1µF
+18V
IC8 LM317
R2 2K
R3 240
+12.5V
C4 1µF
NOTE:
IC6 = 4001
IC7 = 74LS08
IC10 = 7407
IC9 2764
R9 10K
R10 10K
R11 10K
R12 10K
R13 10K
R14 10K
R15 10K
R16 10K
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
Y4
A12
A11
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1
A0
RD
PSEN
RDHI
IC7C

About the circuit

Figure 1 is the schematic diagram of the Microsys' circuitry, minus its EPROM and power-supply circuitry. The system shown in Fig. 1 has just five main components: *IC1* through *IC5*. The 8052AH-BASIC microcontroller is shown as *IC2*. From here on, we'll refer to the microcontroller as either the 8052 or *IC2*.

A major task of *IC2* is reading from and writing to memory and other devices. To do this requires a bus to carry the selected addresses, another bus to carry the data to be read or written, and control signals to initiate and time the processes.

The address bus of the 8052 is 16 bits wide, allowing it to access up to hexadecimal address FFFF. The low address byte is carried on eight multiplexed address/data lines (AD0 through AD7). Eight additional address lines (A8 through A15) carry the high address byte.

One of the components that *IC2* reads from and writes to is 6264 static RAM *IC5*. This RAM provides temporary storage of programs and data and stores up to 8,192 eight-bit words. Thirteen address lines (A0 through A12) are required to address all 8,192 bytes in the RAM. Addresses A0 through A7 are latched from *IC2* to *IC5* through *IC4*, a 74LS373 octal D-type latch. Address lines A8 through A12 connect directly from *IC2* to the corresponding inputs of *IC5*. Data is transferred between *IC2* and *IC5* directly on AD0 through AD7.

Reading and writing to *IC5* can occur only when its chip select input (pin 20) is low. CHIP SELECT is generated by IC3, a 74LS138 3-to-8-line decoder. Data inputs to *IC3* are A13, A14 and A15. These are the three highest address lines. For each combination of these, a unique output of *IC3* goes low. When A13, A14 and A15 are all low, Y0 at pin 15 of *IC3* is also low and *IC5* is enabled. This places the RAM at address 0 in the system. Other components of the Microsys will connect to other outputs of *IC3*.

To write a byte of data to an address in RAM, *IC2* places the low byte of the address on lines AD0 through AD7. It also places the five high bits of the address on A8 through A12. Lines A13 through A15 are low, to enable *IC5*.

A low at pin 3 of *IC7A* latches the low address byte through *IC4* to *IC5*. Then *IC2* places the data on lines AD0 through AD7, and a low at pin 16 of *IC2* (WRITE) causes the data to be written to the RAM at the selected address.

Reading a byte in RAM is a similar process. To do this, *IC2* again places an address on AD0 through AD7 and A8 through A12, with A13 through A15 held low. Pin 3 of *IC7A* again latches the low address byte through *IC4* to *IC5*. A low on pin 17 of *IC2* (READ) then causes *IC5* to place the requested data on AD0 through AD7 for *IC2* to read.

In practice, all of this is easily accomplished on the Microsys. The 8052 provides a special operator that allows you to read or write to external memory with a single statement in BASIC.

The interface for serial communication between the Microsys and the terminal is provided by *IC1*, a MAX232 RS232 driver/receiver. The MAX232 contains two charge-pump voltage converters that generate ±10 volts from the +5-volt supply. Pin 7 of *IC1* is the output of an RS232-compatible driver at +9 volts, and pin 8 is the input to an RS232-compatible receiver. Pins 9 and 10 of *IC1* interface this chip to *IC2* at TTL-level voltages.

A 4.9152-MHz crystal (*XTAL1*) at pins 18 and 19 of *IC2* provides the system clock. On power-up, the slow charging of *C1* through *R1* causes a reset pulse on pin 9 of *IC2* to initialize the system.

The five ICs described in Fig. 1 are the building blocks of the basic Microsys. With this much circuitry, you can write and run programs from your terminal. However, when you power down, any programs stored in RAM will be lost.

For permanent storage of programs, the EPROM circuitry shown in Fig. 2 must be added to the Fig. 1 circuitry. In this circuit, *IC9* is a 2764 EPROM that has a storage capacity of 8,192 eight-bit words (the same as the RAM in Fig. 1). Its data and address lines are wired the same as *IC5*'s, except that pull-up resistors *R9* through *R16* on lines AD0 through AD7 are required for EPROM programming.

As was the case for *IC5*, the pin 20 CHIP SELECT line for *IC9* is controlled by *IC3*. Chip *IC9* is enabled when line A15 is high and lines A13 and A14 are low, causing Y4 at pin 11 of *IC3* to go low. This places the EPROM at hex address 8000.

Reading and programming of *IC9* are controlled by the 8052. Pin 17 (RD) and pin 29 (PSEN, or Program Store ENable) of *IC2* are ANDed in *IC7C* to provide RDHI, the READ signal for *IC9* (and other devices located above hex address 8000).

To program the EPROM, +12.5 volts must be applied to pin 1 of the device. Since this voltage is used only for EPROM programming, it's practical to use battery power to generate it. In this circuit, two 9-volt batteries in series (*B1* and *B2* provide a +18-volt input to LM317 adjustable voltage regulator *IC8*. These batteries can be inserted for EPROM programming and can be removed during "normal" operation of the Microsys.

A reference potential of 1.25 volts is developed by *IC8* across *R3*. This determines the amount of current that flows through *R2*, whose value is chosen so that the output of *IC8* is +12.5 volts. Input bypassing is provided by capacitor *C13*, while transient suppression is provided by *C14* at *IC8*'s output.

When PROG EN (PROGram ENable) pin 6 and RESET pin 9 of *IC2* are

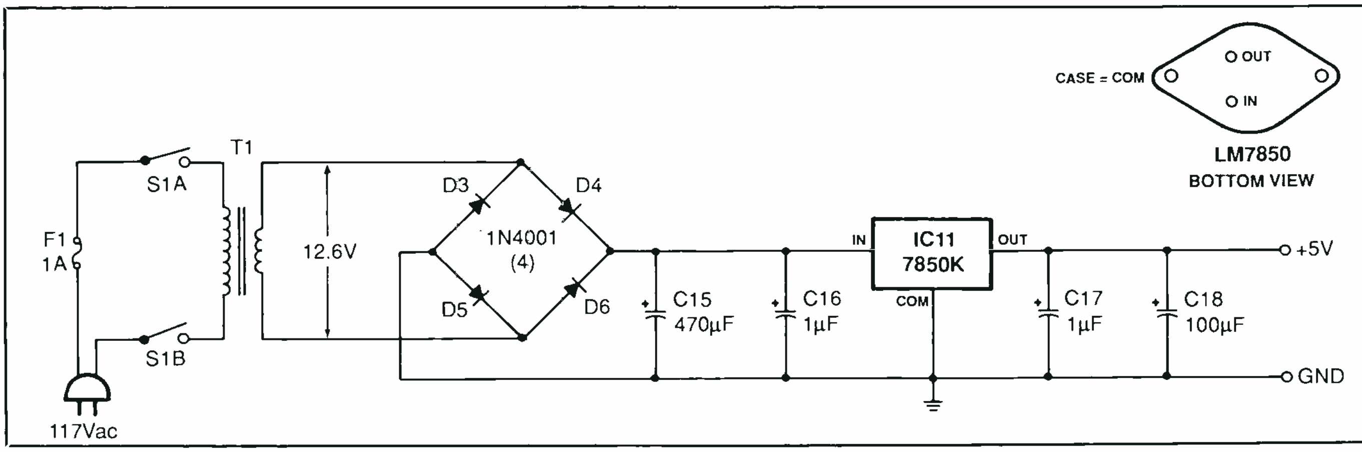


Fig. 3. Schematic diagram of the Microsys' 5-volt dc power supply.

both low, pin 2 of *IC10A* is also low. This sends transistor *Q1* into conduction and switches the + 12.5-volt output of *IC8* to pin 1 of *IC9*.

Series NOR gates *IC6A* and *IC6B* "OR" the PROG-EN and RESET signals. Note that *IC7B* drives *IC10A*, a 7407 open-collector buffer, which allows the 5-volt output of *IC2* to control the programming voltage. Programming pulses from *IC2* are buffered at *IC10B* and are then fed to input pin 27 of *IC9*.

For normal (non-programming) operation, diode *D2* and resistor *R8* hold pin 1 of *IC9* at about +4.7 volts. Diode *D2* is a germanium type, selected to keep the potential at pin 1 as close to +5 volts as possible.

Figure 3 schematically shows the circuitry of the +5-volt power supply recommended for powering the Microsys. Transformer *T1* steps down the incoming 117 volts from the ac line to 12.6 volts ac. Then the bridge rectifier made up of diodes *D3* through *D6* rectify this voltage to pulsating dc, and *IC11* regulates it to +5 volts dc.

Construction

Wire Wrap is the recommended method of construction for the Microsys. (See the "Wire-Wrapping Tips" box for details on wrapping techniques and Wire Wrap equipment.) Use a perforated board with copper-ringed holes on 0.1-inch centers and interleaved power and ground buses. A board that measures 8 by 4.5 inches will accommodate components with room to spare. (The extra room on the board will be used for the components for the Tempwatch that will be described next month, or other components for your own circuit designs.)

The upper photo in Fig. 4 shows the prototype Microsys assembled on perforated board, while the lower photo shows the project wired using the Wire Wrap method.

Addresses of a few suppliers that stock the components used in this project are given at the end of the Parts List. Other suppliers than those cited may also offer most or all of these components.

For connection to the serial-port cable of the terminal, the Microsys requires a female 25-pin D-type connector. In most cases, this connector must be wired to transmit on pin 3 and receive on pin 2, and pin 7 should be used as signal ground. This makes the Microsys' serial port compatible with the DTE (Data Terminal Equipment) type of RS-232 serial ports found on the majority of personal computers. If your computer's serial port is configured differently, you must determine the wiring scheme required and adjust the wiring on the serial-port connector on the Microsys accordingly.

In addition to the transmit, receive, and ground conductors, some serial ports require extra "null-modem" connections for direct communication with the Microsys. These normally involve connecting together pins 4, 5, and 8 and pins 6 and 20 somewhere in the link. If your system requires these connections, they can be wired at the serial-port connector on the Microsys.

Molex or locking-type connectors are recommended for use on the conductors that connect the serial-port connector and power transformer to the circuit board. These will allow you to easily remove the circuit-board assembly from its enclosure, for changes or/and additions you later decide to make to the circuits. One set each of two- and three-pin connectors are required.

The 4.9152-MHz specified for *XTAL1* is one of several frequencies recommended in the MCS BASIC-52 User's Manual to assure best accuracy of the 8052's real-time clock (which will be used in next month's smart thermometer). It's also possible to replace *XTAL1, C2,* and *C3* with a TTL crystal oscillator of the same frequency. In this case, the oscillator's output connects to pin 18 of *IC2*, with pin 19 connected to ground.

Begin construction of the Microsys

Tips On Wire Wrapping

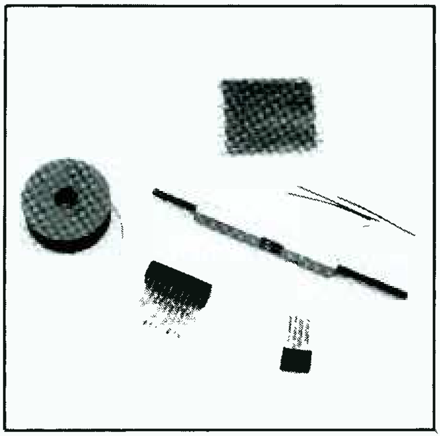
Because of its simplicity and flexibility, the Wire Wrap technique is the recommended method for interconnecting components in the Microsys. Microsys' multiplexed data and address buses can easily be Wire Wrapped, whereas printed-circuit wiring would most likely have required intricate routing of traces between IC pins, or a difficult-to-fabricate double-sided pc board.

Another advantage is that Wire Wrapped circuits can easily be changed. Modifications are made and errors corrected quickly and easily, simply by unwrapping the connections and wrapping new ones.

If you're new to Wire Wrapping, here are some tips on how to use this technique to wire circuits, and on when (and when not) to use it.

Wire Wrap is a largely solder-free method of wiring circuits. Connections are made by tightly wrapping several turns of wire onto special, square Wrap posts, the corners of which bite into the wires to form solid electrical and mechanical connections without the need for solder.

For the beginner, the investment in Wire Wrap equipment is small—$15 or so for a multi-purpose Wire Wrap tool and a spool of the special wire used with it. Perhaps the biggest continuing expense is the special Wire Wrap IC sockets required by the medium. These have long, square posts suitable for several levels of wraps. They are usually more expensive than the solder-type sockets used with printed-circuit boards.



Wrapping wire is available on spools, or in packets of precut and pre-stripped lengths. A single tool strips, wraps, and unwraps the wire onto special Wire-Wrap IC sockets with long, square posts.

A multi-purpose tool will strip, wrap, and unwrap the wires. Electrically powered Wire Wrap tools are also available, but a simple "finger-powered" tool is all you need for occasional use. To make successful Wire Wrap connections, you must use Kynar-insulated No. 30 wire, either in spool form or in packets of pre-cut, pre-stripped lengths.

Wire Wrap tools, hardware and other materials are available from many sources. Shown in the photo is an assortment of such paraphernalia.

A convenient type of circuit board to use for Wire Wrap projects is perforated board with holes on 0.1-inch centers, with copper pads around each hole and interleaved power and ground buses that help ensure that the supply and ground connections are low in impedance and less prone to noise. The pads make it easy to solder the IC sockets to the board. Some boards also include rows of three-hole pads for making soldered connections between components.

You can also Wire Wrap on perforated board that has copper-ringed holes but no buses or multi-hole solder pads. A plain perforated board is another possibility, though the copper-ringed holes are convenient and are recommended for use in large projects.

When building a circuit using the Wire Wrap technique, plan board layout by trial-inserting the IC sockets and other large components you'll be using. As much as possible, arrange the components that interconnect with each other in close-proximity to each other. When you've finished with the layout, install the IC sockets in their planned locations and solder their pins to the pads on the circuit board. If you're prototyping and plan to dismantle the circuit later, tack-solder only two pins diagonally opposite each other to the pads. When you're through using the circuit, desolder the pins and recycle the sockets into other projects. For a permanent installation, however, solder each socket pin to the board.

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by preparing two 8-inch and eight 4-inch lengths of hook-up wire. Strip ½ inch of insulation from the ends of each. If you're using stranded hook-up wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. To one end of five of the 4-inch wires, crimp female pins for the locking connectors. Crimp male pins to one end of the other three 4-inch wires. Determine which are the secondary leads of *T1* and crimp and solder pins to these. Insert the pins on *T1*'s wires into a 2-pin connector, and insert the other pins into the other three connectors.

Next, plan your preliminary parts layout on the circuit board. All components except *T1*, *F1*, and *S1* should mount directly on the board. Group the power-supply components together, and be sure to reserve enough space for *IC11*'s heat sink.

The TO-3 package of *IC11* requires two mounting holes in the circuit board and two slightly enlarged holes for its input and output pins. The case provides the ground connection, so if possible, locate the IC on the board so that at least one of its mounting screws overlaps a ground trace on the board.

A mounting hole is also required for *IC8*'s TO-220 case. Because this voltage regulator is required to deliver just 30 milliamperes, no heat sink is required for *IC8*.

When you have a preliminary parts layout planned, drill the holes for *IC11*, *IC8*, and for mounting the circuit-board assembly inside the selected enclosure. These holes can be

Liberal use of labels on the circuit board helps keep you oriented as you wire the circuit. Small adhesive labels marked with the IC number can be mounted between the rows of pins of each socket on the wiring side of the board. Also, place a dot in one corner of each label to identify pin 1's location.

An alternative to homemade labels is preprinted Socket Wrap ID labels that slip onto the socket pins before wrapping. Pin numbers are labeled on these, and you can add your own identifying information.

To wrap a wire between two socket posts, choose or cut a length of wire long enough to make the connection comfortably and add 2 inches. Avoid routing wires between adjacent posts on a socket, but routing between the two rows of posts on a socket is fine. Route the wires around the rows, even if this means using a slightly longer wire.

Unless you're using pre-stripped wire, strip 1 inch of insulation from both ends of the wire. Most Wire Wrap tools include a slot for stripping the wire. Insert the wire 1 inch into the slot, push the wire to the bottom of the slot, and pull the end to be stripped through the slot. Repeat the process at the other end of the wire. The slot has a sharp blade in it that severs the insulation without nicking the wire.

To wrap the wire onto a post, insert the wire into the smaller of the two holes on the wrap end of the tool. Push the entire stripped end and about ¼ inch of insulated wire into the tool to ensure that the wrap will begin with a turn or two of insulated wire to reduce the chance of a bare wire shorting against an adjacent post. Bend the wire 90 degrees where it leaves the bottom of the tool.

The other hole on the wrap end of the tool fits onto a socket post for wrapping the connection. Push the tool onto the post until it's bottom is flush with the circuit board or a previous wrap. Grip the free end of the wire to keep it from spinning with the tool and rotate the tool several turns, until it spins freely and the wire is wrapped onto the post.

Lift the tool from the post, and follow the same procedure for the other end of the wire. The posts on most Wire Wrap sockets accommodate three or more levels of wraps to permit multiple connections to a given point.

For connections to resistors, capacitors, and other components, you have a couple of options. One is to use special slotted Wire Wrap posts to mount the components. The posts friction-fit into perforated board (soldering is optional). On the component side of the board, the component leads are pressed into the slots on the posts. On the reverse side, connections are wrapped as usual. The advantage of this method is that components can easily be lifted out and changed. The disadvantage is the added cost of the special posts.

Another option is to insert and solder the components directly into the pads on the perforated board. You can Wire Wrap connections onto the leads of most components, but it's a good idea to also solder any such wrap to ensure a sound connection. Some component leads will be too thick or thin to accommodate the wrapping tool and will have to be hand-wrapped with longnose pliers and soldered.

Soldered connections aren't as easily changed as the ones on the Wire Wrap posts, but either method is workable. You might use the posts for components you may have to change and solder the ones that you're confident are permanent.

As you wrap each connection in a circuit, check it off on your schematic diagram (or a photocopy of it) to save you from having to mentally keep track of what you have and haven't yet wired.

To unwrap a connection, push the unwrap end of the tool onto the post and rotate the tool in the opposite direction from the wrap until the connection is free.

Finally, Wire Wrap isn't always the appropriate method to use. High-current circuits (more than 200 milliamperes) aren't suitable for Wire Wrap's small-diameter wires. Also, if you need more than a few of the same circuit, printed-circuit-board construction may be more economical. Quite often, though, Wire Wrap is a good choice. If you haven't yet, or haven't recently, given the Wire Wrap technique a try, consider using it the next time you have to build a circuit.

made by enlarging existing holes in appropriate locations on the circuit board.

Now begin wiring the +5-volt power supply, using Fig. 3 as a guide. The power supply output is several hundred milliamperes, so Wire Wrap (with its small-diameter No. 30 wire) shouldn't be used for these components. Instead, use solid hookup wire of 24 gauge or larger, and solder the wires into place.

Place a small amount of heat-transfer compound between the heat sink and regulator *IC11* to provide efficient heat conduction. Then mount the heat sink and regulator on the circuit board. Ensure that *IC11*'s case makes sound electrical connection to ground on the circuit board. You can make this connection either directly from a mounting screw to the ground bus or via a separate jumper wire to which is attached a spade or ring lug at the mounting screw and a soldered connection to ground at the other end.

Solder a connection between the output of *IC11* and the +5-volt bus on the circuit board. To aid you as you wire the rest of the project, label the buses on the circuit board with indelible marker or adhesive labels and make photocopies of the schematics.

Insert and make appropriate connections for *C15* through *C18*, *D3* through *D6*, and *IC11*. Mark off on the photocopy of Fig. 3 each wire run as you make it, and take care to orient all components correctly. Off-

(Continued on page 80)

The MIDI Music Revolution

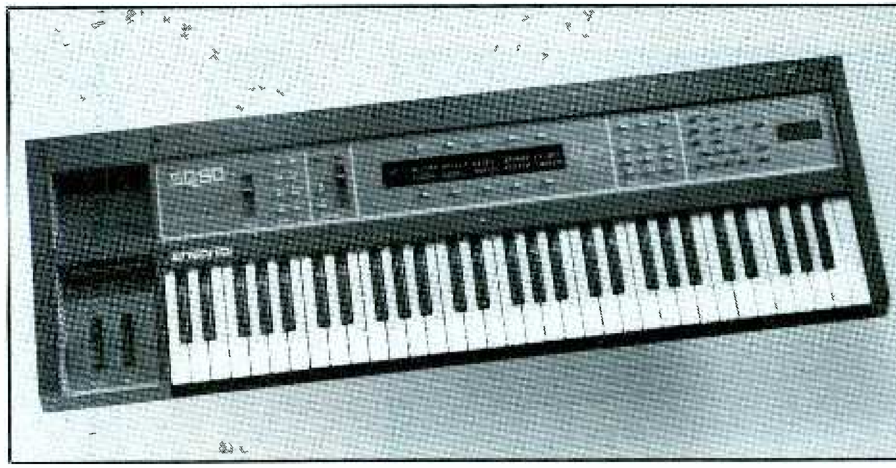
An introduction to what MIDI is all about, musical instruments that use it, and how musicians are exploiting this new frontier

By C.R. Fischer

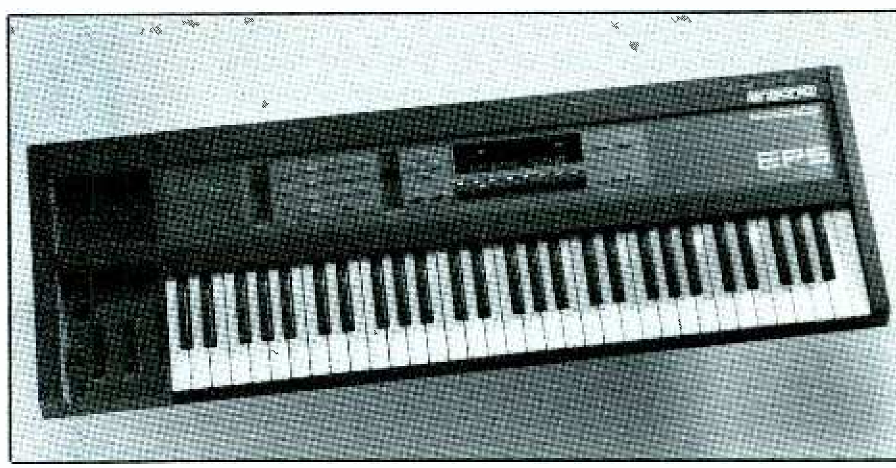
Ever since Thaddeus Cahill's invention of the "Teleharmonium" in 1895, electricity and electronics have played an ever-increasing part in the creation of music. Innovations like the tape recorder, electric guitar, and music synthesizer have provided musicians with endless possibilities for delighting audiences. Another recent innovation—just five years old—has already been the cause of great changes in the way musicians create and perform their work. Widely known as the Musical Instrument Digital Interface, or MIDI for short, it has become the industry-standard interface that allows musical instruments, audio equipment and other devices to be combined into a unified system.

If you use a computer or play a musical instrument, you may have heard about the exciting new world of MIDI. Having heard about MIDI, you may be among the large number

of people whose interest has been deterred by the lack of entry-level information on the subject. If so, this article addresses that shortcoming. Here we'll discuss the MIDI standard, instruments and devices that use MIDI, and how musicians are exploiting MIDI on-stage and in the recording studio.



Ensoniq's Model SQ-80 Cross Wave Synthesizer is just one of the sophisticated MIDI music synthesizers modern musicians use today.



The Model EPS is a state-of-the-art Performance Sampler from Ensoniq offers excellent MIDI implementation with synthesizer and record/playback capabilities.

MIDI Then & Now

Before the MIDI specification went into effect in 1983, musicians working with electronic musical instruments faced a less-than-ideal task. There were no standards that permitted them to combine their instruments to make up a "system." Though a few manufacturers of electronic musical instruments had designed simple interfaces that allowed their own products to be linked together, these were ignored by other manufacturers, who usually claimed that their own designs were superior. Consequently, before MIDI came along, chaos reigned.

By 1982, all but the simplest of music synthesizers contained at least one microprocessor, that powerful little integrated-circuit "chip" that has made possible the current revolution in microcomputers. It was the microprocessor itself that provided the motivation for manufacturers to develop a standard interface for all makes and models of electronic musical instruments. Around this time, a number of U.S. and Japanese companies had begun discussing the idea. After numerous proposals, counter-proposals, disagreements and at least one withdrawal, the basic MIDI 1.0 specification was finally decided upon. This specification was released in August 1983.

This specification was originally written with music synthesizers in mind. The idea was to allow a musician to control a number of "slave" instruments from a "master" keyboard. It's interesting to note that if MIDI had been left at this basic level, its widespread acceptance would have been doubtful. Thus, it has been the additions and enhancements to the specification made in the original version that has made MIDI so useful to today's musicians.

At the outset, the idea of MIDI was greeted with less than overwhelming approval from the music industry. Since the specification was so new and few musicians had any idea of its possibilities, most manufacturers bothered to add it to their products only as an afterthought, and some interfaces had been so poorly designed that they were worthless to the serious user. Another problem was that, because of the two-language nature of the specification, a translation problem between English and Japanese versions led to more than one manufacturer implementing the standard incorrectly. These early disasters led many insiders to the assumption that MIDI wasn't workable and was useless to professional users.

Fortunately, most of these mishaps were ironed out within the first year MIDI was in existence. Many of the software and hardware bugs in instruments were fixed so that, by 1985, MIDI had been established as a *de facto* standard in the music busi-

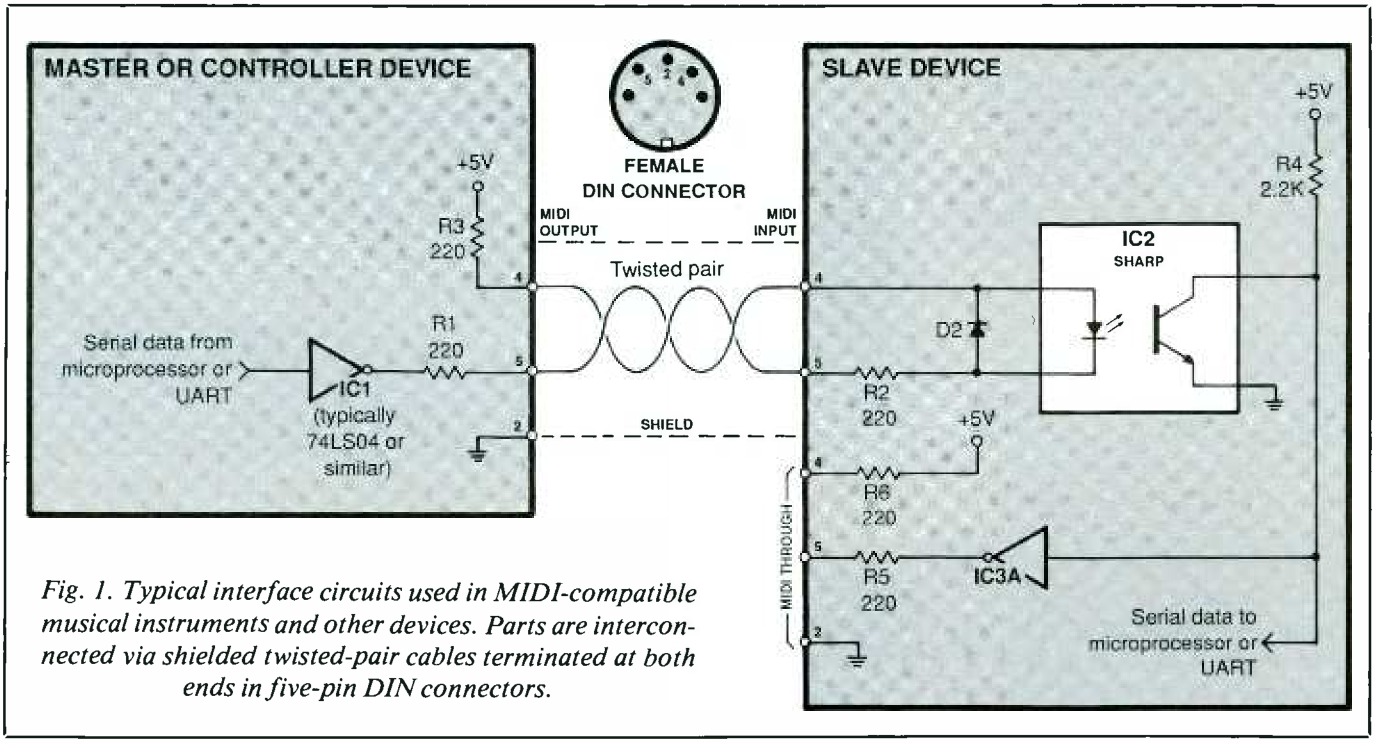


Fig. 1. Typical interface circuits used in MIDI-compatible musical instruments and other devices. Parts are interconnected via shielded twisted-pair cables terminated at both ends in five-pin DIN connectors.

ness. Some of the many instruments and other devices that use MIDI include:

- *Music Synthesizers.* As has already been mentioned, the original MIDI specification was created with a strong prejudice toward electronic music synthesizers. Software commands permit these instruments to be played from an external controller, such as a remote keyboard or sequencer. The controller, as its name implies, controls the notes played, desired program (sound patch), and expressive features like pitch bend and modulation wheels.
- *Samplers.* While synthesizers create sounds using analog or digital sound generators, samplers actually record and replay audio signals using digital recording techniques in a manner similar to that used in compact-disc players. This technique permits musicians to recreate acoustic-instrument sounds, natural sounds and special effects with incredible fidelity. Samplers are also popular for their ability to manipulate these sounds in a variety of unusual ways (the "stuttering" voices heard in radio and TV commercials are created in this fashion). Using MIDI, these sounds can be played from a controller much like a synthesizer.
- *Effects Devices.* Signal processors are used extensively in the recording studio and on the concert stage, as vocals and instruments alike usually require some form of electronic enhancement. There are dozens of processing techniques available, from simple equalizers and compressors to highly sophisticated digital reverberation units and exotic devices for creating special effects. The cost and effort required to manage a number of dedicated devices, however, can present serious problems to the user.

Instead of having to market a variety of specialized processors, manufacturers can now build multi-purpose effects boxes from which the user can select or edit the desired treatment using MIDI control. This capability offers a number of advantages, not the least of which is that instead of having to buy a variety of specialized units, the user need only a smaller number of generic devices. Since the manufacturer could now carry a more abbreviated product line, the lower production costs also led to lower retail prices. Finally, MIDI commands allow a musician or recording engineer to switch between various effects as desired, such as echo on the verse, reverb on the chorus, and flanging for a solo instrument.

- *Sequencers.* One of the most exciting applications of MIDI is the recording of musical performances with perfect fidelity and flexible editing. The sequencer is a device that records MIDI data that represents a musician's performance. Once the data has been recorded, it can be manipulated in many ways that aren't possible with simple tape editing.

As an example of the above, a song can be recorded at very slow tempo to make up for a musician's limited

technique. After recording, the song can be changed as required. If a few notes had been played out of rhythm, the sequencer can "quantize" the notes to correct their timing. Other editing functions permit notes to be added, changed and deleted. Because no audio signals are being recorded, only digital data that represents a performance, sounds can be changed instantly without the need for re-recording.

Sequencing has become one of the most important uses of MIDI. It's not uncommon for a lone musician to use a sequencer and several MIDI'd instruments to record an entire album at home. Individual parts are recorded and edited until the results are perfect, at which point, the musician brings his or her sequencer and instruments to a recording studio, where the results are recorded in just a few hours time! The savings in studio time and money are substantial.

• *Computers.* Personal computers play a central role in MIDI setups. With the proper interface and software, a computer can perform many useful tasks. For example, a computer can serve as a professional-quality sequencer as described above. Another use of the computer is as a patch librarian that stores hundreds or even thousands of synthesizer sound programs known as "patches" on a floppy disk. Similar programs allow the user to edit and modify these patches while viewing the result on the computer's video display monitor. Still other programs print MIDI data in traditional musical notation for other instruments and copyright purposes.

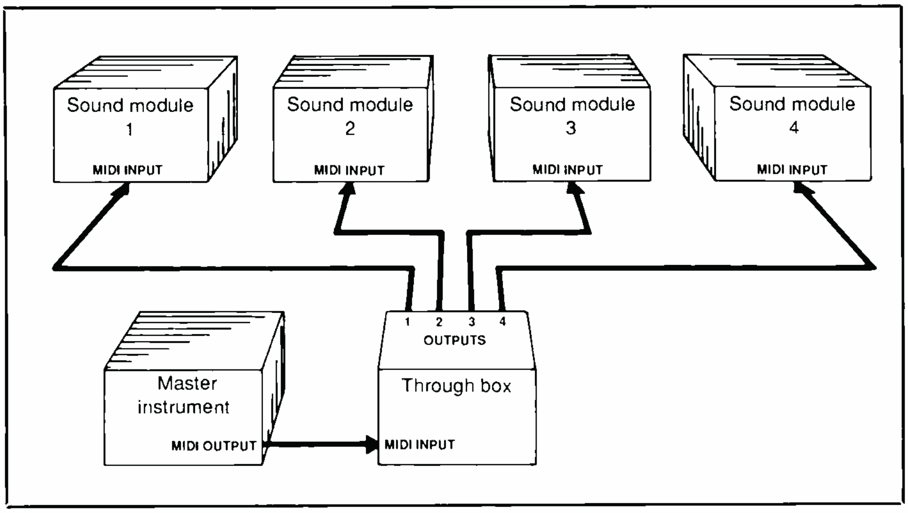


Fig. 2. A number of sound modules, including synthesizers and samplers, can be assigned to individual MIDI channels. By changing the transmitting channel of the master controller, various sounds can be instantly selected.

MIDI Circuitry

Hardware used in MIDI circuitry is straightforward electronics, thanks to the wishes of manufacturers for low cost and simplicity in design. To receive or send data, devices typically use two or three serial ports that are operated at a fixed transfer rate of 31.25K baud. These ports are commonly referred to as "MIDI Input," "MIDI Output" and "MIDI Through," depending on which function they are to perform.

Shown in Fig. 1 is a schematic diagram of the data path that exists between two MIDI devices. Data from the master instrument's microprocessor is converted into serial data that is then buffered by hex inverter *IC1*. This buffering isolates internal components to prevent loading and external short circuits, while *IC1* is able to supply adequate current for reliable signal transfer. Resistor *R1* limits the inverter's output current and also serves to protect the inverter from short circuits and excessive voltages that might arise as a result of wiring errors.

At the slave instrument, incoming data flows in a current loop through *R2*, optical isolator *IC2* and *R3* to return to the master instrument. Current through this loop causes the light-emitting diode (LED) inside *IC2* to turn on and cause the internal transistor's collector to be brought to ground. With the LED off, the transistor's collector is pulled high by *R4*. Diode *D2* protects the optoisolator from damage as a result of reverse-polarity connection. This diode doesn't conduct under normal conditions. Though this design is inexpensive and reliable, it can drive only one MIDI Input at a time.

To remedy the drive limitation, a third type of connector, called MIDI Through, appears on a number of devices. This port simply buffers incoming data at the optoisolator to allow multiple devices to be connected together in "daisy-chain" fashion. The problem with this approach is that connecting multiple devices in series with each other results in a slight delay time in each optoisolator to accumulate, eventually resulting in an audible delay. A preferred solution, therefore, is to use a MIDI Through box designed to drive multiple MIDI ports from a single optical isolator, thus minimizing any delay.

The MIDI specification calls for five-pin DIN-type connectors as standard. These connectors are inexpensive, reliable and widely available. Pins 4 and 5 connect to the current loop, as illustrated in Fig. 1. Pin 2 connects the cable's shield conductor to circuit ground on the instrument that is sending data to prevent ground loops.

Cables that carry MIDI data must be shielded and consist of twisted-pair conductors that exhibit low resistance and capacitance. While the original specification permitted cable lengths of no more than 50 feet, many instruments can drive longer-length cables of high quality with no difficulty.

MIDI Software

Software commands used in MIDI were chosen specifically for their use to musicians and radio engineers. Because music relies heavily on emotion, as opposed to the black-and-white world of digital logic, a great deal of thought went into allowing expressive parameters to be set via MIDI. The original designers of the specification realized that defining every possible command would only hasten the obsolescence of MIDI. Therefore, they wisely left a good deal of room for future developments.

MIDI data is sent in 8-bit packets, or bytes. Most commands require two or three bytes. To increase the number of possible messages, two categories of bytes exist: status and data. Status bytes tell a receiving device how to interpret the data following their arrival. In this case, the two types of messages that can be defined by the status byte are channel and data messages.

Channel messages are used to tell instruments to play or release notes; change programs (patches); transmit the force used whenever a key is struck (velocity) or finger pressure is applied to a key after a note is down (pressure sensitivity or aftertouch); and transmit patch bends and modulation (vibrato and other effects) to increase the musician's expressive capabilities.

Channel messages can be sent to specific instruments by placing each slave instrument on a specific channel (which can be done from 1 to 16). This causes each slave instrument to respond to data only on its specific channel. Whether you prefer rock, classical or other music, you'll notice that each instrument in a group has a specific part to play. Channel messages allow MIDI to do the same thing. Some sophisticated sequencers may have four separate MIDI outputs, each of which has 16 channels. This can be used to control up to 64 individual musical instruments or other devices.

Data messages are not channelized. They are used to control devices in real time. Among these commands are: the start, stop and timing messages that permit multiple sequencers to remain synchronized; song select that requests a sequencer to play a specific selection; and system-exclusive commands.

While most messages are understood by all MIDI instruments, system-exclusive commands are assigned to specific instrument models. This permits two instruments of the same type to send sound patches and other data to each other as well as allow computers to act as patch librarians or editors that allow users to edit and store large numbers of patches on a single computer disk. Creating sounds on a synthesizer using its front panel is often a lengthy, tedious job; use of a computer makes the task a more pleasant one.

Since the original MIDI specification appeared in 1983, a number of additions and enhancements have been implemented. Some permit guitars, horns and other instruments to be used as MIDI controllers as an alternative to the keyboard. A sampler data dump standard for sending the large amounts of data used by samplers via a MIDI link has enhanced the standard. A very useful addition is the MIDI Time Code (MTC) that permits synchronizing music and sound effects to SMPTE time codes used in audio and video work and controls tape recorders and other studio equipment.

(Continued on page 94)

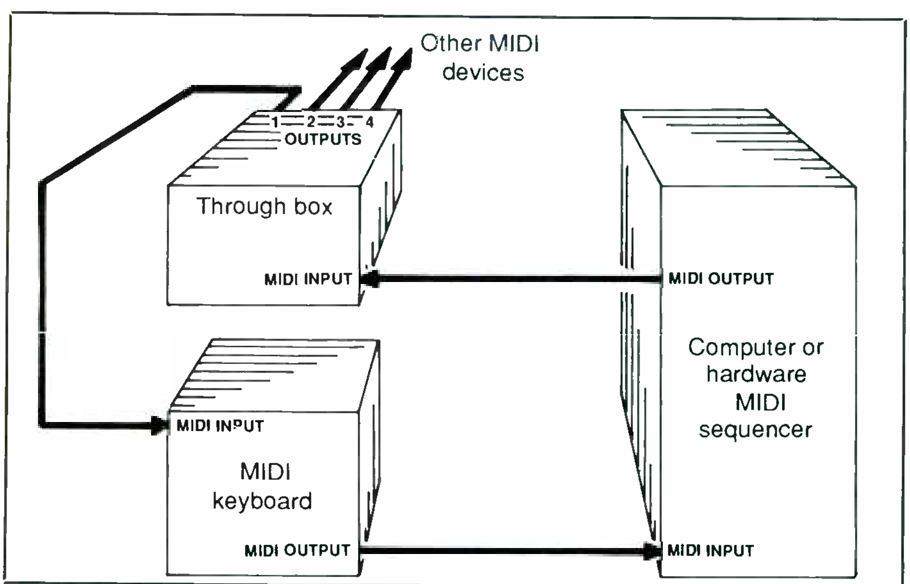


Fig. 3. Combining a MIDI controller, computer- or hardware-based sequencer and one or more MIDI modules forms a powerful tool for musical composition and performance. The controller and sequencer can record and play back a number of separate musical parts simultaneously, allowing a single musician to become a true "one-man band."

Using Sweep Frequencies In Electronics Troubleshooting

This technique greatly reduces the time needed to trace a fault to a particular component in a circuit

By Robert G. Middleton

Troubleshooting procedures can often be considerably speeded up by using a sweep-frequency rather than an adjustable-frequency signal generator. A sweep-frequency generator automatically and rapidly varies the frequency of the test signal over the range of frequencies of interest for immediate display of the associated frequency response curve on an oscilloscope's screen.

Unlike the one-shot display obtained with an adjustable-frequency generator, a sweep-frequency generator's display provides a panoramic view for the frequency response for a network or for a section of a network. It does so in a small fraction of the time that would ordinarily be required for you to make repeated observations with an ordinary adjustable-frequency signal that requires you to plot by hand the response using discrete frequencies you must pump into the circuit.

In this article, we will discuss in depth electronics troubleshooting and analysis using swept frequencies. In our analyses, we will discuss RC filter characteristics and how to read and interpret abnormal filter frequency-response curves.

Sweep Frequency Advantages

As an illustration of the above, consider the basic pseudo-active RC high-pass filter arrangement shown in Fig. 1. To check the frequency response of this filter, input voltage E_{in} can be from an audio oscillator and output voltage E_{out} can be applied to an ac DVM or DMM set to the ac volts function. After half a dozen measurements have been made at progressively higher frequencies, you can determine if the circuit has normal response. This procedure requires several minutes at the very least to complete.

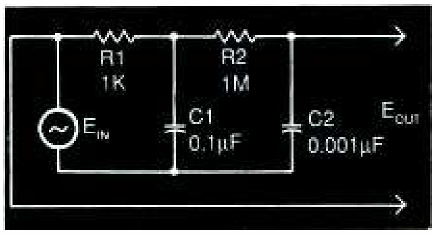


Fig. 1. A basic pseudo-active RC high-pass filter configuration.

Next, if an audio sweep generator and oscilloscope are employed, as in Fig. 2, the circuit's response is obtained almost instantaneously over the entire frequency range of interest, as illustrated in Fig. 3. The curves shown here depict normal response of the filter and the distorted response that results if *C1* in Fig. 1 is open. Under such a fault condition, the circuit has no "gain" and its cutoff characteristic is considerably slower than would be the case for normal operation.

It may be noted that this filter arrangement provides a maximum "gain" of approximately 15 percent when both sections in the configuration have the same time constant and when the second section has an input impedance that is at least an order of magnitude greater than the output impedance of the first section. This is just another way of saying that any circuit fault that upsets the equality of time constants for the two sections becomes apparent as a reduction of "gain" in the displayed waveform.

Bandpass Filter Checkout

Consider now the next basic bandpass-filter arrangement shown in Fig. 4. This circuit configuration is made up of a high-pass RC filter section followed by a low-pass RC section. Its passband between the half-power (–3-dB) frequency points is determined by the values of resistance (*R*) and capacitance (*C*) used to make the filter. Its passband is also affected by the value of load resistance *RL*, which may represent the input impedance of a driven device

Fig. 2. Typical basic setup for troubleshooting with sweep-frequency signals.

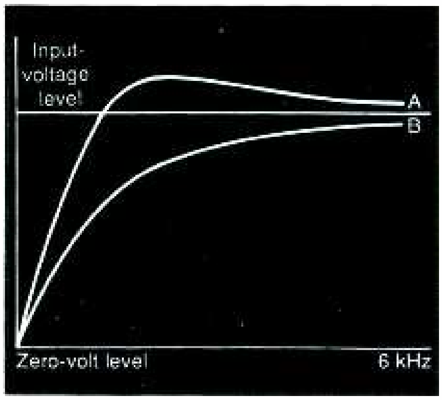


Fig. 3. Sweep-frequency curves showing (A) normal response and (B) with C1 in the Fig. 1 circuit open.

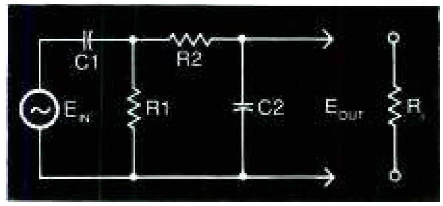


Fig. 4. A basis RC high-pass filter configuration.

like a bipolar or a MOS transistor. If a bipolar transistor is the driven element, its effective load resistance is comparatively small. Conversely, if a MOS transistor is the driven element, its load resistance is extremely large.

As a practical example of filter operation, let us assume that *R1* has a value of 20,000 ohms, *R2* a value of 150,000 ohms, *C1* a value of 0.01 microfarad, *C2* a value of 0.0004 microfarad and that R_L's value is virtually that of an open circuit with a value of 5 megohms. With these values, normal frequency response for the bandpass filter is illustrated in Fig. 5(A). It is evident here that the filter imposes an insertion-loss penalty of approximately 30 percent in normal operation. Its low-frequency cutoff characteristic has a fairly rapid rolloff, but its high-frequency cutoff characteristic has a slower rolloff.

Also illustrated in Fig. 5 are the distorted waveforms that are generated when *C2* is open and when *C2* is shorted. Under these fault conditions, insertion loss of the circuit is significantly less than it would be in a properly operating circuit.

Observe in Fig. 5 that the low-frequency cutoff characteristic is dominated by the frequency response of the high-pass filter section and that the high-frequency cutoff characteristic is dominated by the frequency response of the low-pass filter section. In normal operation, the peak frequency of the filter characteristic is approximately the same as the crossover frequency for the low- and high-pass filter sections.

Three-Section Filter Waveforms

It is helpful to consider the sweep-frequency waveforms for the basic three-section RC low-pass filter arrangement shown schematically in Fig. 6. This circuit provides outputs from the first, second and third sections. Typical component values are: *R1* = 1,000 ohms, *C1* = 0.01 microfarad, *R2* = 10,000 ohms, *C2* = 0.01 microfarad, *R3* = 100,000 ohms and *C3* = 0.001 microfarad. Any two of the output waveforms can be simultaneously displayed on the screen of a dual-trace oscilloscope, or all three waveforms can be displayed simultaneously if you are fortunate enough to have access to a scope that has three vertical inputs.

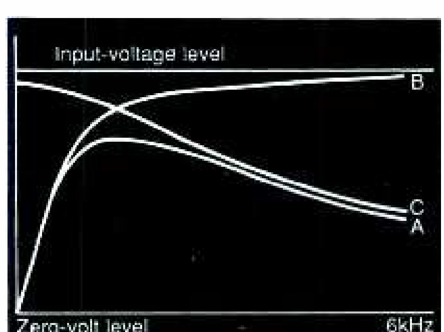


Fig. 5. Sweep-frequency response of an RC bandpass filter showing (A) normal response, (B) distorted response with C2 in Fig. 1 open, and (C) distorted response with C1 shorted.

Figure 7 illustrates the normal frequency responses for all three Fig. 6 filter sections. Note here that the rolloff becomes more rapid following each section. Also note that if two or three low-pass sections are utilized in the Fig. 4 circuit, the resulting high-frequency rolloff would be more rapid than that shown in Fig. 5. Rolloff is measured in terms of decibels (dB) per octave or dB per decade. An octave is defined as a doubling in frequency, a decade as an increase of one magnitude (10 times) in frequency.

Practical troubleshooting procedures are usually more concerned with qualitative characteristics than with quantitative characteristics of waveforms. Accordingly, you should become familiar with some of the features illustrated by the waveforms in Fig. 8. In the event that *C1* in the Fig. 6 circuit becomes open, the first filter section exhibits a very slow rolloff when compared with the rolloff rate shown in Fig. 7. In the event that *C2* in the Fig. 6 circuit becomes open, you will apparently observe two curves displayed, although all three curves will actually be on the screen. The reason why one curve will effectively be "dropped" from the displayed group is as follows.

Inspection of the Fig. 6 circuit will reveal that when *C2* is open, there is only resistive voltage-division action present between the output of the first and third filter sections. Accordingly, if *R2* has a comparatively low value of resistance, the waveform at the output of the second filter section will be practically the same as the waveform at the output of the first section. Alternatively, if *R3* has a comparatively low value, the waveform at the output of the second filter section will be practically the same as the waveform at the output of the third section. For component values given above, *R2* would have a comparatively low value, with the result that the waveform at the output

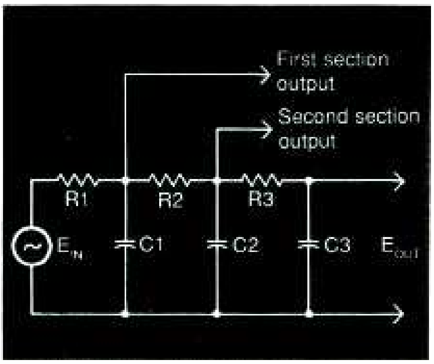


Fig. 6. A basic three-section RC low-pass filter configuration.

of the second filter section would seem to be coincident with the waveform at the output of the first section.

With the above analytical approach in mind, it is evident that if *C3* becomes open in the Fig. 6 circuit, only two waveforms will appear to be displayed on the scope's screen even though all three output waveforms are being traced. This situation results from the fact that when *C3* is open there is no wave-shaping element present between the output from the second filter section and the scope's input terminal. Accordingly, the output from the third filter section effectively merges with the output waveform from the second section. These are operative points for you to bear in mind when checking out three-section filters.

Equivalent Inductance

Referring to Fig. 9, it is a well-known fact that an RC L section has an equivalent RL L section and that an equivalent RL filter will have the same frequency response as its RC counterpart. Equivalent RC and RL L sections have the same time constant. That is, the time constant of an RC L section is equal to R × C and the time constant of an RL section is equal to L/R. RL filters are less commonly encountered in electronic circuits than are their RC counterparts because inductors are more expensive than capacitors, are more susceptible to unwanted stray-field (electromagnetic) pickup, and have lower Q values than equivalent capacitors. Nevertheless, this is a relationship that is of great importance from the viewpoint of "reading" oscilloscope waveforms.

Moving now to Fig. 10, you can see the equivalent RC and RL low-pass circuit configurations. This might appear to be of routine interest to you in your electronics work, but there is a kernel of an entirely different class of circuit action "hidden" in this relationship. In other words, an equivalent low-pass filter can be arranged from an RL section followed by an RC section, as illustrated in Fig. 11. Now you have a new "ballgame" going for you.

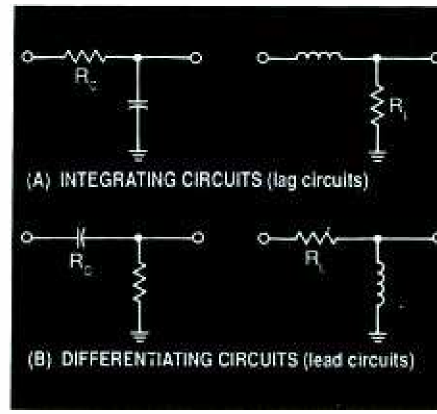


Fig. 9. Equivalent RC and RL sections: (A) integrating (lag) circuits and (B) differentiating (lead) circuits.

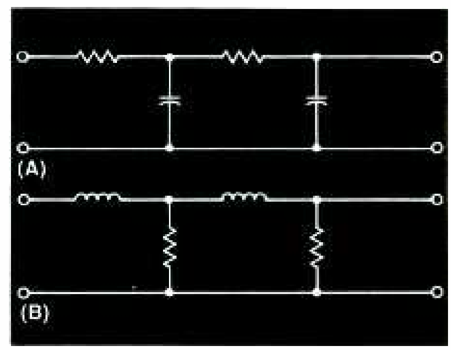


Fig. 10. Equivalent (A) RC and (B) RL low-pass filter configurations.

Observe in Fig. 11 that the inductor is connected in series with a capacitor via a resistive divider. This divider and capacitor has an equivalent circuit made up of another value of resistance connected in series with another value of capacitance. This equivalent resistor lowers the Q of the coil, but the inductance is connected in series with the capacitance and the resulting series LC circuit can be analyzed with respect to voltage magnification at its resonant frequency.

Returning to Fig. 3 for a moment, you can observe that the three-section RC pseudo-active high-pass filter has a resonant frequency and that a voltage magnification of approximately 15 percent is realized at resonance. This voltage magnification is

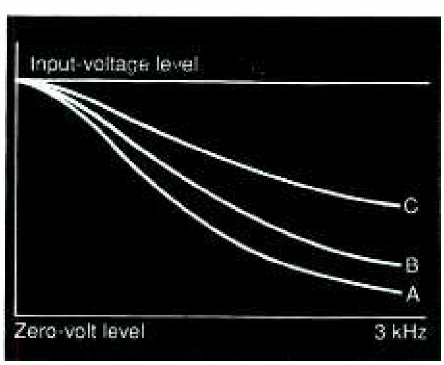


Fig. 7. Sweep-frequency response for basic three-section RC low-pass filter: (A) output from third section, (B) output from second section, and (C) output from first section.

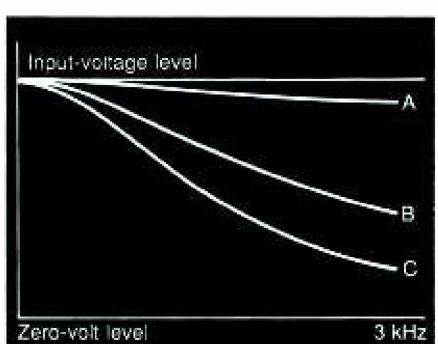


Fig. 8. Abnormal sweep-frequency response for basic three-section RC low-pass filter with C1 in Fig. 6 open: (A) first-section, (B) second-section, and (C) third-section outputs.

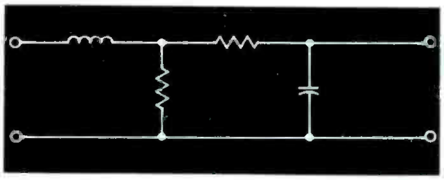


Fig. 11. Example of a low-pass filter made up of an RL section followed by an RC section.

equal to Q times the applied voltage, or the Q of the inductor (or of the capacitor, depending upon your point of view) is equal to 1.15. This circuit-action analysis makes it evident that pseudo-activity has a classical relationship to conventional filter arrangements. It also reveals that the Fig. 1 circuit contains pseudo-inductance.

Inductance is basically a circuit element or configuration that draws a lagging current in response to an applied voltage. Although it is commonly considered that an inductor consists of a spiral of wire wound around a physical coilform, you can now see that the reading of waveforms from the screen of an oscilloscope leads inevitably to the conclusion that an inductor may also consist of a pair of resistors and a pair of capacitors. This is the easy-to-understand foundation of sophisticated operational-amplifier filters like the "gyrator" that is effectively a large inductor without any windings. Think of them as "wireless coils."

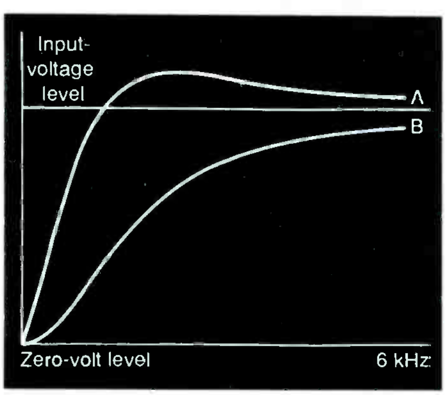


Fig. 12. Sweep-frequency waveforms showing comparative rolloff of basic filters: (A) two-section high-pass pseudo-active RC filter, (B) conventional two-section high-pass lead-circuit RC filter.

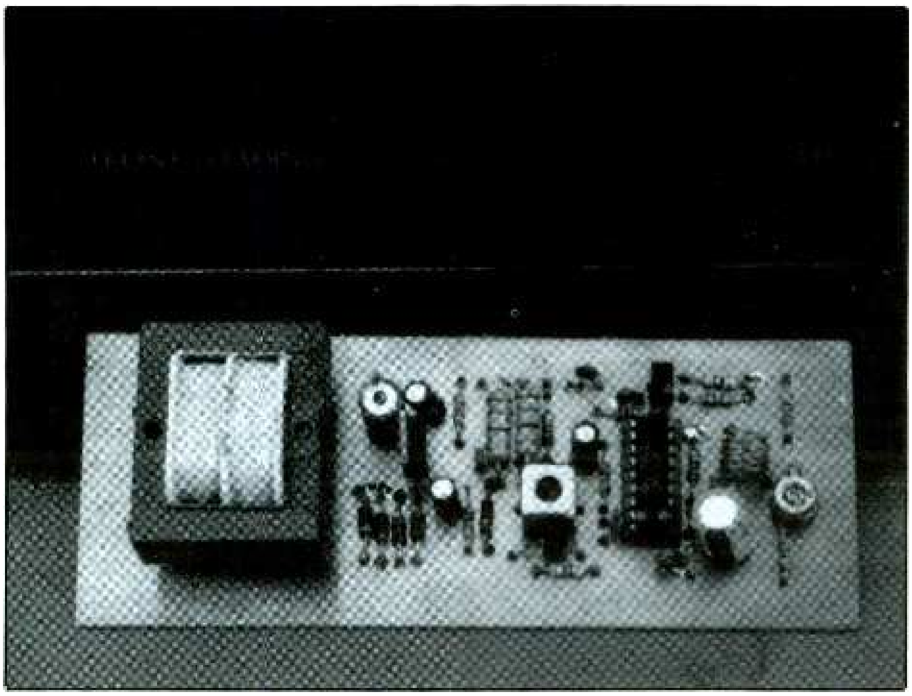
Rolloff Characteristics of Basic Filters

Comparative oscilloscope waveforms show the rolloff characteristics of filters to good advantage, as illustrated in Fig. 12. Here you see the rolloff (cutoff) characteristic of a two-section high-pass pseudo-active RC filter compared with its conventional counterpart. The waveforms reveal that the pseudo-active circuit configuration has a much steeper rolloff than does a conventional lead configuration. Rapid rolloff is frequently desired in practical applications to separate one band of frequencies from another. **ME**

VCR Modulator

Puts a VCR's audio and video outputs on an r-f carrier that is radiated through the air and is picked up by any TV receiver in a room near it

By Anthony J. Caristi



Many U.S. households have more than one TV receiver but only one VCR, which is usually dedicated for use with one specific TV set. With this arrangement, if you want to view a taped program on a different set, you normally have to physically move the VCR to that set. A much better way—one that doesn't require physical movement and subsequent wear and tear on connectors and cables—is to use a miniature TV transmitter like the VCR Modulator described here to distribute the audio and video information to other receivers by wireless means. It modulates the audio and video output signals from a VCR with an r-f carrier and radiates the composite signal to any TV receiver within range that is tuned to the Modulator's frequency (TV channel 3 or 4).

A special IC that was designed to modulate the audio and video outputs from a VCR with an r-f carrier signal for distribution to very-nearby TV sets is at the heart of this project. Designed to be directly connected to the antenna input of a TV receiver, the IC can also be used, as it is in this project, as a miniature TV broadcast "station" whose signal can be picked up by any nearby TV set tuned to it, without the need for running wires. With the project installed, viewing of video tapes in your household is no longer limited to a given TV set.

Since the project is driven by the video and audio outputs from a VCR, it doesn't interfere in any way with normal operation of the VCR or TV receiver to which the VCR is connected. It simply provides a modulated r-f carrier on the unused TV channel 3 or 4 frequency in your area that can be picked up by another nearby TV receiver.

In addition to using the VCR Modulator as a VCR distribution center, it can be used to reconcile the differences between Beta and VHS media. That is, you can have the video and audio outputs from a Beta or VHS modulate the project's r-f carrier that is then radiated to and picked up by a VCR of a different format for recording the action being shot.

About the Circuit

The complete schematic diagram of the VCR Modulator is shown in Fig. 1, including its ac-line-operated power supply. The heart of the circuit is r-f modulator integrated circuit *IC1*. This chip accepts suitable audio and video signals and modulates them with a low-vhf carrier, in this case a carrier whose frequency is on either TV channel 3 or 4. Channel choices are the same as for many other video accessories, such as VCRs and videodisc players, because in any geographical area in the U.S. either one or the other channel's frequency will be unoccupied.

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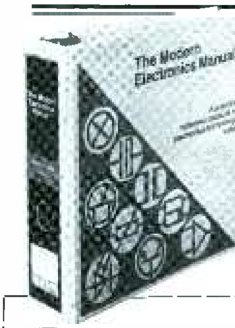

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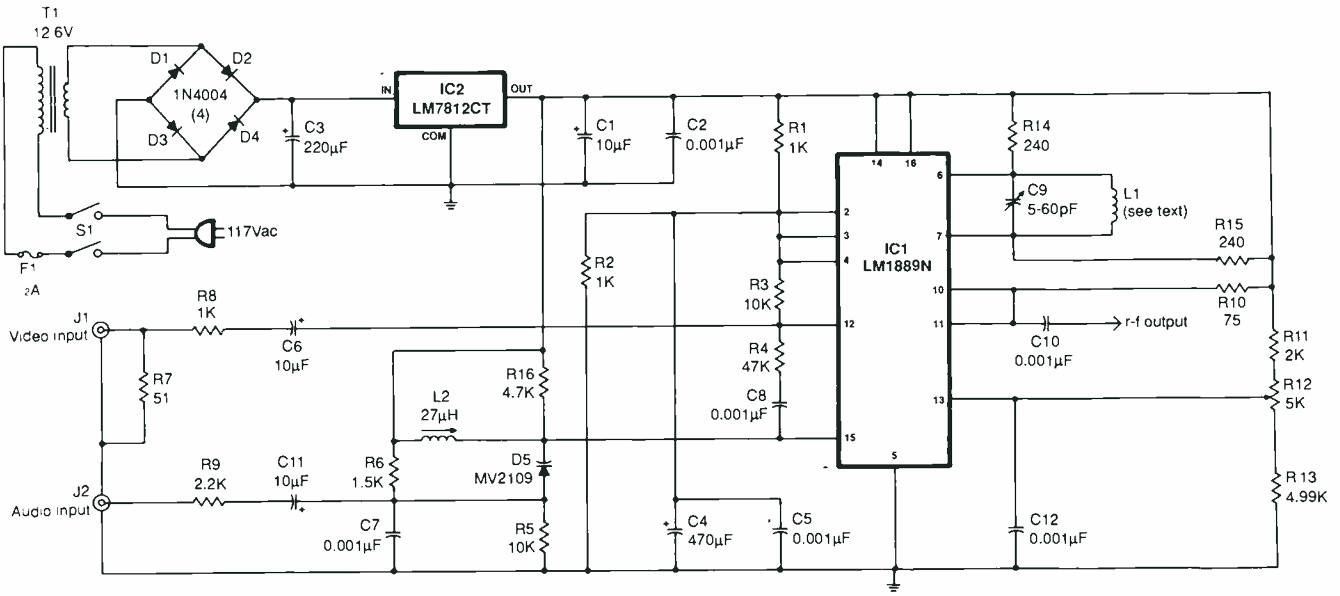


PARTS LIST

Semiconductors
D1 thru D4—1N4004 or similar silicon rectifier diode
D5—MV2109 (Motorola) or similar voltage-variable-capacitance diode
IC1—LMN1889N r-f modulator
IC2—LM7812CT +12-volt fixed voltage regulator

Capacitors
C1—10-µF, 16-volt radial-lead electrolytic
C2,C5,C7,C8,C10—0.001-µF, 50-volt ceramic disc
C3,C4—220-µF, 25-volt radial-lead electrolytic
C6,C11—10-µF, 16-volt radial-lead electrolytic
C9—5-to-60-pF trimmer capacitor (Radio Shack Cat. No. 272-1340A or similar)

Resistors
(¼-watt, 1% metal-film)
R1,R2,R11—1,000 ohms
R5—10,000 ohms
R6—1,500 ohms
R13—4,990 ohms
(¼-watt, 5% tolerance carbon)
R3—10,000 ohms
R4—47,000 ohms
R7,R10—75 ohms
R8—1,000 ohms
R9—2,200 ohms
R14,R15—240 ohms
R16—4,700 ohms
R12—5,000-ohm pc-mount cermet trimmer potentiometer

Miscellaneous
F1—½-ampere slow-blow fuse
L1—Hand-made coil (5½ turns No. 20 enameled wire—see text)
L2—27-µH coil (Toko No. 154ANS-1014Z)
S1—Dpst slide or toggle switch
T1—12.6-volt power transformer (Radio Shack Cat. No. 273-1385 or similar)
Printed-circuit board (see text); suitable enclosure; 18-pin DIP socket for IC1; holder for F1; 3-conductor ac line cord with plug; coaxial or shielded cable (see text); phono jacks (2—optional; see text); rubber grommets; spacers; machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: ready-to-wire pc board, $12.95; LMN1889N, $4.95; LM7812CT, $1.95; 27-µH coil, $3.50; MV2109 Varactor, $3.50; set of six metal-film resistors, $2.50. Add $1.50 P&H. New Jersey residents, please add state sales tax.

Fig. 1. Complete schematic diagram of the VCR Modulator, including its ac-line-operated power supply.

Part 15, govern the characteristic of the modulated r-f TV signal. This signal can occupy a standard TV channel bandwidth of 6 MHz. Peak carrier power for applications such as this project is limited to 3 millivolts rms in a 75-ohm system or 6 millivolts in a 300-ohm system. This project has been designed to conform to all Part 15 specifications of the FCC Rules and Regulations when built exactly as described later.

In addition to the single IC that performs all signal processing in this project, the circuit also contains two tuned circuits and dc biasing networks. A regulated 12-volt dc source completes the circuit.

Frequency of the picture carrier is determined by the values of the components used in the LC tank network made up of *L1* and *C9*. Adjustment of *C9* provides sufficient tuning range to easily cover the portion of the low-vhf band occupied by TV channels 3 and 4. Frequency of oscillation of the LC circuit is stable enough for the automatic frequency control (afc) of just about any modern TV receiver to handle.

Luminance (picture detail) and chrominance (color) information contained in the composite video signal is impressed upon input pin 12 of *IC1*. This pin is biased at about half the power-supply potential by means of the voltage divider made up of resistors *R1* and *R2*.

To preserve the dc component of the video signal, amplitude modulation (AM) of the picture carrier is performed in only one direction, with increasing-amplitude video signals causing decreasing carrier levels. This ensures that the peak carrier level doesn't change with scene brightness and provides a constant sync modulation level for the receiver.

Since it's the offset between the two signal pins of the internal balanced video modulator at pins 12 and 13 that determines modulation level, an adjustment of the dc level fed to pin 13 is provided by potentiometer *R12*. This control provides the means by which the circuit can be "tuned" for optimum picture quality.

Since the picture carrier frequency is generated by an LC oscillator operating in the vhf band, it is not stable enough to permit a similar circuit to be used for the sound carrier, which must be at a frequency that is 4.5 MHz above the video carrier frequency. The reason for this is that the difference in frequencies between the two carriers must be held to within 15 kHz or less to avoid creating audio distortion and sound "buzz" in the TV receiver. This potential problem is solved by using a 4.5-MHz sound inter-carrier system that is frequency modulated (FM) by the audio signal to amplitude modulate the picture carrier through the network made up of *R4* and *C8*.

Coil *L4* and voltage-variable-capacitance (Varactor) diode *D5* make up the 4.5-MHz tuned circuit. Since this type of inter-carrier circuit uses a relatively low frequency of 4.5 MHz, frequency drift will not be a problem.

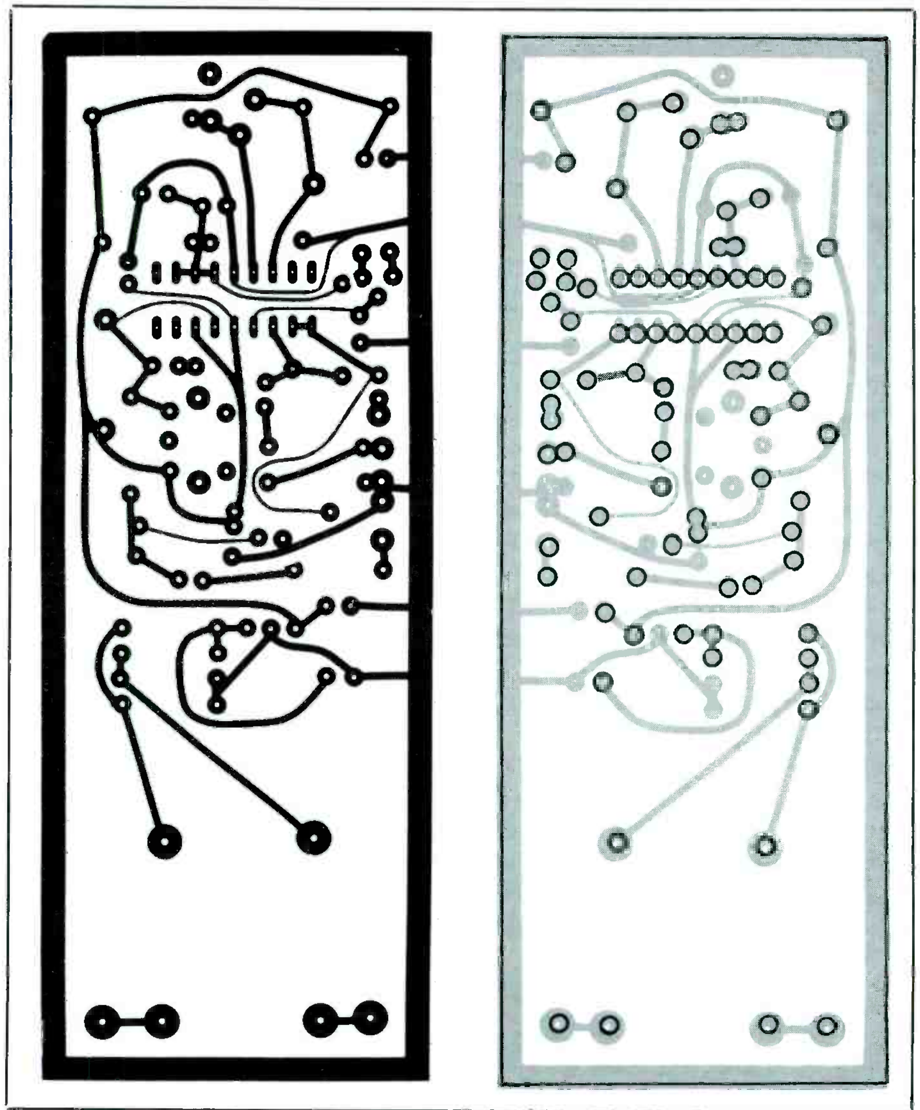


Fig. 2. Actual-size etching-and-drilling guide (A) and top-of-board ground plane (B) for fabricating printed-circuit board for project. Circles indicate holes from around which extra copper cladding must be removed in ground plane so that component leads plugged into these holes do not short to ground.

Frequency modulation of the 4.5-MHz audio inter-carrier is achieved with *D5*. This voltage-variable-capacitance diode has the relatively unique ability to change its capacitance in response to the changing amplitude of the audio signal. Resistors *R5* and *R6* provide dc bias to *D5* so that the Varactor diode operates in the desired range of capacitance.

R-f output of the modulator is provided at pins 10 and 11 of *IC1*. Containing luminance, chrominance, sync and audio information, the composite r-f output signal can then be fed to a TV receiver, which then demodulates the signal to produce the picture and sound of the program being fed into the VCR Modulator.

There are three inputs to and one

output from the project. One input is ac line voltage that powers the circuit. The AUDIO and VIDEO inputs are at phone jacks *J1* and *J2*, respectively. The R-F OUTPUT through *C10* is for connection to an external antenna for radiation to TV receivers in the nearby vicinity.

Power for the VCR Modulator is provided by the ac line. The input 117 volts ac is stepped down by power transformer *T1* to 12.6 volts ac. This ac signal is then converted to pulsating dc by the bridge-rectifier arrangement made up of *D1* through *D4*. The resulting pulsating dc is filtered to pure dc by capacitor *C3* and regulated to + 12 volts dc by fixed voltage-regulator chip *IC2*. Capacitor *C2* provides output filtering for the power supply, and capacitor *C2* bypasses any high-frequency noise on the dc bus to ground.

With the power-supply configuration shown in Fig. 1, the positive voltage bus is essentially ripple-free, and the potential will not change level with changes in input ac line voltage. This ensures stable r-f and inter-carrier frequencies.

Since the project operates at a very low power level, consuming a maximum of 35 milliamperes at 12 volts, you might want to power it from a 12-volt rechargeable nickel-cadmium or lead-acid gel-cell battery. By going this route, the project can be operated even where ac line power is not available, such as when you're shooting outdoors action with a camcorder.

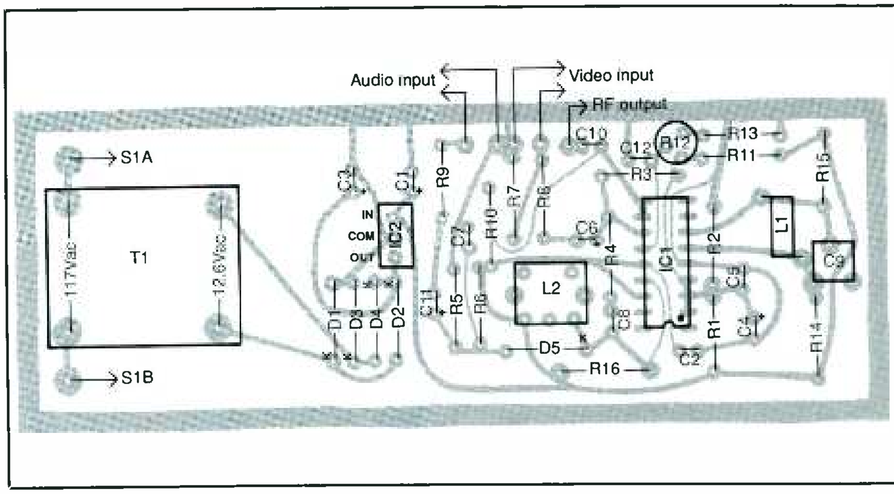


Fig. 3. Wiring guide for pc board.

Construction

As is the case with all high-frequency circuits, the method of construction chosen is very important to achieving desired operating results. Building the VCR Modulator is no exception. Though it may be possible to use other component mounting and wiring techniques to build the project with good results, the best approach is to use a printed-circuit board that has the conductor pattern on one side and a solid copper ground plane on the other side. The ground plane, which is really nothing more than an unetched side of the double-sided pc board, ensures proper performance.

Figure 2 is the actual-size artwork for those people who wish to fabricate their own pc boards. (A) is the bottom-of-the-board artwork, while (B) shows where to remove copper to prevent component leads that should not touch the ground plane from doing so. Though (A) is actual artwork, (B) is simply a guide. Do *not* attempt to prepare an exposure mask for the ground-plane side of the board.

After thoroughly cleaning the double-sided pc blank, allow it to completely air dry. If you wish to speed up this process, you can use a hair blow dryer. Handle the blank only by its edges; do *not* touch the cleaned copper at any time.

Completely cover one side of the cleaned pc blank with wide masking tape. Burnish the tape solidly down to remove air bubbles and to assure that all edges are solidly stuck. If you have to use more than one strip of tape, overlap it by ⅛ to ¼ inch and solidly burnish the seam. The tape-covered side of the blank is the ground-plane side of the board.

Sensitize the other side in the usual manner. When the photoresist has completely dried, expose it through an artwork mask made using Fig. 2(A) and develop it. Etch the board and, when done, thoroughly clean it. Then drill the holes in all indicated locations.

After drilling all component-lead holes using Fig. 2(A) as a guide, flip over the board. Strip away and discard all tape. Now, using Fig. 2(B) as a guide, *carefully* circle all holes indicated by the large circles. Do *not* circle any other holes. All circled holes must have copper removed from the ground-plane side of the board.

Use a very sharp, preferably new, 3/16"-diameter drill bit to clear away unwanted copper from the circled holes. Do this manually, using a pin drill. Do *not* use an electric power drill; if you do, you will almost certainly drill clear through the board and ruin your work. Monitor copper removal carefully and stop drilling when you can see a ring of board base around each hole as you drill.

It is very important that you remove copper from only the indicated hole locations in Fig. 2(B). The remaining holes in the board accommodate leads that are to be soldered to both the specific pad on the bottom of the board and the ground plane on the top of the board. This assures a good r-f ground connection in each case.

Shown in Fig. 3 is the wiring guide for the pc board. Though all components mount on the ground-plane side of the board, the see-through illustration references component installations to the conductor pattern on the bottom of the board. By making the conductor pattern the reference for component installation, you're less likely to install any given component in the incorrect location.

Start populating the board by installing and soldering into place the 18-pin DIP socket for *IC1* in the indicated location. Note that although pin 5 of this IC is grounded (see Fig. 1), *all* holes for the socket's pins must be cleared of copper. Connection to circuit ground for pin 5 is made from the trace on the bottom of the board.

Once the socket is installed, proceed to installation of the resistors and then the capacitors. Make sure each electrolytic capacitor is properly polarized before soldering its leads into place. Then install and solder into place the diodes, again making sure that each is properly oriented before soldering its leads into place. Bear in mind that reversal of one polarity-sensitive component will render the project inoperative and may even cause permanent damage to one or more components.

When installing any component that has a grounded lead, as detailed in Fig. 1, be sure to solder that lead to the copper pad on the bottom of the board *and* the ground plane on the top of the board. This is important because it ensures that the ground connection to the component is as short as possible. Some components, such as radial-lead electrolytic capacitors cannot be soldered to the ground plane on the top of the board. In these situations, it will suffice to have just one solder joint on the bottom of the board for the ground connection.

Inductor *L1* must be hand-wound, which is a very easy task to perform.

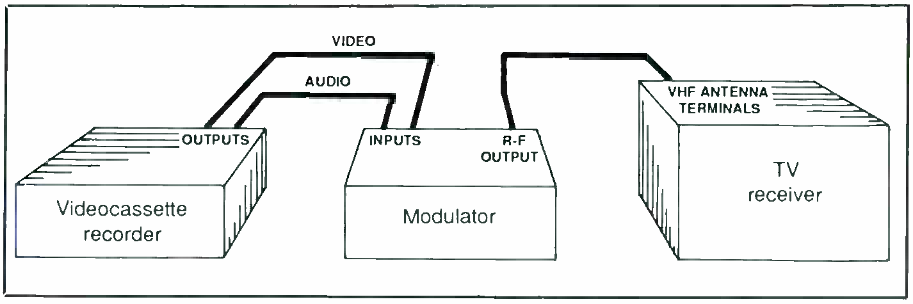


Fig. 4. Test setup to use for aligning project.

Use solid 20-gauge wire, enamel-insulated if possible but Teflon-insulated if not. Start with a wire exactly 6½ inches long. Scrape away ¼ inch of enamel (or strip ¼ inch of insulation) from both ends of the wire. Now wind 5½ closely spaced turns of this wire around an ordinary wooden pencil.

Slide the coil off the pencil and position the ends parallel to each other and pointing in the same direction. Spread the turns of the coil so that about one wire diameter of air space is between all turns. Plug the ends of the coil into the L1 holes in the board and position the coil about ³⁄₁₄ inch above the ground plane as you solder first one and then the other lead into place.

Once the coil has been installed and soldered into place, inspect the turns to be sure that none is shorting to the other or any other part of the circuit-board assembly. If necessary, adjust the spacing between the turns to one wire diameter. This done, install and solder *L2* into place.

Regulator *IC2* installs on the board standing straight up. Because power consumption by the circuit is very small, this IC requires no heat sink. Install the device in the IC2 location, making sure it's properly based before soldering its pins into place.

Strip ¼ inch of insulation from both ends of three 6-inch-long hookup wires. If you're using stranded hookup wire, tightly twist together the fine conductors at both ends and sparingly tin with solder. Plug one end of these wires into the holes labeled S1 (two wires) and R-F OUT and solder into place. (Note: You can make the connection to the project's antenna via 75-ohm coaxial cable instead of hookup wire. If you do this, plug the inner conductor into the R-F OUT hole and solder into place and then solder the shield directly to the board's ground plane.

There are two ways to prepare the inputs of the project. One is to use phono jacks that mount on a panel of the project's enclosure and separate plug-in cables. The other, preferable, method is to connect the input cables directly into the J1 and J2 holes in the circuit-board assembly.

If you use the jacks and separate-cable arrangement, prepare two 6-inch lengths of coaxial or shielded cable as follows. First, remove 1 inch of outer plastic jacket from both ends of both cables and separate the shields at both ends of the cables back to the plastic jacket. Next, tightly twist together the fine wires that make up the shield and tin with solder. If you're using cable that has a foil shield with wire tracer, peel the foil back to the remaining plastic jacket and trim away the foil but *not* the wire. Now strip ¼ inch of insulation from the inner conductor at both ends of the cable. Finally, if this conductor is made up of stranded wire, tightly twist the conductors together and sparingly tin with solder.

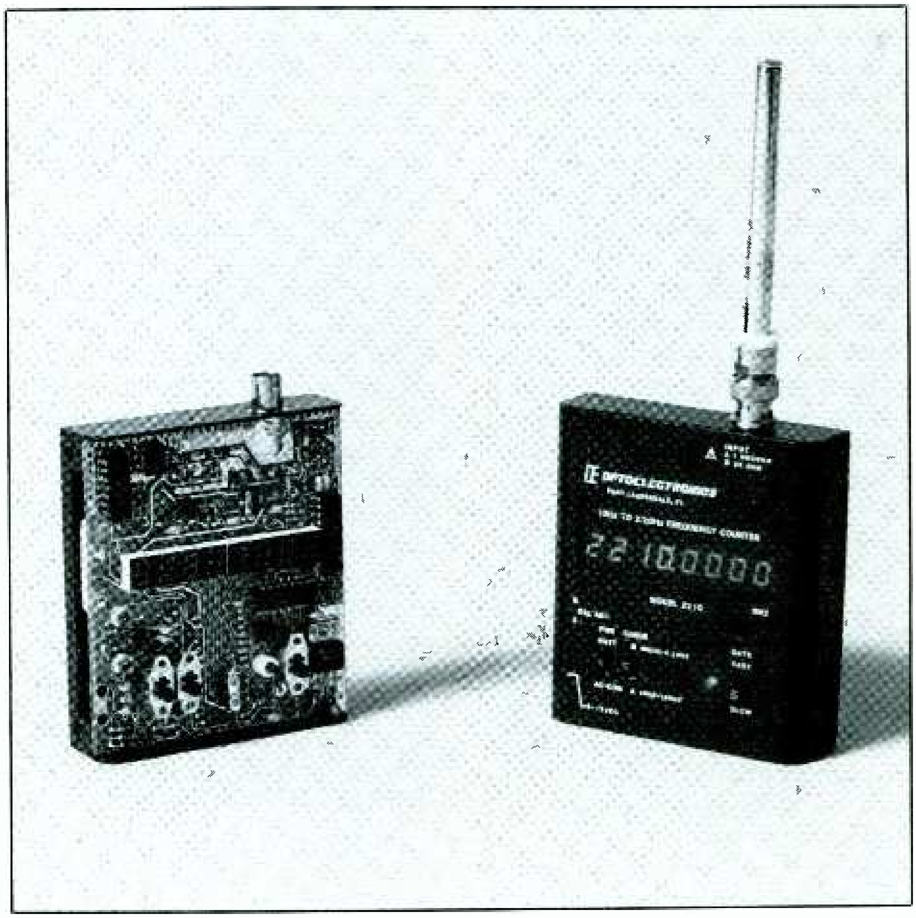
If you're eliminating the jack ar-

(Continued on page 84)

A 10-Hz to 2.2-GHz Frequency Counter

A hand-held general-purpose counter that performs like an instrument costing many times more than its moderate price

By Bill Owen



A frequency counter that operates from the low audio range to beyond 2.2 GHz has traditionally been very expensive and quite bulky. Now you can *build* such a counter for $100 in electronic components package and the printed-circuit board. Add another $50 to equip it with ac and dc powering options and a durable metal enclosure. Furthermore, the new instrument can fit into a jacket pocket and delivers big counter performance.

The basic counter has input amplifiers and two temperature-stabilized crystal oscillator timebases that assure sensitive, accurate operation and reads out measured frequencies in an eight-decade LED display.

Our general-purpose instrument can count frequencies down to 10 Hz and up to and beyond 2.2 GHz in two user-selectable ranges. It permits both antenna and direct input connections, making it suitable for a wide range of applications. For example, you can use it to check the clock frequency in a computer or pick up a cellular or cordless telephone signal or a ham, marine or aircraft vhf transmitter signal. With the antenna, its sensitive input can pick up a strong police, fire or public-service transmission, whose indicated frequency can then be punched up on a scanner for listening.

This counter's diminutive size and dual powering options make it ideal for service work on your testbench and in the field. It easily fits into a tool kit or even a jacket pocket. If you wish, you can also build this compact counter into a piece of equipment that has space for it and use it as a permanent panel-meter function of the equipment.

About the Circuit

Shown in Fig. 1 is the block diagram of the frequency counter. A signal whose frequency is to be counted en-

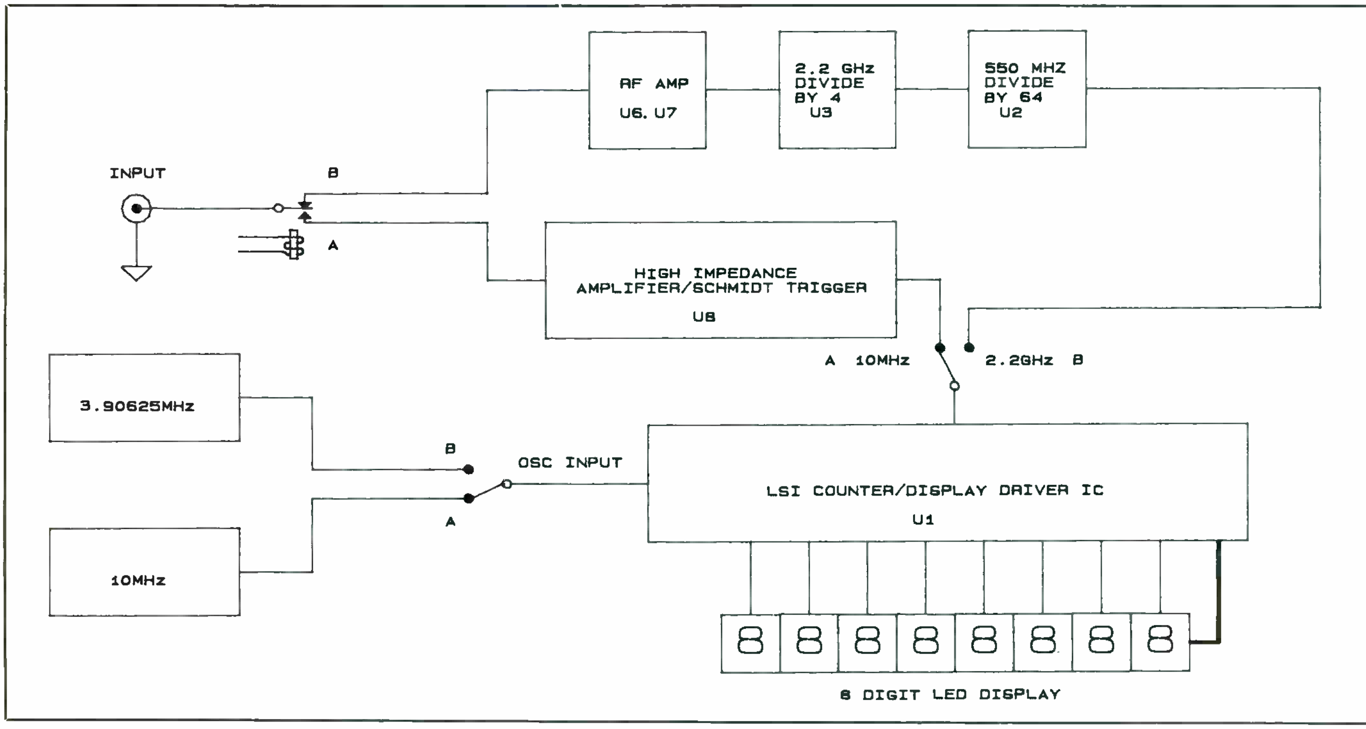


Fig. 1. Block diagram of the 10-Hz to 2.2-GHz counter's circuitry.

ters through the BNC connector labeled INPUT. A relay then routes this signal via either path A or path B. Path A is the direct input that bypasses the scaling circuits for signals whose frequencies are less than 12 MHz. Signals whose frequencies are greater than 10 MHz are routed via path B for prescaling. This is needed here because main LSI counter/display driver chip *U1* cannot reliably operate at frequencies beyond 12 MHz or so.

Signals to be counted in path A are amplified in several stages. For details of the A input amplifier, turn now to the complete schematic diagram of the counter shown in Fig. 2. Exiting the relay, the signal passes through coupling capacitor *C1* and is limited to approximately 0.7 volt by back-to-back diodes *CR1* and *CR2*. Resistor *R13* limits current through the diodes, and resistor *R32* is predominant in determining the low-frequency input impedance.

N-channel junction field-effect transistor *Q7*, along with pnp bipolar transistor *Q2*, make up a high-impedance, low-capacitance wide-band unity-gain buffer, the output of which is capacitively coupled to the first stage of an MC10116 triple line receiver. This ECL (emitter-coupled logic) device provides amplification with its first two stages and Schmitt-trigger action with its third stage. Schmitt-trigger action is accomplished with positive feedback through *R29*.

Low-frequency and noisy signals must be converted to clean fast-rise-

New Bipolar Technology

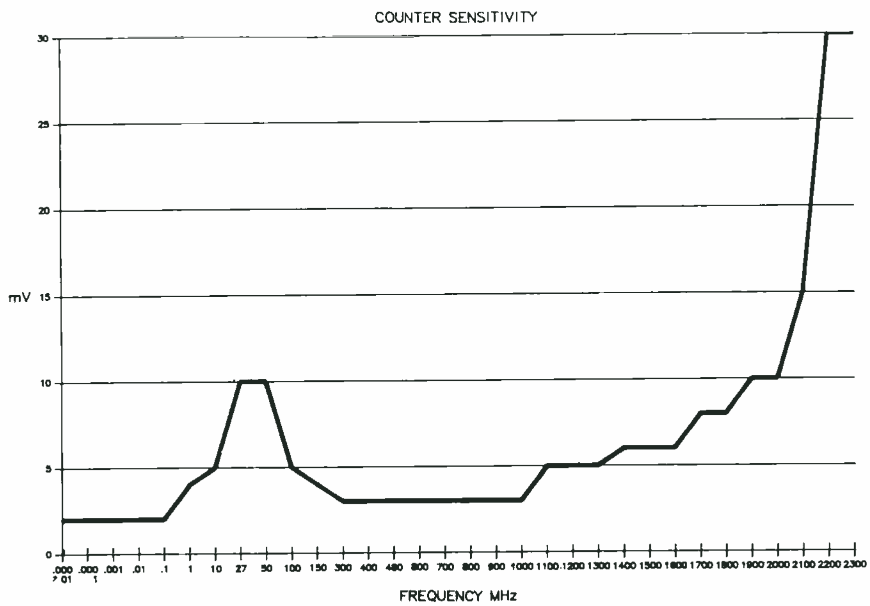
Though MOS technology seems to be getting all the publicity these days in the speed area, makers of silicon bipolar devices are quietly improving their products. Our frequency counter is the beneficiary of recent developments in this technology. In fact, the key components in the counter—a prescaler and a pair of microwave miniature integrated-circuit (MMIC) amplifiers—are new silicon bipolar devices. These new high-technology components are responsible for our frequency counter.

NEC's B582C 2.2-GHz prescaler chip is responsible for the counter's microwave performance. NEC states that the chip's "... high performance can be attributed to a newly developed process called Direct Nitride Passivated Base Surface II, which permits production of transistors with less parasitics, improved passivation and emitter line widths of 1 micron. The result [is an] f_T as high as 10 GHz, improved noise figures and reliability."

The microwave miniature integrated circuit amplifiers used in the counter are also a fairly new development. These Mini-Circuits MAR-6 devices are also a product of silicon bipolar technology. They are small surface-mount ICs that each provide 20 dB of gain and a 2-GHz bandwidth. For complete information on these devices, see the Table in a "1-MHz to 2-GHz Amplifier" in the September 1988 *Modern Electronics*.

Frequency Counter Specifications

	Input A	Input B
Range	10 Hz to 12 MHz	10 MHz to 2.2 GHz
Input impedance	1 megohm/30 pF	50 ohms
Sensitivity	(see Counter Sensitivity graph below)	
Timebase frequency	10 MHz	3.90625 MHz
Stability (20° to 40° C)	± 2 ppm	± 2 ppm
Aging	4 ppm/yr	
Calibration adjustment	Screwdriver adjust through front panel	
Resolution/gate period		
Fast	10 Hz/0.1 second	1 kHz/0.25 second
Slow	1 Hz/1 second	100 Hz/2.5 seconds
Display	8-decade 0.28" orange LED	
Dimensions	3.9"H × 3.5"W × 1"D	
Weight	9 ozs.	
Power requirements	9 volts dc at 200 mA from 117-volt ac 60 Hz plug-in adapter; 2 hours operation	
Internal battery	Rechargeable Ni-Cd; gives 2 hours operating time; recharges in 16 hours while operating from ac adapter	



time pulses by the Schmitt trigger. Because the characteristic ECL output of this circuit is not compatible with our circuit, bipolar npn transistor *Q5* provides level shifting for CMOS counter *U1*.

Signals that are routed via path B are amplified by *U6* and *U7* and enter *U4* where frequency division by a factor of 4 takes place. The signal exiting *U4* is coupled to *U2*. where it is prescaled again, this time by a factor of 64. The total prescale factor is then 256. Hence, one pulse enters *U1* for every 256 periods of signal entering the counter.

According to the above, if the prescale factor is a multiple of 10, it would be a simple matter to move the decimal point in the display to the appropriate location to permit direct display of the counted frequency without having to interpret the numbers. In this case, however, the counter's clock frequency must be changed to compensate for the divider ratio.

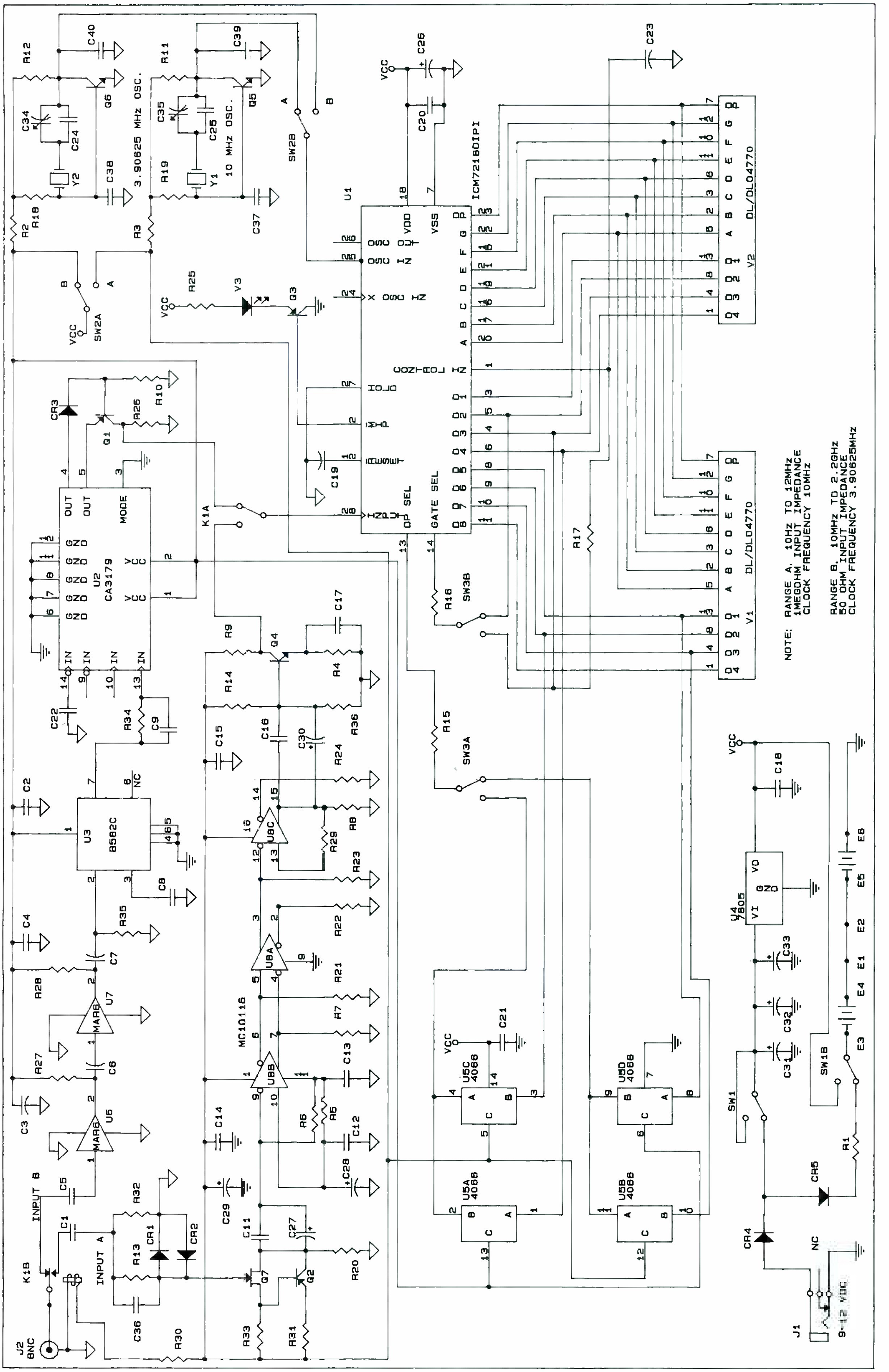
A frequency counter is an electronic device that gives a decimal display of the number of cycles of electrical events that occur during a given period of time. The unit of frequency is the Hertz (Hz), which is equal to one complete cycle per second. This counter uses millions of Hertz or megahertz (MHz) as its unit of measurement. To assure accuracy, the counter uses a clock reference to control the amount of time pulses are counted by it's electronic counters. All of this activity occurs inside *U1*, which is designed to use a 10-MHz clock for its reference.

Any deviation from the 10-MHz clock frequency results in a corresponding change in the length of time the counters inside *U1* will count. This is used to advantage in our counter. When the 2.2-GHz maximum signal frequency is prescaled by 256, the result is a frequency of 8.593750 MHz. Therefore, the clock frequency must be reduced so that the counters accumulate pulses for a longer period of time.

Since the counter uses a display made up of eight decades (digits), 22000000 is the number that should be displayed at the counter's maximum operating frequency. With the standard 10-MHz clock frequency, the displayed figure would be 8593750 after 1 second. To give the correct display, the counter would have to accumulate pulses for 2.56 seconds, which is a lengthening the gate time by a factor of 2.56.

To arrive at the correct clock frequency, you would divide 10 MHz by 2.56 to obtain 3.90625 MHz. At this clock frequency, the FAST and SLOW

Fig. 2. Complete schematic diagram of counter's circuitry.



3.90625 MHz OSC.
10 MHz OSC.
ICM7216DIPI
CA3179
8582C
MC10116
DL/DL04770
NOTE: RANGE A, 10HZ TO 12MHZ
1MEGOHM INPUT IMPEDANCE
CLOCK FREQUENCY 10MHZ
RANGE B, 10MHZ TO 2.2GHZ
50 OHM INPUT IMPEDANCE
CLOCK FREQUENCY 3.90625MHZ
INPUT A
INPUT B
J2 BNC
9-12 VDC

PARTS LIST

Semiconductors

CR1,CR2,CR3—1N4148 or similar small-signal diode
CR4,CR5—1N4005 or similar rectifier diode
Q1—PN3625A pnp transistor
Q2,Q3—PN5139 pnp transistor
Q4,Q5,Q6—PN2369 npn transistor
Q7—J309 n-channel field-effect transistor
U1—ICM7216 counter/timer/display driver
U2—CA3179/9321-012 prescaler
U3—B582C prescaler
U4—7805 +5-volt fixed regulator
U5—CD4066 quad bilateral switch
U6,U7—MAR-6 MMIC r-f amplifier
U8—10116P triple line receiver
V1,V2—DL/DLO4770 common-cathode 4-decade, 7-segment LED display
V3—T1 red light-emitting diode

Capacitors

C1 thru C4—0.1-μF surface-mount chip
C5 thru C10—1,000-pF surface-mount chip
C11 thru C22—0.1-μF, 50-volt monolithic
C23—100-pF disc
C24,C25—15-pF NPO disc
C26—100-μF, 6.3-volt electrolytic
C27 thru C30—47-μF, 6.3-volt electrolytic
C31,C32,C33—330-μF, 16-volt radial-lead electrolytic
C34,C35—1-to-23-pF pc-mount trimmer
C36—220-pF monolithic
C37,C38—390-pF monolithic
C39,C40—47-pF monolithic

Resistors (¼-watt, 5% tolerance)

R1—100 ohms
R2,R3,R4—100 ohms
R5 thru R12—1,000 ohms
R13 thru R17—10,000 ohms
R18,R19—100,000 ohms
R20 thru R26—510 ohms
R27,R28—150 ohms
R29—2,200 ohms
R30—a2.7 ohms
R31—51 ohms
R32—1 megohm
R33—680 ohms
R34—3,600 ohms
R35—27,000 ohms

Miscellaneous

B1—6-volt Ni-Cd rechargeable battery (4 AA cells in series)
J1—Pc-mount dc power jack (to match 9-volt dc plug-in power supply)
J2—Chassis-mount female BNC connector (modify as described in text)
K1—Pc-mount 5-volt dc relay with dpdt contacts
SW1,SW2,SW3—Miniature slide or toggle dpdt switch
Y1—3.90625-MHz solder-mount crystal
Y2—10-MHz solder-mount crystal
Printed-circuit board; socket for U1 (see text); 9-volt dc, 300-mA plug-in power supply; suitable enclosure; machine hardware; solder; etc.

Note: The following items are available from Optoelectronics Inc., 5821 N.E. 14 Ave., Ft. Lauderdale, FL 33334 (800-327-5812; in Florida, 305-771-2050): Kit of all components, but not enclosure, $99. Available separately; double-sided pc board with plated-through holes, No. PCB-2210, $25; 9-volt dc, 300-mA plug-in power supply, Part No. AC-22, $9.99; Ni-Cd battery, Part No. NiCad-22, $20; enclosure & hardware, Part No. CAB-22, $20.00. Also offered is an assembled and calibrated unit, Model 2210, for $189. Add 5% for P&H. Florida residents, please add 6% state sales tax.

gate times become 0.256 and 2.56 seconds, respectively, with the resolution or least-significant digit 1,000 and 100 Hz, respectively. Selection between the FAST and SLOW gate times is via *SW3B*, while *SW3A* switches the decimal point as needed in the *V1/V2* display via *U1*.

Notice in Fig. 2 that two clock oscillators are provided. One or the other is manually selected according to desired range by switch *SW2A*. In position A, the 10-MHz clock is used since path A directly couples into counter chip *U1* without undergoing prescaling. Position B of *SW2A* switches the 3.90625-MHz clock into the line during the prescaling operation. Both clock oscillators have separate calibration trimmer capacitors that permit adjustment for maximum accuracy.

Both clock oscillators are a modified Pierce design built around bipolar npn transistors *Q5* (10 MHz) and *Q6* (3.90625 MHz). Power to each oscillator is switched by RANGE switch *SW2A*. The other half of this switch, *SW2B*, routes the oscillator outputs to COUNT IN pin 25 of *U1*.

Count accuracy is determined by accuracy of the timebase clock oscillator. Trimmer capacitors *C34* and *C35* permit you to adjust each oscillator so that it is precisely on frequency. A precisely known reference frequency must be read by the counter and each oscillator must be adjusted until the frequency in the counter's display is "on the money."

After calibration, normal aging will cause the oscillators' frequencies to change over a period of time. This aging is caused by several factors. One is that microscopic particles may get knocked off the quartz of which the crystals are made over a period of time, slightly changing the mass of the quartz and, thus, the frequency at which it oscillates. Another is that the plating on the crystal will undergo some oxidation, even though the crystal housing is filled with inert gas. Also, the plating may undergo stress relief.

These processes will slow down after the first year to a more predictable rate. Until then, though, it is wise to check calibration as often as possible and make whatever adjustments are needed to compensate for the aging effects.

Temperature will also effect the accuracy of the crystal oscillators. If calibration is done at room temperature and a reading is taken at a higher or lower temperature, there will be some error in the displayed figure. This is why it is desirable to have some type of temperature compensation. Larger counters can use a crystal oven where temperature is precisely maintained. This counter does not have an oven.

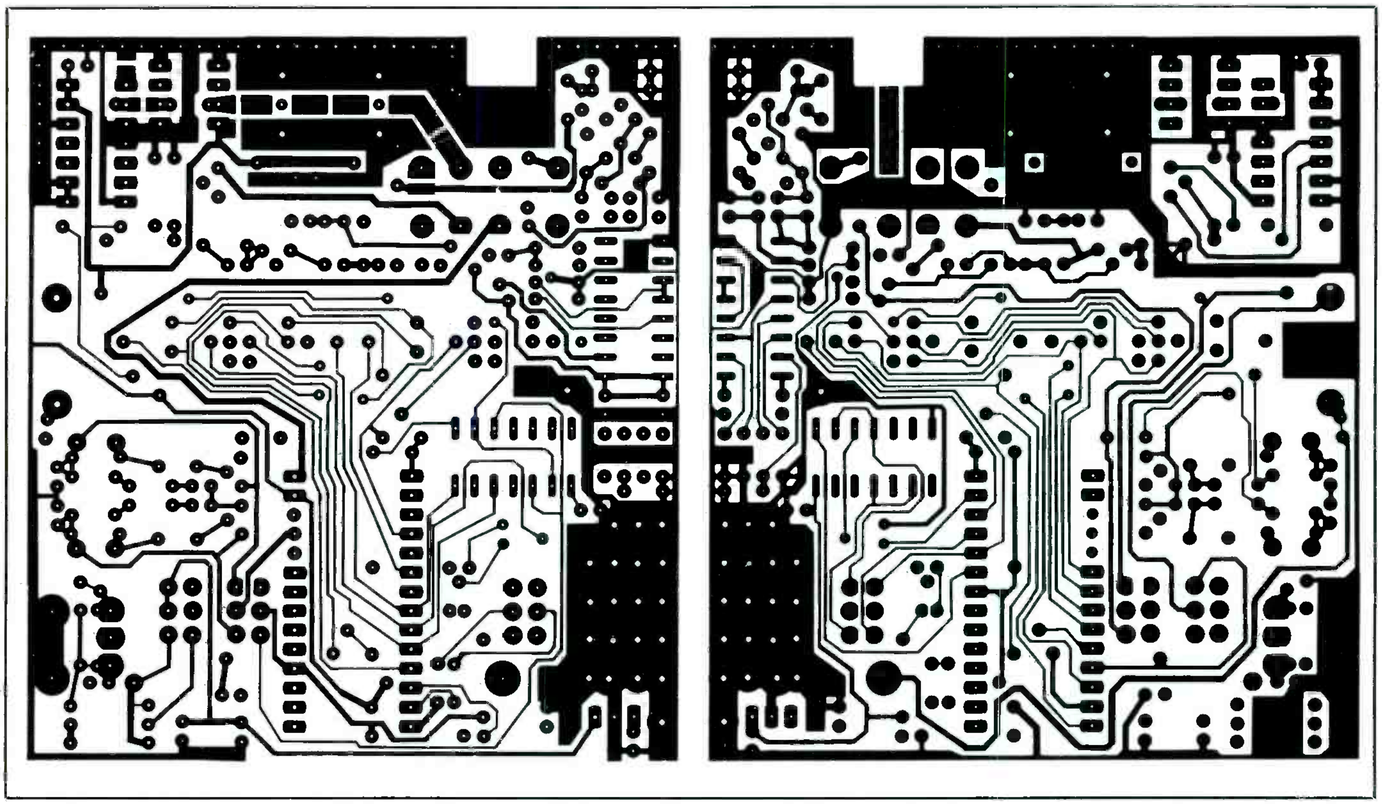


Fig. 3. Actual-size top (left) and bottom (right) etching- and-drilling guides for project's printed-circuit board.

An additional factor that affects the accuracy of this counter is its quantization error. During one gate period, the gate may close while a pulse is being counted, but during the next period it may close between pulses, even though the same frequency was being counted in both cases. Because of this possibility, the count observed in the display should always be viewed as being within ± 1 count in the least-significant (farthest-right) decade.

As the frequency being measured increases, the impact of the quantization error decreases. At 1,000 MHz (1 GHz), the least-significant digit may be 100 Hz, which corresponds to an error of only ±0.1 part per million (ppm). At low frequencies, an altogether different situation exists. At 100 Hz with 1 Hz resolution, the error is 1 percent, which greatly overshadows the timebase error. With decimal-point selection, there are four different combinations, two for range A and two for range B. To allow for four possible states without using multiple-pole mechanical switches, CD4066 analog switch *U5* is used. This chip has on-board four internal switches and is controlled by switching the positive supply rail as needed, using *SW3A*.

Since this frequency counter is designed to be portable, it must operate from a battery in locations where ac line power is not available. In this design, four AA nickel-cadmium (Ni-Cd) cells can be used to provide power for the counter for several hours before recharging is needed.

For bench use and in the field where ac power is available, a 9-volt dc, 300-milliampere wall transformer can be used to power the counter. This transformer can also be used to charge the battery while the counter is in use. Resistor *R1* regulates charging current.

When powered from the ac line via the adapter/charger, 7805 regulator *U4* delivers 5 volts dc to the circuits that make up the frequency counter. When operating from a battery, no regulation is needed. This scheme works quite well, but do note that the counter remains on continuously as long as it is plugged into the charger. To maintain steady, clean dc supply power, bypass capacitors and filter capacitors are used liberally throughout the circuit.

The ICM7216DIPI used for *U1* has been around for a number of years now and is a proven performer. Before this chip appeared on the scene, it took 20 to 40 integrated circuits to perform all the functions this single IC does. The 7216 drives the seven-segment light-emitting diode display digits, of which there are eight decades. This chip has a total of 16 display-drive lines, one for each segment and one for each digit. Using multiplex drive, the chip is able to fill the display only one decade at a time. Because the scan rate is quite

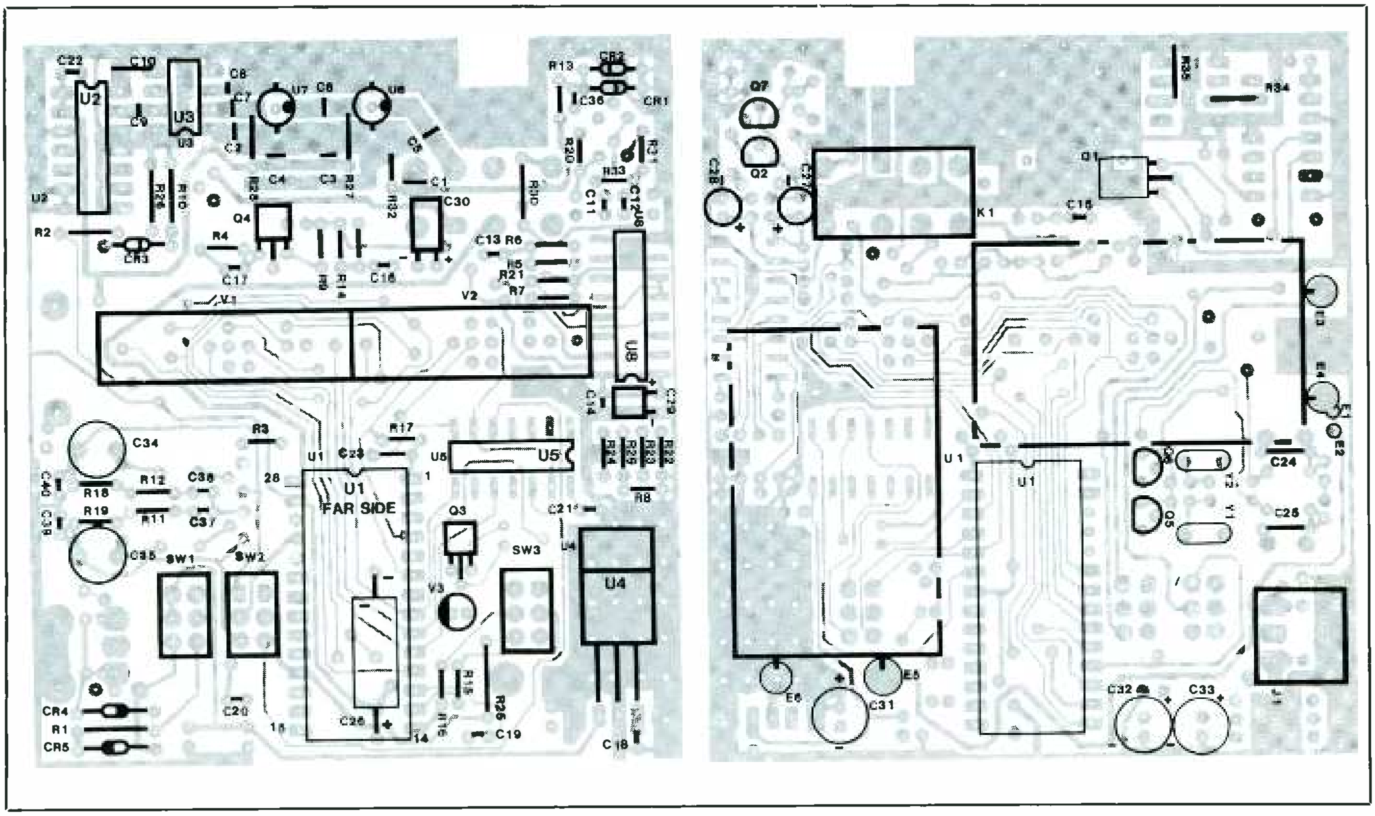


Fig. 4. Wiring guides for top (left) and bottom (right) of the pc board. All components mount directly on the pc board, including a cluster of surface-mount capacitors and IC amplifiers at upper-left in top view.

fast, however, all digits in the display appear to be on continuously.

Pin 2 of *U1*, labeled MIP is a measurement-in-progress status output indicator. When a count is being made, the signal at this point sends *Q3* into conduction and turns on light-emitting diode *V3*.

Construction

Printed-circuit construction is a must for this project. This board should be double sided. You can fabricate your own pc board or purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. If you make your own board, lack of plating-through for the holes will require that you solder all component leads and pins to the copper pads on *both* sides of the board and that you make provisions to continue conductors from one side to the other of the board where soldering access is not possible at a component. Use the actual-size etching-and-drilling guides given in Fig. 3 to fabricate your board.

Note in the wiring guides for the board given in Fig. 4 that components mount on *both* sides. The "top" side of the board is the one on which the numeric displays and majority of the components that make up the circuitry mount. The bottom of the board will have on it *U1*, the relay, the AA cells that make up the battery and a handful of discrete components.

Before installing any components on the pc board, prepare a chassis-mount female BNC connector to fit into place over the edge of the pc board in the notched area. Do this by cutting a slot across the threaded portion of the shell with one side offset just enough so that it is in line with the connector's center conductor pin and the other side spaced the thickness of the board away. Do this by clamping the connector in a vise between two pieces of soft wood and slicing very carefully with a hacksaw. Make the slot just wide enough to fit over the edge of the board without biting into the copper cladding.

Set the connector in place, as in the "bottom view" illustration in Fig. 4. Solder the center-conductor pin to the narrow pc trace at the bottom of the notch in the board. Make sure this pin touches only the specified trace when you are done. Then use a high-wattage soldering iron or a soldering gun to liberally solder the connector shell to the copper cladding on *both* sides of the board and on both cut edges on the same side.

Next, install and solder into place the relay on the bottom side of the board. Flip over the board and refer to the "top view" drawing in Fig. 4 to install and solder into place ICs *U2* and *U3*. Make sure each is properly oriented before soldering any pins.

There are 10 chip capacitors (*C1* through *C10*) and two integrated-circuit amplifiers (*U6* and *U7*) that are surface-mount devices. All are located in the upper-left in this drawing. The capacitors have no leads, and the amplifiers have very short pins. There are no holes in the board for leads for any of these components. You install the capacitors and amplifiers by setting them in place on the copper-trace pattern and soldering one lead down with a small-tip soldering iron.

Begin with the capacitors. There are two values for these chip capacitors, the smaller ones being 1,000-picofarad (0.001-microfarad) units that are identified with the legend 103) and the larger being 0.1-microfarad (identified with 104) units. Install each in the proper locations, referring to the Parts List.

Set the first capacitor in place and use a needle to hold it there with gentle pressure as you solder one end to the trace it touches. Use the needle to reposition the capacitor if it moves during the soldering operation. Do the same for the remaining nine capacitors. When you are done, gently solder the other sides of all capacitors to the other pads on the board. Take care to avoid stressing these tiny fragile chip capacitors. Also, to avoid damaging them with heat, do *not* solder the second end to their traces immediately after soldering the first.

Next, solder the tiny MAR-6 amplifiers into the U6 and U7 locations. These devices should fit snugly into the holes in the board to help in soldering. Keep in mind that the white dot on the case of each device *must* point towards the relay.

Bend the pins of the 7805 voltage regulator back at a 90-degree angle (toward the metal tab) ⅜ inch from where they join the plastic case. Before installing the regulator, you might want to fill the large holes in the board in the U4 location with solder to aid in heat sinking. This done, position the regulator in the U4 location, plug its pins into the indicated holes and solder them into place. Then liberally solder the regulator's metal tab to the large copper pad under it on the board.

Once the surface-mount devices are in place, install the resistors and capacitors on the top of the board. Be sure to properly orient the electrolytic capacitors and diodes before soldering their leads into place. Also, note that capacitors *C29* and *C30* must lie flat against against the board. Bend their radial leads at a 90-degree angle to their cases before installing these capacitors. The same applies to transistors *Q3* and *Q4*. Bend their two outer leads ⅛ inch and their inner leads ¼ inch from the cases at a 90-degree angle toward the rounded rear of the cases. Plug the leads into the indicated holes and solder them into place.

Now install integrated circuits *U5* and *U8* in their respective locations on the top of the board. Do *not* use sockets for these ICs (the only IC that should be installed in a socket is *U1*, which mounts on the bottom of the board). Make certain you orient these devices properly before soldering their pins into place.

Install and solder into place two seven-segment LED numeric displays in the V1 and V2 locations. Make certain that the decimal points in both displays are oriented toward the bottom of the board before soldering any pins into place.

Use a 0.1 × 0.25-inch nylon spacer to mount GATE light-emitting diode *V3* in place. Be sure to properly polarize this LED before soldering its leads into place. The cathode lead goes into the left hole.

Plug the lugs of the switches into the holes for them in the board and solder them into place. This completes wiring of the top side of the board. Turn over the board and carefully clip all protruding leads and pins as close as possible to the board's surface.

Now wire this side of the board, beginning with installation of the resistors and capacitors (observe polarity with the electrolytics). Then install and solder into place the remaining transistors. Only *Q1* mounts flat against the board's surface in the same manner as those on the top of the boar. The other transistors mount upright in the traditional manner. Be sure to plug the transistor leads into the appropriate holes before soldering them into place.

Install and solder into place the power jack in the J1 location and the two crystals in the Y1 and Y2 locations. Be sure with regard to the latter that you plug the correct-frequency crystal into each location.

Place two rechargeable Ni-Cd AA cells in opposition orientation to each other. Line up their ends and wrap with plastic or strapping tape. Solder a short length of insulated hookup wire from the positive (+) pole of one cell to the negative (−) pole of the other. Strip ¼ inch of insulation from both ends of two 1-inch hookup wires. Set the two-cell arrangement before you flat on your work surface with the remaining positive pole to your left. Tack-solder one end of one wire to the positive pole with the free end pointing away from your work surface. Do the same with the other wire and negative pole of the battery. Wrap together the battery pair, top to bottom, with more tape. Then repeat all steps for the remaining two AA cells.

Plug the free ends of the wires you soldered into the poles of one pair of cells into the holes labeled E3 and E4, with the positive-pole wire going to the E3 hole and the negative-pole wire going to the E4 hole. Similarly, plug the free ends of the wires on the other cell pair into the holes labeled E5 (+) and E6 (−), respectively. Place a wide strip of ⅛-inch-thick double-sided foam tape between each cell pair and the circuit-board assembly to provide resilient mounting.

Now install and solder into place a

(Continued on page 88)

Getting Started In Virtual Instruments: A Storage Oscilloscope Computer Program

By Forrest M. Mims III

This month's column is for anyone who uses, owns or plans to purchase electronic test instruments or data-acquisition systems. Hopefully, this includes everyone who reads *Modern Electronics*. First, I'll cover some important developments that will transform a personal computer into a wide variety of test instruments. I'll also describe some of the ways stand-alone instruments equipped with interface ports can be used with a personal computer. Much of the hardware and software needed to create computerized or computer-controlled instruments is very expensive; but it doesn't have to be. I'll conclude this column by showing you how to use a low-cost analog-to-digital (A/D) converter board to transform a personal computer into a storage oscilloscope.

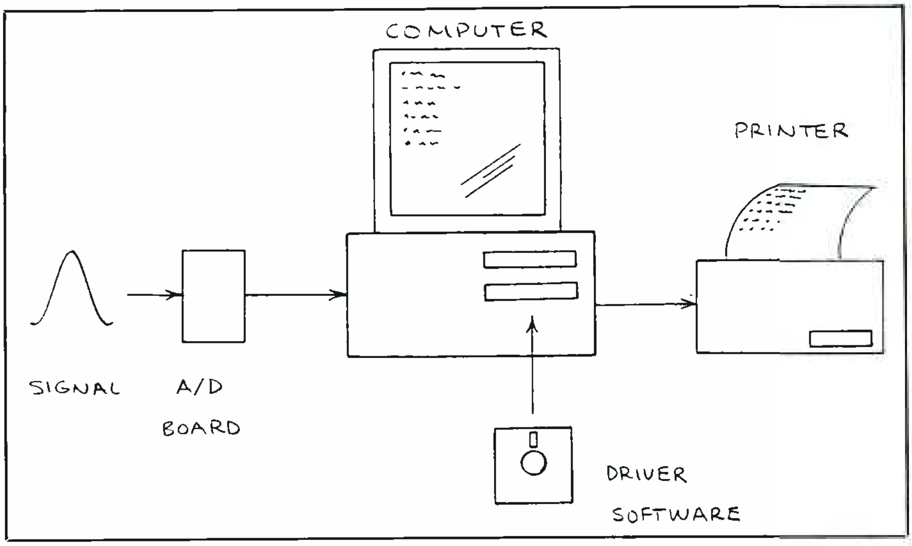


Fig. 1. Block diagram of a virtual digital voltmeter.

Virtual Instruments

The term "virtual instrument" refers to an instrument that has been created by combining a personal computer, one or more interface cards and some driver software. A printer or plotter can be added to this arrangement to provide permanent hard-copy output from the virtual instrument.

An amazing degree of flexibility is the most important feature of virtual instruments. For example, the battery-powered laptop computer into which these words are being typed can be quickly transformed into a digital voltmeter, storage oscilloscope, frequency generator and many other kinds of virtual instruments.

Shown in Fig. 1 is a block diagram of how a computer can be transformed into a digital voltmeter. The voltage to be measured is applied to an analog-to-digital conversion board. A simple program "reads" the digital signal from the A/D converter board and prints the equivalent voltage on the computer's video display monitor.

The program used with the Fig. 1 virtual instrument can be expanded to give the basic voltmeter dozens of extra features and capabilities. For example, graphics can be used to paint an image of a real voltmeter on the monitor's screen. A mouse-driven cursor can be used to select the voltmeter's various functions that are displayed on the screen. And the computer's RAM and disk drive can be used to store voltage readings—which can later be retrieved, averaged, graphed or otherwise manipulated.

Fig. 2 is a block diagram of how a computer can be transformed into a function generator. Here the computer is connected to a digital-to-analog (D/A) conversion board. Relatively simple programs are then used to send sequences of binary numbers to the D/A converter. The result is a waveform or analog signal that can be easily modified by changing the driver program.

The program can be expanded to add many features to the function generator.

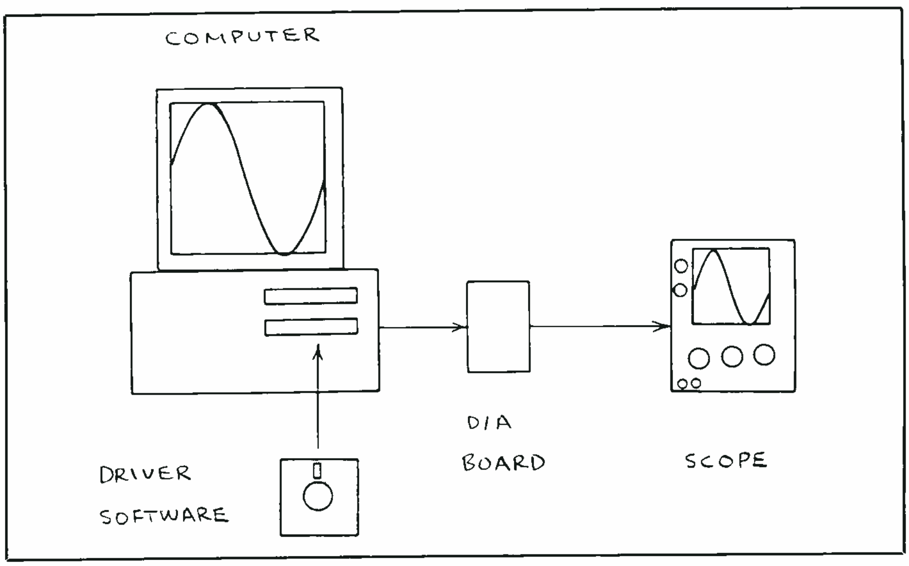


Fig. 2. Block diagram of a virtual signal generator.

Graphics commands, for example, can be used to produce an image of a function generator on-screen, and custom waveforms that you create can be saved for later use.

While virtual instruments are the wave of the future, it's important for you to know that many stand-alone instruments can be used in conjunction with a computer. For example, an oscilloscope or digital voltmeter equipped with an output bus or port can communicate with a computer equipped with appropriate software and interface boards. Though the instrument can be used alone, its power is substantially expanded upon by connecting it to a computer.

Virtual Instrument Trends

A decade ago, most virtual instrument software and hardware was designed to be used with expensive minicomputers. The arrival of the personal computer made virtual instruments available to a great many more users. More than five years ago, I began writing simple programs to transform personal computers into virtual instruments. One program transformed a Radio Shack Color Computer into a storage oscilloscope. Another program converted an IBM PC*jr* into a light meter.

Some of my programs were published in *Computers & Electronics* and in *Forrest Mims's Computer Projects* (Osborne McGraw-Hill, 1985). The October 1988 installment of this column described a computerized chart recorder developed by my son, Eric Mims.

Much has taken place in the virtual instrument field in recent years. Personal computers have become much more powerful, and many companies now develop and sell virtual instrument software and hardware for them. While most of these companies publish excellent literature and catalogs that describe their products, it's very difficult to evaluate virtual instruments simply by reading about them. A first-hand demonstration is a must.

There are several ways for you to see and operate computers that have been

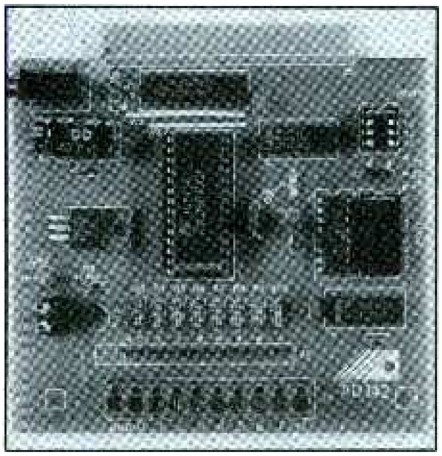


Fig. 3. Alpha Products' eight-bit A/D converter board.

transformed into virtual instruments. One way is to attend electronics trade shows. Another is to visit a company that develops or sells virtual instrument products. Yet another is to visit a company, technical school or university that uses virtual instruments.

The day before I began to write this column, Eric and I drove to Austin, Texas to attend a seminar called "Data Acquisition and Instrument Control Using Next Generation Personal Computers." The seminar was conducted by National Instruments (12109 Technology Blvd., Austin, TX 78727), a leading manufacturer of hardware and writer of software products for computerized data acquisition and instrument control.

Eric and I wanted to attend the National Instruments seminar because of the hands-on approach the company promotes. Instead of simply listening to a series of boring talks, each of the participants was seated at a table equipped with a powerful AT-compatible computer equipped with data-acquisition boards and software, a Tektronix Model 2230 storage oscilloscope and various other items. Total cost of these goodies is about $10,000. Applications engineers from National Instruments then guided us through a series of hands-on demonstrations of some of this company's state-of-the-art applications.

First, we used QuickBASIC to send a sine wave from the computer to the storage oscilloscope over an IEEE-488 bus. We then stored the waveform in the scope. Next, we sent a second sine wave from a D/A converter card in the computer to one of the scope's input probes. Following this, we used National Instruments' "LabWindows" software to

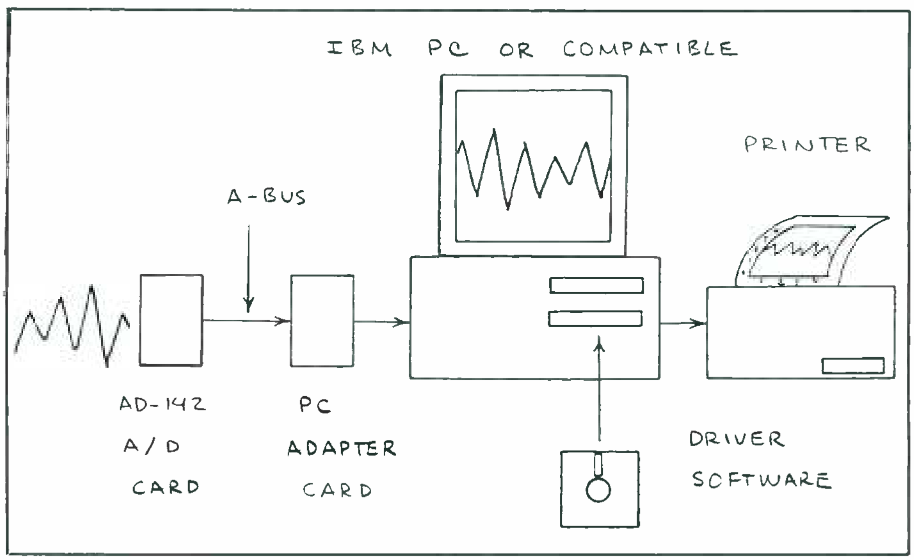


Fig. 4. Block diagram of a virtual storage oscilloscope.

transfer back to the computer the waveform stored in the scope. The Tektronix Model 2230 scope is only one of hundreds of instruments that can be interfaced to a computer via the IEEE-488 general-purpose interface bus.

Next, we used Lotus 1-2-3 and National Instruments' "Measure" software to build a digital thermometer. This thermometer provided real-time temperature readings and a graph of a series of readings made over a 5-second period of time.

We then used LabWindows to acquire an audio signal from a portable digital keyboard instrument. LabWindows then performed a spectral analysis of the signal and plotted the power spectrum of the waveform on the screen of the computer's video monitor.

Finally, we examined a variety of ways to combine various forms of data on a single screen. One particularly impressive demonstration displayed seven separate graphs with a variety of background colors on the same screen.

Eric and I were very impressed by this hands-on seminar. We came away convinced that electronics companies and laboratories that don't make the move to virtual instrumentation will be left far behind by those who do. But our enthusiasm was tempered by the fact that very few individuals can afford to buy state-of-the-art virtual instrumentation hardware and software.

Fortunately, there's an alternative approach. If you already own a computer, there are several ways for you to create virtual instruments for it on a low budget basis. If your computer is equipped with analog joystick ports, it already has the ability to receive variable voltages and resistances. For more resolution, you can add an inexpensive A/D card. You can also add various other interface cards. The catch to all this is that you'll have to write your own instrument software. As we'll presently see, that's not nearly as difficult a task as you might think.

Virtual Storage Scope

A key specification for oscilloscopes is operating speed. The 100-MHz bandwidth of my dual-trace analog scope is essential for viewing very fast response times of the laser diodes and photodiodes with which I often experiment.

While I often work with very fast circuits, I frequently have a need to measure and monitor very slowly changing signals. For example, a horizontal scan speed of minutes or even hours per division is necessary to record the discharge time of rechargeable cells and batteries and super capacitors. A slow scan speed can also be used to record changes in solar energy, temperature and many other physical phenomena.

To monitor slowly changing signals like these, I've developed several simple programs that transform various computers into virtual slow-scan storage oscilloscopes. Some of these programs take advantage of the internal A/D conversion capability provided by the computer's joystick ports.

To obtain greater resolution, I recently purchased the AD-142 eight-bit A/D conversion board pictured in Fig. 3. This board, which is manufactured by Alpha Products (242-M West, Darien, CT 06820) and sells for $129, accepts up to eight analog inputs with a range of 0 to 5.1 volts each. Its provides an output resolution of 20 millivolts.

A/D boards made by other companies

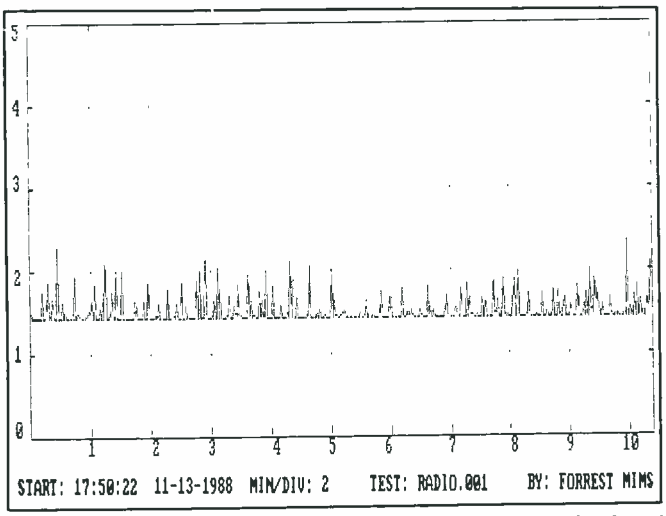


Fig. 5. The amplitude of voices on a radio talk show as displayed by the virtual storage oscilloscope resulting from use of the program presented in this column.

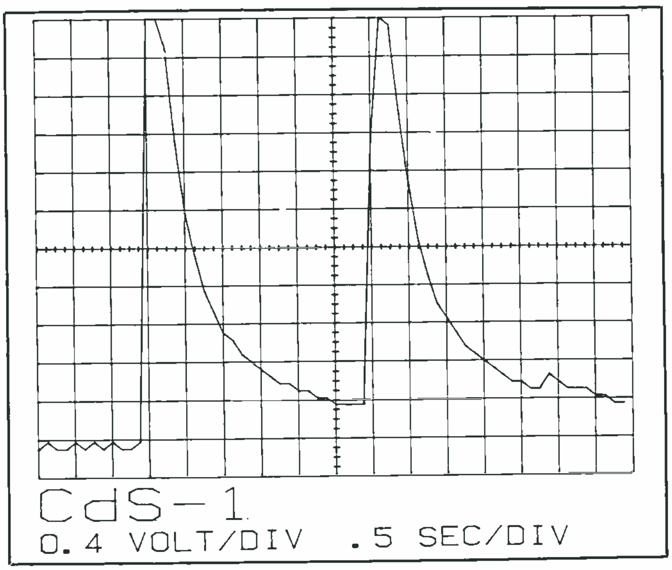


Fig. 6. The output from a cadmium-sulfide photocell struck by two pulses of light, as drawn by a plotter driven by do-it-yourself virtual instrument software.

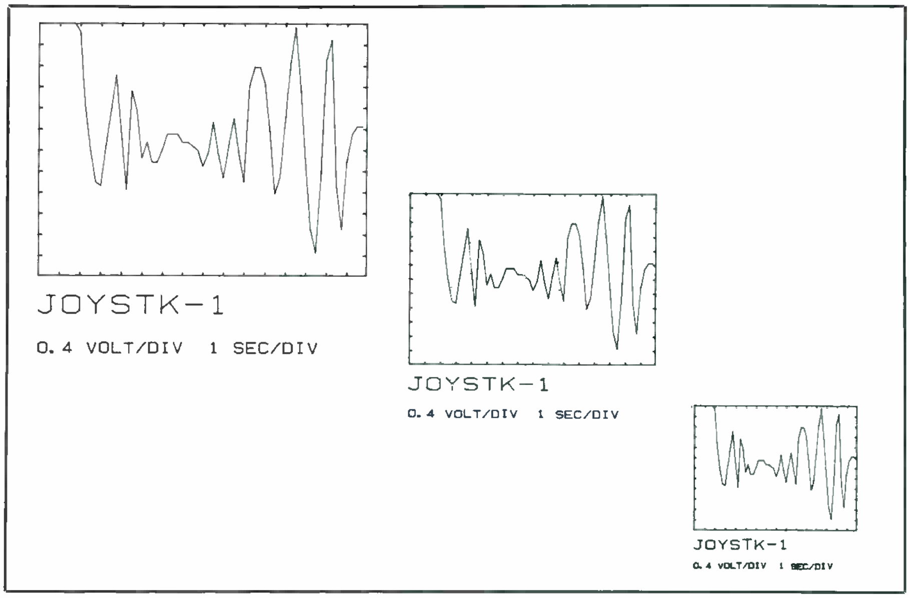


Fig. 7. One of the ways a plotter can display multiple plots on the same sheet of paper.

can also be used, or you can design and build your own. I selected the AD-142 A/D converter because it's one of a series of relatively inexpensive boards that can be connected to many different computers by means of Alpha Products' A-BUS system. Other boards in the A-BUS system include a relay card, four-channel D/A converter, 12-bit A/D converter, Touch Tone™ decoder, stepper motor driver and a digital input card.

A working A-BUS system requires an A-BUS adapter for the particular computer being used, one or more A-BUS cards and a cable to connect the adapter to the card(s). An A-BUS motherboard is available if more than two cards are used.

The storage oscilloscope program I developed is designed to run on an IBM PC or compatible computer. In operation, the IBM PC A-BUS adapter card (which

sells for $69) installs in one of the computer's card slots. The adapter card then connects to the A/D converter by means of a cable. The adapter card is powered by the computer's bus. The A/D card can also be powered by the computer, or it can be powered by a transformer module that is supplied with the card. Shown in Fig. 4 is a block diagram of what's required for this virtual storage oscilloscope.

Be sure to carefully follow all relevant instructions that are supplied with any A/D converter you plan to use. One that applies to *all* devices that plug into a computer's bus or ports is that you must do the plugging with the computer turned off. In the case of the AD-142 board, be sure to apply power to the card *before* switching on the computer.

It's necessary to specify an unused port that can be accessed by the A/D card. I used port 1024 for my Tandy 1000 computer and AD-142 board combination. The following short program will read channel 0 of the AD-142 and print any voltage present on the computer's monitor screen:

```
10 OUT 1024,0
20 A = INP(1024)
30 PRINT A
40 FOR T = 1 TO 300:NEXT T
50 GOTO 10
```

Any of the card's eight channels can be read out simply by listing the appropriate number (0 through 7) after the port number in line 10.

The BASIC program listing included here will transform the IBM PC or clone computer into a slow-scan storage oscilloscope. Only 100 lines long, the program will acquire a signal, plot its waveform on a calibrated graticule, store the sampled signal on disk and recall a previously stored signal waveform. The program is specifically designed for used with the AD-142 A/D converter, but it can easily be modified for other A/D boards.

After the program is loaded and run, an on-screen prompt asks if you want to store a signal or retrieve a previously stored trace. If you want to store a new signal, additional prompts ask you to enter the name for the trace, number of minutes per division and your name. This information, plus time and date, is then printed on your computer monitor's screen below a displayed oscilloscope graticule.

Keep in mind that you should connect the A/D converter to the signal you plan to monitor *before* you run your program. This is because the program immediately begins sampling the input voltage, whether or not one is present.

Program operation is straightforward. Lines 10 through 150 contain the user prompts and other introductory functions. Lines 180 and 190 save to disk your responses to the prompts.

Lines 170 to 200 establish the scope's time base. The TIMER function returns an integer that represents the number of seconds since the latest system reset. The *X* axis of the graticule is divided into one major division for each 60 pixels. Therefore, the fastest sweep speed is 1 minute per division.

The variable "X" in line 160 of the program specifies the column number (16) at which the first data point will be

BASIC Program Listing For Using an IBM PC or Compatible Computer as a Virtual Storage Oscilloscope

```
10 CLS:KEY OFF:SCREEN 2
20 PRINT "A-BUS SLOW SCAN STORAGE OSCILLOSCOPE":PRINT
30 PRINT "COPYRIGHT 1989 BY FORREST M. MIMS, III":PRINT
40 PRINT "FILE: A-BUS.000":PRINT:PRINT
50 PRINT "PRESS 1 TO SELECT STORAGE MODE.":PRINT
60 PRINT "PRESS 2 TO RETRIEVE A STORED TRACE.":PRINT
70 Q$=INKEY$:IF Q$="1" THEN 110
80 IF Q$="2" THEN 90 ELSE 70
90 INPUT "ENTER TRACE TO BE RETRIEVED AND DISPLAYED: ",T$
100 GOTO 450
110 Z$=TIME$:D$=DATE$
120 INPUT "NAME OF TEST";T$
130 INPUT "MINUTES PER DIVISION";M
140 INPUT "TEST CONDUCTED BY WHOM";N$
150 GOSUB 600 :'DRAW AND LABEL GRATICULE
160 X=16
170 TIMER ON
180 OPEN T$ FOR OUTPUT AS 1
190 WRITE #1,Z$,D$,T$,M,N$
200 ON TIMER (M) GOSUB 230
210 GOTO 210
220 'ADVANCE TO NEXT COLUMN (INCREMENT X)
230    X=X+1
240    IF X=640 THEN 330
250 'GET SAMPLE, PSET ON SCREEN AND SAVE ON DISK
260    OUT 1024,1
270    A=INP(1024)
280    'CONVERT A TO VOLTS:INVERT A FOR DISPLAY
290    A=A*.6824:A=174-A
300    LINE -(X,A)
310    WRITE #1, A
320    RETURN 210
330    CLOSE #1:BEEP
340 'TRACE COMPLETED; DISPLAY USER OPTIONS
350    FOR P=1 TO 10000:NEXT P
360    BEEP:CLS
370    PRINT "THE TRACE LABELED ";T$;" IS SAVED ON DISK."
380    PRINT "PRESS ANY KEY TO DISPLAY ";T$;".":PRINT
390    PRINT "AFTER ";T$;" IS DISPLAYED, PRESS ANY KEY TO
400    PRINT "RETRIEVE ANY OTHER TRACE FOR DISPLAY."
410    PRINT "OR ENTER 'QUIT' TO EXIT SCOPE AND RETURN TO SYSTEM."
420    Q$=INKEY$:IF Q$=""THEN 420
430    GOTO 450
440 'RETRIEVE TRACE FROM DISK.
450    OPEN T$ FOR INPUT AS 1
460    INPUT #1,Z$,D$,T$,M,N$
470    GOSUB 600
480    X=16
```

```
490     INPUT #1,A
500     IF EOF(1) THEN GOTO 540
510     LINE -(X,A)
520     X=X+1
530     GOTO 490
540     CLOSE #1
550 'OPTION FOR RETRIEVING PREVIOUSLY STORED TRACE.
560     Q$=INKEY$:IF Q$="" THEN 560
570     INPUT "ENTER RUN, QUIT OR NAME OF TRACE TO DISPLAY: ",T$
580     IF T$="RUN" OR T$="run" THEN 10
590     IF T$="QUIT" OR T$= "quit" THEN SYSTEM ELSE 450
600 'ANNOTATED SCOPE GRATICULE SUBROUTINE
610      CLS:LOCATE 25,8:PRINT Z$
620      LOCATE 25,38:PRINT M
630      LOCATE 25,51:PRINT T$
640      LOCATE 25,69:PRINT N$.
650      LOCATE 25,1:PRINT "START:"
660      LOCATE 25,18:PRINT D$
670      LOCATE 25,30:PRINT "MIN/DIV:"
680      LOCATE 25,45:PRINT "TEST:"
690      LOCATE 25,65:PRINT "BY:"
700      LOCATE 22,1:PRINT "0"
710      LOCATE 18,1:PRINT "1"
720      LOCATE 14,1:PRINT "2"
730      LOCATE 9,1:PRINT "3"
740      LOCATE 5,1:PRINT "4"
750      LOCATE 1,1:PRINT "5"
760      LOCATE 23,10:PRINT "1"
770      LOCATE 23,18:PRINT "2"
780      LOCATE 23,25:PRINT "3"
790      LOCATE 23,33:PRINT "4"
800      LOCATE 23,40:PRINT "5"
810      LOCATE 23,47:PRINT "6"
820      LOCATE 23,55:PRINT "7"
830      LOCATE 23,63:PRINT "8"
840      LOCATE 23,70:PRINT "9"
850      LOCATE 23,77:PRINT "10"
860      LINE (16,0)-(639,0)
870      LINE (16,175)-(639,175)
880      LINE (16,0)-(16,175)
890      LINE (639,0)-(639,175)
900      FOR X=76 TO 616 STEP 60
910        FOR Y=35 TO 140 STEP 35
920          LINE (X,175)-(X,171)
930          LINE (X,0)-(X,4)
940          LINE (16,Y)-(20,Y)
950          LINE (639,Y)-(635,Y)
960          PSET (X,Y)
970        NEXT Y
980      NEXT X
990      PSET (16,0):'RESETS CURSOR
1000     RETURN
```

plotted. Columns 0 through 15 are reserved for numeric labels. Lines 230 and 240 advance the scope to the next column after a data point has been plotted.

Lines 260 and 270 retrieve a sampled voltage from the A/D converter. Line 290 includes a correction factor that converts the sampled value into its respective voltage and inverts the number so that it's plotted with the correct orientation relative to the *X* axis. Line 300 connects the previously plotted point with the new point, and lines 310, 320 and 330 save the sampled voltage to disk.

Lines 350 through 430 prompt the user for various options after a trace has been completed. Be sure to keep in mind that if you select QUIT you will immediately exit the program and be returned to your computer's operating system prompt.

Lines 450 through 540 and 560 through 590 contain the instructions that retrieve a previously stored waveform from the disk and write it to the computer monitor's screen.

Finally, lines 610 through 1000 make up a subroutine that draws and annotates an oscilloscope graticule on the computer's display screen.

Figure 5 shows a typical trace generated by this virtual storage oscilloscope. This trace shows the amplitude of the audio output from a radio station broadcasting a talk show over a period of 20 minutes.

Going Further

Virtual instruments provide a means for transforming personal computers into highly useful tools and test instruments. You can create various kinds of low-resolution digital multimeters, light meters and oscilloscopes simply by inputting your signals into your computer's analog joystick port(s). Add an interface board to greatly increase the resolution of the instruments you create. The only limit to the instruments you can create is your imagination and programming skills.

If your principal interest is a virtual storage oscilloscope, you can improve the BASIC listing given here by adding new features. The conversion time of the AD-142 A/D board is 160 microseconds. This being the case, you might want to consider developing an assembly-language routine that will greatly speed up the scope's sweep speed.

If you have a computer with enhanced graphics capability (EGA, VGA, etc.), you can modify the program to greatly improve the quality of the display. You can even display multiple oscilloscope screens on different portions of the same monitor screen. Finally, you can add a plotter driver routine that will draw a publication-quality screen image like the one shown in Fig. 6. This figure shows the output from a cadmium-sulfide photocell that has been illuminated by two flashes of light.

Figure 7 shows just one of many ways a plotter can be used to display multiple plots on a single sheet of paper. These images were drawn by a Hewlett-Packard Model HP7470 plotter using a program given in *Forrest Mims's Computer Projects* (pages 7 though 27). **ME**

A Sampling of Spring 1989 English-Language International Shortwave Broadcasts

By Gerry L. Dexter

Note: There are hundreds of broadcasts aired in the English Language every day on the shortwave broadcast bands, many of them directed to North American audiences. This is a representative listing and not intended to be a complete reference. The listing is as accurate as possible, however, stations often make changes in their broadcasting hours and/or frequencies, often with little or no advance notice. Some broadcasters air only part of the transmission in English, or may run English into the following hour or may have altered schedules on weekends. Numbers in parenthesis indicate a start time for English that many minutes past the hour. All times are UTC.

Time	Country/Station	Frequencies
0000	R. Austria International (30)	9875
	BRT Belgium (30)	9675, 9925
	Radio Beijing, China	9655, 9665, 9770, 11715, 15455
	Vatican Radio (50)	6150, 9605, 11780
	WSHB, S. Carolina	11980, 13760
	WCSN	9850
	WRNO	7355
	REE, Spain	9630, 11880
	RCI, Canada	5960, 9755
	RBI, E. Germany (45)	6080, 11890
	R. Luxembourg	6090
	R. Budapest, Hungary (30)	6110, 9520, 9585, 9835, 11910, 15160
	R. Sofia, Bulgaria	9700, 11720
	RHC, Cuba	9655
	R. Kiev, Ukraine (30)	5980, 6020, 6200, 7165, 11790, 13645, 15180, 15455
	HCJB, Ecuador (30)	9720, 11775, 15115
0100	R. Yugoslavia	5980, 9620, 9660
	RFPI, Costa Rica	7375
	R. Prague, Czechoslavakia	5930, 6055, 7345, 9540, 9740, 11990
	R. Budapest, Hungary	6110, 9520, 9585, 9835, 11910, 15160
	KVOH	13695
	R. Baghdad, Iraq	11775
	Kol Israel	7460, 9385, 9435
	RAI, Italy	9575, 11800
	R. Japan	11905
	Voice of Germany	6040, 6085, 6145, 9735, 11865
	Voice of Greece (30)	7430, 9420, 11645

Time	Country/Station	Frequencies
	R. Moscow	6000, 6045, 6115, 9700, 9720, 9765, 11710, 12010
0200	R. RSA, South Africa	9580, 9615, 11760
	R. Sweden (30)	9695
	WSHB, S. Carolina	13760
	RCI, Canada	9535, 9755, 11845, 11940
	RBI, E. Germany	6080, 1890
	R. Portugal (30)	6060, 9680, 9705
	Kol Israel	7460, 9385, 9435
	R. Bucharest, Romania	5990, 6155, 9510, 9570, 11830, 11940
	RAE, Argentina	11710
	R. Netherlands (30)	6020, 6165, 9590, 9895
	SRI, Switzerland	6095, 6135, 9725, 9885, 12035, 17730
	VOFC, Rep. of China	5985, 9680, 9765, 15345
	Radiobras, Brazil	11745
	V. of Nicaragua	6100
	R. Cairo, Egypt	9475, 9675
	RHC, Cuba	6140, 9655, 9770
	R. Tirana, Albania (30)	7065, 9760
0300	R. Beijing, China	8425, 9770, 11715, 11860, 15180, 15290, 15455
	Vatican Radio (10)	6150
	R. Prague, Czechoslavakia	5930, 6055, 7345, 9540, 9740, 11990
	R. Finland (30)	11755
	R. New Zealand (30)	15150, 17705
	TWR Bonaire	9535
	V. of Turkey	9445
	HRVC, Honduras	4820
	R. Bucharest, Romania	5990, 6155, 9510, 9570, 11830, 11940
	R. Japan	5960, 11870
	V. of Greece (40)	7430, 9395, 9420
	R. Kiev, Ukraine	5980, 6020, 6200, 7165, 11790, 13645, 15180, 15455
	V. of Germany	6085, 6130, 9545, 9605, 9700
	RFI, France (15)	9800, 11670

Time	Country/Station	Frequencies
	R. Tirana, Albania (30)	7065, 9760
	R. Yerevan, Armenia (50)	11790, 11860, 13645
	BBC, England	5975, 6175, 7325, 9590, 9660, 9915, 12095
0400	R. Austria, Intl (30)	6015, 6155, 15410
	R. Bucharest, Romania	5990, 6155, 9510, 9570, 11830, 11940
	R. Sofia, Bulgaria	7115, 11720, 11735, 11765
	HCJB, Ecuador	6230, 9720, 11775, 15155
	R. Beijing, China	8425, 15180, 15290
	R. Norway (Sun)	9650, 11760
	WSHB, S. Carolina	6005, 9455
	WCSN	9870
	KVOH	11960
	WRNO	6185
	WMLK	9465
	RBI, E. Germany	9620, 11785
	R. Lesotho	4800
	RAE, Argentina	11710
	SRI, Switzerland	6135, 9725, 9885, 12035
0500	R. Beijing, China	9770, 11860
	KUSW	6175
	REE, Spain	9630
	ELWA, Liberia (55)	4760
	V. of Nigeria	7255
	R. Japan	5960, 11870
	R. Netherlands (30)	6185, 9715
	Kol Israel	9435, 9815, 11585, 11655, 11700
	V. of Germany	5960, 6120, 6130, 9635, 9700
	V. of Nicaragua	6100
0600	WSHB, S. Carolina	6005, 9455
	WCSN	7365
	WRNO	6185
	R. Korea	6060, 9570
	GBC, Ghana	4915
	WMLK	9455
	RHC, Cuba	11760
	RCI, Canada	6050, 6140, 7155, 9740, 9760, 11840, 15235
0700	KUSW	6135
	VOFC, Rep. of China	5985
	HCJB, Ecuador	6130, 9610, 9745
	WYFR	11580
	TWR, Monaco	7105
	SIBC, Solomon Is.	5020, 9545
0800	WSHB, So. Carolina	9495
	KNLS	6065
	HCJB, Ecuador	6130, 9745, 11925
	KUSW	6135
	R. Australia	9580
	TWR, Guam (05)	11805
0900	V. of Germany	6160, 9650, 11945
	R. Afghanistan	6085, 15255
	R. Korea	9570
	RCI, Canada	5960, 9755
1000	KYOI, Saipan	11900
	WSHB, So. Carolina	6150
	V. of Vietnam	9840, 12030, 15010
	RBI, E. Germany	9665, 11890
	R. Netherlands (30)	6020, 9565
	KSDA, Guam	9465
	R. New Zealand	6100, 9850
	WYFR	5950
	SLBC, Sri Lanka	11835
1100	R. Beijing, China	9665
	AIR, India (35)	7110, 9610, 9765, 11850, 15320
	HCJB, Ecuador	11740
	R. Nacional Venezuela	9540
	R. Pakistan	15606, 17660
	KUSW	6130
	V. of Vietnam	9840, 12030, 15010
	TWR Bonaire (10)	11815, 15345
	R. Pyongyang, N. Korea	9600, 9977, 11735
	R. Japan	6120
	R. Australia	6060, 9580
	VOIRI, Iran (30)	11790
1200	R. Austria Int'l. (30)	6155, 13730, 15450

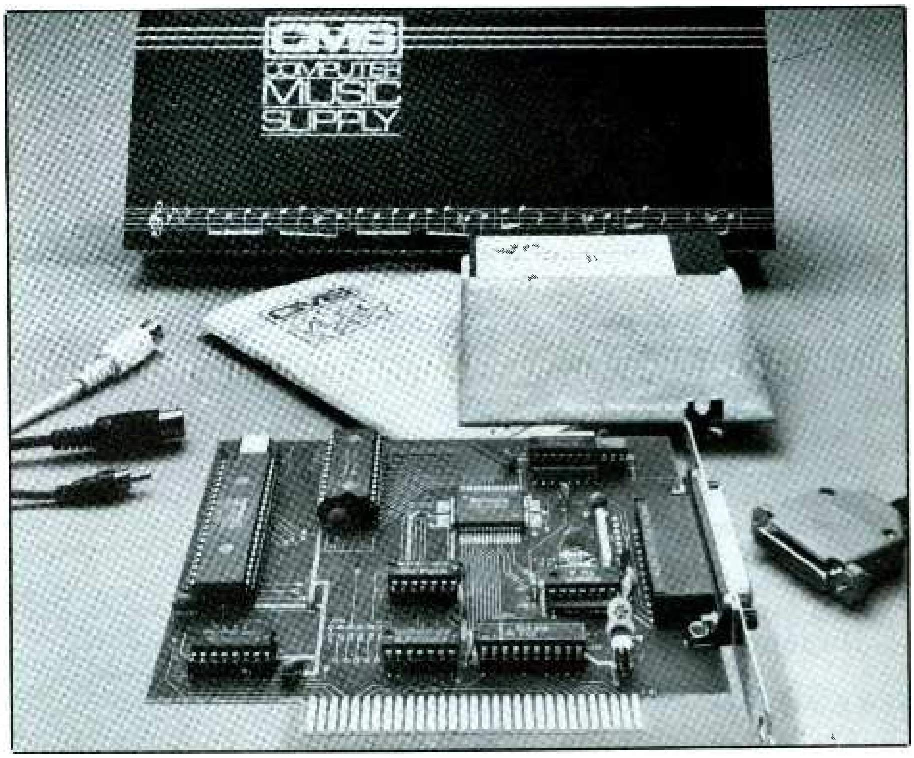
Time	Country/Station	Frequencies
	R. Beijing, China	9665, 15110, 17710
	R. Ulan Bator, Mongolia	9615, 12015
	R. Finland	11945, 15400
	R. Sweden (30)	9565, 15430, 17780
	WSHB, So. Carolina	13760
	WCSN	5980
	R. Bangladesh (30)	15195, 17710
	R. Tashkent, Uzbek	7275, 7325, 9600, 9715, 11785
	V. of People of Kampuchea	9695, 11938
	FEBC, Seychelles	15325
	SBC, Singapore	5052, 11940
	AIR, India (30)	9615, 11620
1300	BRT, Belgium (30)	17555, 21815
	R. Beijing, China	11600, 11660, 15280
	FEBC, Philippines	11850
	R. Yugoslavia	11735, 15325, 15380
	R. Finland	11945, 15400
	R. Norway (Sun)	6035, 9590, 15310, 21705
	V. of Vietnam (30)	9840, 12030, 15010
	RCI, Canada	9625, 11855, 17820
	AIR, India (30)	9545, 11810, 15335
	R. Jordan	9560
	R. Pyongyang, No. Korea	9600, 11335, 11735
1400	R. RSA, So. Africa	11925, 21535, 21590, 21670
	R. Finland	11945, 15400
	R. Norway (Sun)	15190, 15250, 15310, 21700
	R. Sweden	15345, 17860
	WSHB, So. Carolina	17640
	WCSN	13760
	KVOH	17775
	R. Korea	9750, 15575
	R. Australia	9580
	Peace & Progress, USSR	9790, 11655, 13700, 17645
	V. of Mediterranean, Malta	11925
1500	V. of Greece	17565
	KYOI, Saipan	11900
	WRNO	11965
	KNLS	7355
	R. Jordan	9560
	R. Japan	5990, 9505
	V. of Nigeria	11770
	BBC, England	11775, 15260
	R. Veritas, Philippines	11760, 15220
1600	R. Norway (Sun)	11760, 15310, 21705
	R. Pakistan	9475, 9775, 11615, 13675
	UAE Radio	11730, 11955, 15435, 17865
	WCSN	21460
	KUSW	15580
	RTVM, Morocco	17595
	RFI, France	6175, 11705, 15360, 17620, 17795
	BSKSA, Saudi Arabia	9705, 9720
1700	R. Norway (Sun)	9655, 15220, 15310
	WMLK	9465
	BBC, England	11775, 15260
	V. of America	9760, 11760
	R. Moscow	5905, 5980, 6095, 9655, 9875, 9898, 11840, 12050
	RHC, Cuba	9760
	R. Africa, Eq. Guinea	9553
	R. Surinam Int'l (40)	17840
1800	KVOH	17775
	RCI, Canada	15260, 17820
	R. Kuwait	11665
	V. of Nigeria	11770, 15120
	BBC, England	11775, 15260
	Radiobras, Brazil	15265
	R. Jamahiriyah, Libya	15450
	Africa No. 1, Gabon (55)	15475
	V. of Greece (40)	11645, 15630
1900	R. Norway (Sun)	6015, 9590, 15225
	V. of America	15410, 15445, 15585, 15600, 17785
	R. Afghanistan	9635, 9655
	RCI, Canada	15260, 17820
	R. Algiers, Algeria	9640, 15215, 17745
	VOIRI, Iran (30)	9022
	RCI, Canada	5995, 7235, 11945, 15325, 17875
	HCJB, Ecuador	15270, 17790

Time	Country/Station	Frequencies
2000	WSHB, So. Carolina	15225, 17750
	WCSN	9495
	KUSW	15580
	AIR, India	9910
	V. of Indonesia	15150
	V. of Nigeria	11770
	BSKSA, Saudia Arabia	9705, 9720
	Kol Israel	9435, 9855, 11605
	WINB	15185
	R. Damascus, Syria (05)	12085, 15095
	R. Cairo, Egypt (30)	15375
2100	RFPI, Costa Rica	13660
	WRNO	15420
	RCI, Canada (30)	11880, 15150, 17820
	R. Baghdad, Iraq	9770, 15230
	R. Damascus, Syria (10)	12085, 15095
	KVOH	17775
	V. of Nigeria	15120
	SRI, Switzerland	9885, 13635, 15570
	HCJB (30)	15270, 17790
2200	R. Austria Int'l (30)	5945, 6155, 9870, 11780
	BRT, Belgium	5915, 9925
	R. Yugoslavia	5980, 7130, 9620, 9660
	R. Finland	6120, 9670, 11755
	WSHB, So. Carolina	15205, 17640
	RBI, East Germany	9730
	R. Mediterranean, Malta	6110
	R. Sofia, Bulgaria (30)	9700, 11720
	Kol Israel	9435, 9855, 11605
	RAE, Argentina	15345
	RCI, Canada	9760, 11945
	RHC, Cuba	6165
	R. Polonia (30)	5995, 6135, 7125,. 9270
2300	R. New Zealand (45)	17705
	RCI, Canada	9755, 11730
	R. Pyongyang, No. Korea	11735, 13650
	R. Korea (30)	15575
	R. Vilnius, Lithuania	5980, 6020, 6165, 9800, 11790, 11860, 13645
	V. of Turkey	9445, 9685
	R. Prague, Czechoslavakia	6055, 9740
	R. Tirana, Albania	6200, 7065, 9760
	V. of Vietnam	9840, 15010
	V. of Greece (35)	7430, 9395

ME

MIDI Basics; Casio's MT-520 Music Studio & Twelve-Tone's "Cakewalk" Sequencer Software For PCs; Intelligent Music's "Jam Factory" for Apples

By Ted Needleman



The CMS-1 MIDI Studio includes a PC interface card, software and Casio synthesizer.

In last month's column, I briefly discussed the history of electronic musical instruments and how the technology developed into today's computer-augmented musical components. One of the most exciting (and confusing) of these developments is the MIDI (Musical Instrument Digital Interface) network, a method of linking instruments and computers together. This month, we'll take a look at some products that apply computers to control MIDI devices, and next month finish off our excursion in computer music with a look at musical hardware and software which are computer-based, rather than MIDI-based.

To briefly review some of last month's column, a basic MIDI setup consists of at least four components. The first of these is a sound source and/or controller. In many cases, this will be a MIDI-capable synthesizer.

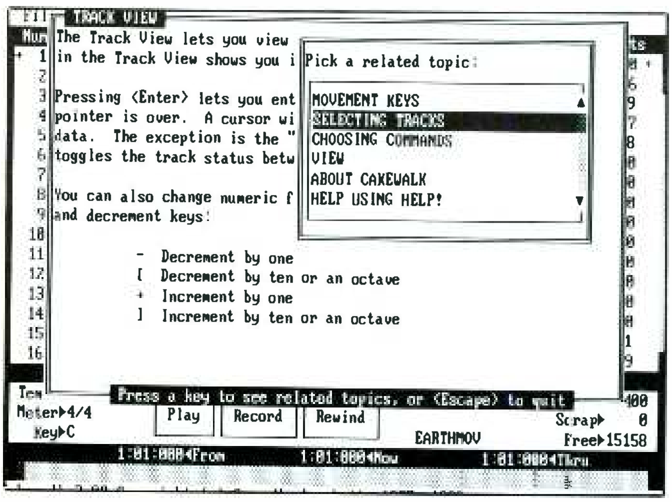
As an input device to the system, the controller, whether a keyboard or other device, must generate certain basic information. It must, of course, generate information on the note being played. This includes both the note itself (C D E F G A B), and whether the note is sharped or flatted, as well as where in the total audible spectrum the note appears (the *octave*). In addition, the controller must provide the length of time the note is to be played (the *duration*), and may determine the particular instrument the note is being played on (*voicing*).

Sophisticated controllers can even supply information on attack and decay characteristics, such as how hard the key is being played, and how quickly it is released (called *velocity* and *aftertouch*, respectively). I should mention that even though a controller may generate some or all of this information, once it is captured by the computer program, it is fairly easy to modify any and all of these characteristics. Think of the musical information being generated by a controller as similar to a text document being typed into a word processor. Once the document has been saved, you can call it up and change words and paragraphs, altering the flow and meaning of the text at will.

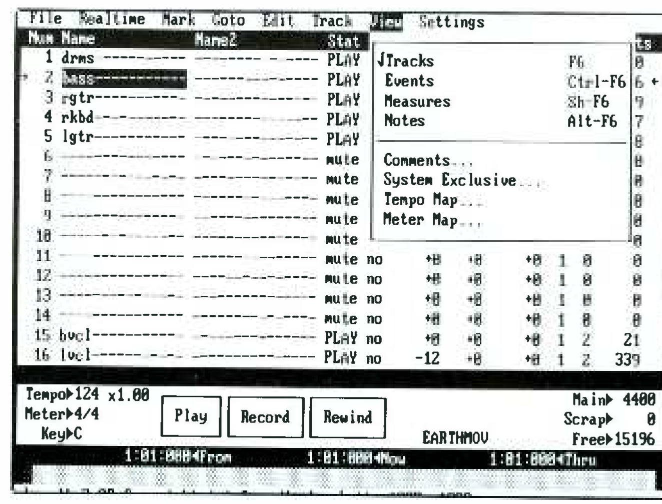
The controller is often used as an output device as well. This is the second component of a music system. It is all well and good to be able to capture the musical components of a song, but we must also have some method of listening to the finished product. As an output device, a MIDI keyboard must be capable of responding to one or more MIDI channels. These channels may be assigned to specific instruments or voices, either by the keyboard itself, or by information coming in on a particular MIDI channel.

As with the output, these MIDI messages contain information beyond just what note to play. They may also command the keyboard to switch to a particular instrument sound, or voice, and will contain information on the duration of notes and their octave. If the sound generator will support it, the input to the device may also contain velocity and aftertouch data.

By the way, the sound generator, like the controller, does not have to be a keyboard. While it is convenient to use a keyboard as both an input device (controller) and an output device (sound generator), both controllers and sound generators come in several formats. A controller can be almost any device that generates a message to the MIDI network. These include (but are not limited to) keyboards, MIDI drums, MIDI guitars, MIDI wind



On-line help is a useful Cakewalk feature.



Cakewalk offers multiple instrument tracks , pull-down menus.

instruments such as clarinets and saxophones, and even computers. While output devices don't vary quite so much, MIDI drum machines are available, as are rack-mountable synthesizers. These devices are complete synthesizers, except that they have no keyboard. They are completely controlled by data coming in on the MIDI channels.

In between the input and output, we need some method of capturing, storing, and modifying the MIDI data. This is where the computer comes in. The two final components of our MIDI system are a MIDI interface, so that the computer can tap into the MIDI network, and a software program, called a *sequencer*, which lets the computer interpret, store, modify, and play back the MIDI information. A sequencer program is not unlike a multi-track tape recorder, only it records information received over the MIDI network, rather than through a microphone. Unlike a tape recorder, though, this information is easily manipulated. As with a word processor, you can edit it extensively. It is this editing capability which has fueled the computer-controller MIDI music explosion.

MIDI interfaces are also available in various formats and capabilities. Some computers, such as the Atari ST, have this interface built in. Others, such as the Macintosh and IBM PCs and compatibles require an add-on. Because a MIDI interface is really a type of serial network, the interfaces are a specialized type of serial I/O port. For PCs, most MIDI interfaces are in the form of a plug-in card.

One of the earliest interface cards available for PCs was from a company named Roland, and its MPU-401 has become a *de facto* standard. In fact, many third-party manufacturers use Roland's chip set in their products, which helps to ensure compatibility. Roland, however, recently introduced a PC MIDI interface which plugs into a serial COMM port. Over the next several months, you can expect to see other companies emulate this.

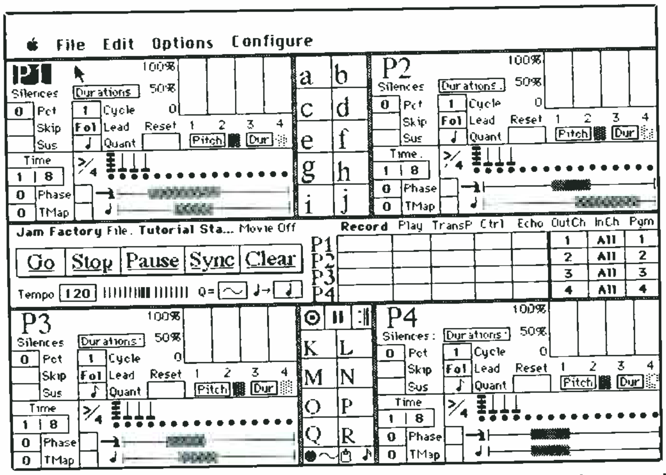
On the Macintosh side, MIDI interfaces plug into either the modem or printer ports. This approach was taken because only the Mac SE and MAC II models have expansion ports; all other Macs are not internally expandable.

For most computer-driven music applications, the hardware itself will be of less importance than the software. While I don't deny that there is a great deal of difference between a $150 synthesizer and one that costs $1,000, how easily you can make use of whatever features the synthesizer offers will greatly depend on the software you're using. With this in mind, let's take a look at two different approaches.

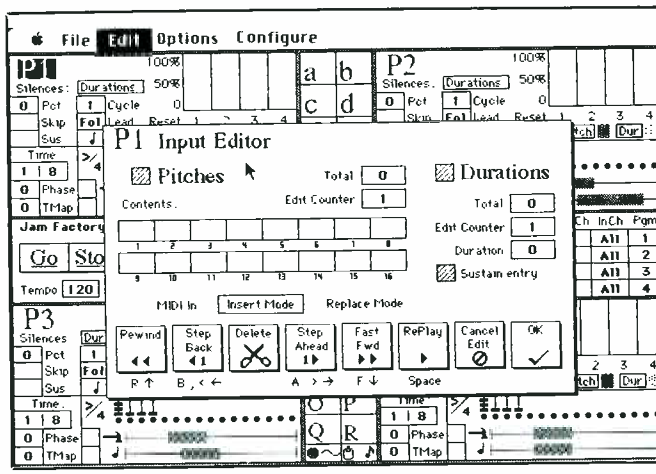
A Complete MIDI Studio

One of the most difficult things for a novice musician to do is to put together his or her first MIDI setup from scratch. How do you decide which interface, synthesizer, and sequencer to buy? And when you've decided, how easily can you get everything working together. For those of you who want to get started in MIDI-based sequencing at a reasonable cost, Computer Music Supply (CMS) has put together a complete package consisting of interface card, synthesizer, and sequencer software. You need only add an IBM PC or compatible, and some time to experiment.

As cited earlier, there are four basic components of a synthesizer system. In



Jam Factory's display includes vertical and horizontal control panels and panels that let you adjust each player's performance.



Jam Factory's Input Editor window provides many basic sequencer operations.

the CMS-1 package, a Casio MT-520 synthesizer supplies two of these basic components—a keyboard controller and a sound generator. The MT-540 is a consumer-level synthesizer. As such, it is both less expensive and lacking in some features that some of the company's other products, aimed at professional musicians, offer. Still, it is remarkable in the features it does provide. For example, the MT-520 has 49 mid-size keys which span two octaves up and down from middle C. It is a 10-note polyphonic instrument, which means that it can play 10 notes simultaneously.

The keyboard provides 20 built-in voices, 20 auto-rhythms, and a feature called Tone-Bank. Tone-Bank allows you to combine any two voices together. These voices, when combined, will play simultaneously whenever a key is depressed. Casio's synthesizer also has a real-time memory, holding up to 1250 notes, that you can store and play back from. The Casio Chord function allows you to play one-finger chords, or complete one-finger accompaniment, including chords, bass, and drums.

The keyboard also has eight sound-effect buttons, four of which, when the MT-540 is in MIDI mode, serve to assign voices to the four MIDI channels the keyboard contains. The Casio Chord auto-accompaniment and auto-rhythm functions are not accessible from the MIDI channels. If you wish to play drums from the sequencer, you'll have to assign one of the four channels to percussion.

The MT-540 has MIDI in and out ports on it's back panel. It does not, however, offer a MIDI-through port. Many higher-end MIDI instruments offer this additional port, which allows MIDI messages not aimed at that particular instrument to continue down the MIDI network and control an additional instrument. Some MIDI setups can consist of 5, 10, or even more MIDI-capable instruments, all being controlled from a single controller.

CMS also provides the other two components of a MIDI setup. The PC interface is CMS' own CMS-401, a Roland MPU-401 compatible. This is a half-size card which plugs into an empty expansion slot in the PC. A special cable, included with the CMS-401, plugs into a DB-type connector on the CMS-401, and provides MIDI in and out cables, as well as a third cable, ending in an RCA plug, which provides a metronome or clock tick to an external source. The documentation received with the CMS-1 did not give any information about where this RCA plug goes; my best guess would be an external amplifier. The CMS-401 can provide 16 MIDI channels in or out, though it, also, does not offer a MIDI-through port.

The last piece of the MIDI studio is Twelve-Tone System's Cakewalk 2.0 sequencer software. Cakewalk is one of the better-known IBM sequencers, and offers up to 256 tracks of recording and playback, though you'll be hard pressed to use all of these tracks with the four MIDI channels the Casio synth provides. The software is relatively easy to use, offering support for a mouse and pull-down menus. Just as with a word processor, you can cut and paste sections of your scores and, if you wish, even loop certain sections to play continuously or for a preset time.

I'm sure that Cakewalk, the Casio MT-540, and the CMS-401 interface all have many other features I haven't discovered, and this is one of the two major problems with the CMS-1 MIDI studio. There is very little documentation, and what there is of it could be greatly improved. For example, the CMS-401 interface came with two sheets of paper. The first told you how to insert the card into your PC, but gives no information about the card other than that it uses the PC's IRQ-2 interrupt and 330H and 331H port addresses.

If your PC already uses these interrupts and/or addresses for something else, you may be out of luck, or you may not be—I can't tell. The second sheet of paper concerns FCC interference regulations, and what to do if your CMS-401 equipped PC blows the picture off your TV receiver's screen.

Casio's operation manual, though more voluminous, is hardly much better. It is printed in two languages (english and spanish) with 31 pages in each language, covers two different synthesizers (MT-540 and CT-460), and has two pages on the keyboard's MIDI functions. Casio's manual is fine if you want to play the keyboard, but if you want to get most of a MIDI system with it, be prepared to experiment (and to call CMS occasionally). Incidentally, CMS' customer support on the MIDI studio is excellent. I called several times and received quick, courteous answers to what must have, at times, seemed to be stupid questions.

Cakewalk's documentation is the best of the three. It's 95 pages long and quite comprehensive. It does have small print and an absence of screen illustrations. From my point of view, it also assumes a level of musical and MIDI knowledge above rank beginner, which is where I am at the moment. If you return the warranty card accompanying Cakewalk, Twelve-Tone Systems will also answer your questions on the software, though CMS was able to answer mine, so I had no occasion to call Twelve-Tone.

All things considered, the CMS-1 MIDI studio is a good buy at $399 ($249 if you already have a MIDI capable synthesizer). It would be a great buy if the documentation was improved. I've spoken to CMS about this, and they're considering my comments. In the meantime, if you don't have a fair amount of background with MIDI, be prepared to buy at least one of the books mentioned last month. The CMS-1 is a lot of fun, though, and if you don't mind playing around with it, you'll both learn a great deal about MIDI and computer-assisted music, and (hopefully) produce some listenable music.

Jam Factory

While the IBM and its compatibles are popular among musicians for controlling MIDI instruments, they're certainly not the only computers used in music. Ataris, Amigas, Commodores, and Apples (Macintosh, Apple IIe and IIGS systems) are all popular music machines. In researching this set of columns, I received the loan of a MIDI interface for my Macintosh 512E from Apple. As with PC interfaces, Apple is only one of the suppliers of MIDI interfaces for the Mac.

Their's is a relatively bare-bones unit with a cable that plugs into the Mac, and two additional cables for MIDI in and out. As with the CMS-401 interface described previously, there is no MIDI-through connection on Apple's interface, though this connection is supplied on some interfaces from different suppliers. At $99, with support from a large number of Apple dealers, it's a reasonable way to get your Macintosh to "talk MIDI." Just add a sequencer and MIDI keyboard controller, and you're in business.

While there are a number of excellent Macintosh sequencer programs, one of the more unusual pieces of MIDI software is Jam Factory from Intelligent Music. At its most basic, Jam Factory is a sequencer, similar to those discussed above. You can record, edit, and play back music from a MIDI instrument, modifying the "sound track" to your heart's content. The files created by Jam Factory can be used with other Macintosh sequencer packages, and many of the files created by these other packages can be imported into Jam Factory.

Where Jam Factory differs from other sequencer software, though, is that it can take your musical input and improvise around it! If you've ever sat in on a "Jam Session," where one musician starts playing a chord progression, and others just jump in and improvise, you'll have a good idea of what can happen when you set Jam Factory loose.

Unlike most other sequencers, Jam Factory has "Players" rather than tracks. Each of the four Players is assigned to an instrument, though this instrument can be switched during the course of the song. This assignment is made by varying the "Pgm" number for the Players in the center control box.

Each Player has its own box, which contains various controls for adjusting that Player's performance. There is also a central control box that's used for assigning MIDI in and out channels, Pgm (Program, or MIDI instrument voice), recording and playing for a particular Player, and setting the tempo. A second, vertical control panel allows you to create and recall presets for Players, and set up record macros.

Jam Factory is used by recording parts for each of the Players in the quartet. Once each piece is "recorded" (actually it is captured from a MIDI keyboard or other controller), you can edit the Player's part just as you would be able to with most sequencers.

You call up the editor by first clicking the mouse cursor on the big "P" in the particular Player you want to edit, then pulling down the "EDIT" menu. Choose the "Edit Player Input" selection from the pull-down menu, and you are presented with a box that lets you step through a Player's box and modify the pitch and

PC CAPERS...

duration of each note. The "EDIT" menu also has selections which let you cut, paste, delete, copy, and restore from preset for a particular Player.

The thing that makes Jam Factory so interesting and unique, though, are the controls in each of the Player's boxes. Once you've recorded a track for each Player, you can adjust controls to change the accent, transpose pitch during playback, and introduce pitch and rhythm variations into the recorded material. You set the amount that each Player can vary from what is recorded. Describing these functions doesn't really give you an idea of what the effect actually accomplishes.

While you'd have to hear the changes to believe how different settings affect the line you've laid down, keep in mind that you can easily tell the difference between two musicians playing the same piece note for note by how they accent the notes, and how they use different timings and durations. You can even adjust the relative tempos of each of the Players so that they are slightly off within their own music lines, then synchronize the timings together. This gives your improvisation a more "human," less mechanical sound.

Jam Factory is a cleverly written program that lets you use the computer's own calculation capability to add depth to your performances. The software can even be controlled from a remote keyboard or other MIDI device for use during a live performance. You'll get the most out of Jam Factory if you're already an accomplished musicians, of course. But even "hunt-and-peck" keyboardists like me can enjoy themselves, and produce some unusually creative music.

My one complaint with Jam Factory is that it uses a key-disk copy-protection scheme. You can install it on a hard disk up to two times, but you will need the original program disk to make it run. Music software, especially on the Macintosh and other non-IBM compatible computers, is one of the few areas where copy-protection is still widespread.

Even copy-protected, at $199, Jam Factory is a lot of fun. If you have a Mac-oriented MIDI setup, you owe it to yourself to try this program. **ME**

Products Mentioned

CMS-1 MIDI Studio
Computer Music Supply
382 N. Lemon Ave.
Walnut, CA 91789
(714) 594-5051
(800) 322-MIDI

Jam Factory
Intelligent Music
P.O. Box 8748
Albany, NY 12208
(518) 434-4110

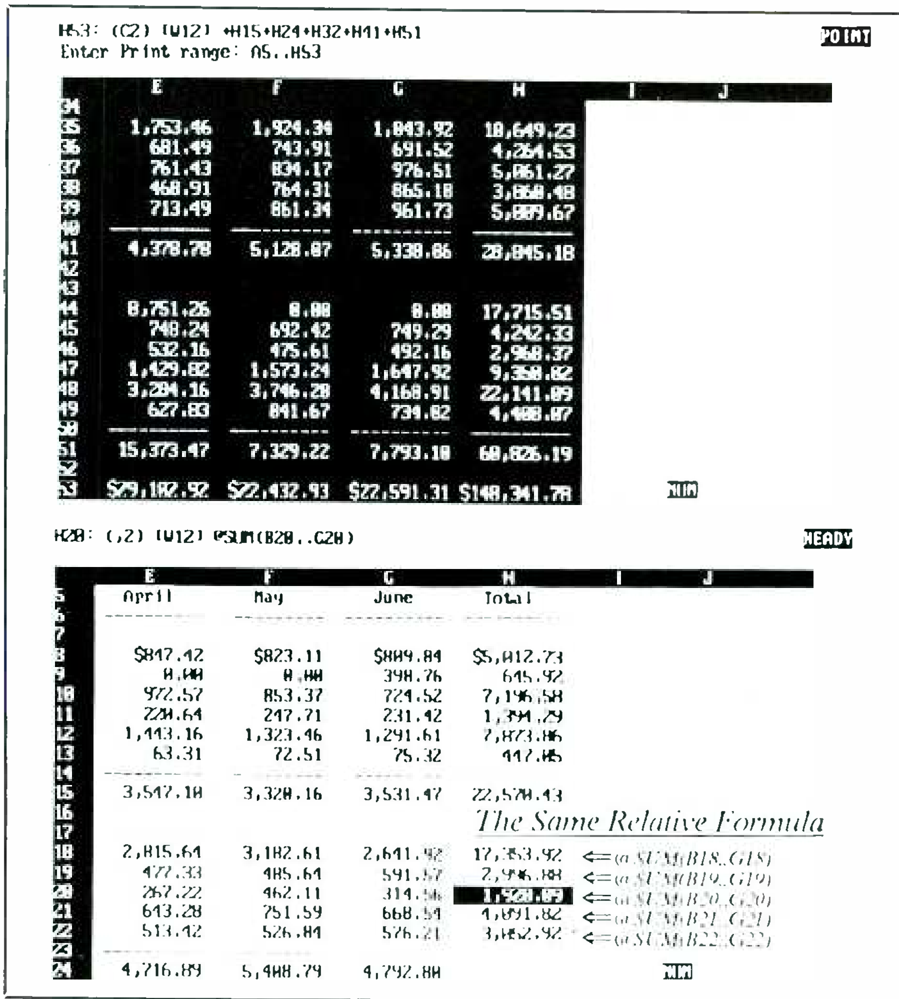
SOFTWARE FOCUS

Watch the Spreadsheet

By Art Salsberg

Lotus 1-2-3, still the corporate world's most widely used electronic spreadsheet, continues to spawn spin-off software related to it. It might be a utility to make up for some 1-2-3 shortcoming or, as in this case, a course to teach you how to work with this application program.

Leading Edge Products, Inc., the well-know IBM-compatible computer maker, is in the courseware business, too, under the banner of Leading Edge Video Products, Inc. As the modified corporate name implies, it produces video tapes. The one examined here—The Leading Edge SoftVision Companion for Lotus 1-2-3—is a tutorial package that's subtitled "Introduction to Spreadsheets." It consists of an 84-minute video program (VHS cassette), a diskette (5.25" or 3.5" format) and a workbook. It costs only $29.95, directly from the company (1-800-343-6833 or if in Massachusetts, 617-828-8150).



Examples of screen displays from the Leading Edge Video Products "SoftVision Companion Series for Lotus 1-2-3" Student Workbook: Specifying the print range (upper) and Copying the same relative formula.

In-Use Comments

Thirty bucks doesn't buy much nowadays in the high tech field, I thought, so let's see what they've got and what's missing that only more dollars can buy.

The video tape was surprisingly good. We've seen enough educational tapes now to welcome a truly professional job. The color was excellent; text where shown was large and with fine contrast; and video screen spreadsheet matter was tops, from full screen to close-ups. Equally important, the two characters in the tutorial, a man and a woman, were polished actors. Topping it off, the material, directed to raw beginners in the 1-2-3 world, was a fine learning presentation.

The material is divided into a handful of sections. At the conclusion of each one, key lesson headings are recapped and then the viewer is advised to stop the tape and do exercises in the accompanying workbook and on the floppy disk. Both are well-done, supporting and expanding upon what the video shows.

Using three mediums—video tape, printed book and floppy disk—is a nice touch. The trio from Leading Edge will put a 1-2-3 computer spreadsheet beginner on the fast road toward working with the popular application software. The $30 buys you an introduction only, you should understand. There are plenty of basics that are left untouched, such as working with Windows, Protecting Cells, Macros, and what-not. And this doesn't even touch other programs integrated into the whole, which are Graphics and Database.

The Leading Edge Companion is not a powerhouse tutorial in breadth or even depth. It comes without such pretensions, though. What it is is an appealing, down-to-earth, professionally presented introduction to 1-2-3 that will hold the viewer's attention longer than a book or disk-based-only tutorial can, owing to the great power of the Tube. As such, it's a shining example of using video to teach and is worth the $30 if you've never worked with 1-2-3 and haven't the patience to fight your way through more formal courses or texts.

It's expected that advanced courses will be introduced as part of a series of video/disk/workbook Companions for learning how to work with Lotus 1-2-3. Corporations will likely welcome these self-teaching productions. **ME**

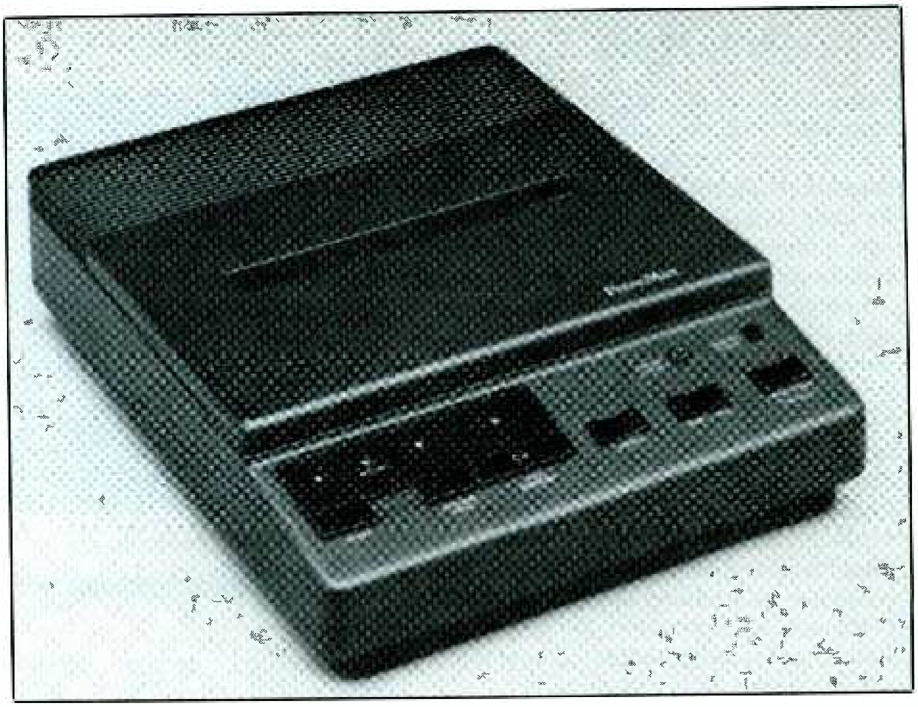
Telephone Answering Machines

By Curt Phillips

Telephone answering machines have been much cussed and discussed since their use exploded in popularity on the telephone scene some years ago. Many people hate the so-called impersonal nature of answering machines, while others just get tongue-tied when they're being recorded. Still, their utility in business situations and convenience in home use is indispensable.

This is evidenced by the example of one businessman who had to call me several times over a period of weeks but always refused to leave a message on the machine when I was out. All he would say about it was, "I hate to leave messages on answering machines!" Ultimately, I called *his* business once when no one was there and, you guessed it, I was answered by a machine. He hated to leave messages on them but couldn't deny their usefulness.

A PhoneMate 7200 I've been examining doesn't do anything to assuage the wrath of those who hate answering machines, but it does have plenty of features for those of us who use them. Basically, the 7200 is a dual-cassette answering machine with Time/Day stamp.



The PhoneMate 7400 two-cassette telephone answering machine.

Some answering machine designs today are using a voice memory chip to record the outgoing message, but there are several reasons why I prefer a cassette for the outgoing message. The "endless-loop" cassettes used for outgoing messages are available in a variety of lengths. In contrast, machines that use integrated circuits for the outgoing message restrict you to 15 to 20 seconds (actually, all the ones I've seen limit you to exactly 16 seconds). To overcome a caller's reluctance to leave a message, and because I am a former radio DJ, I usually do musical outgoing messages. These often run in the 30-to-45-second range; so I need the extra flexibility an outgoing-message cassette provides. Also, the fidelity of the taped message is better (although marginally appreciable over a phone line) on a cassette than on the electronic chips. I haven't seen any specs on this, but it is a personal observation.

Many people like to have different messages for various circumstances to provide their callers with more information. One message might say, "We'll be back later today," another might say, "We'll be back on Monday," and yet another, "We'll be back from vacation on June tenth." Rather than having to re-record each message every time you want to change it, a dual-cassette machine allows for different outgoing cassettes to be prerecorded for each circumstance and to be popped into the machine as needed.

The "Time/Day Stamp" is accomplished by an on-board clock that uses a synthesized voice to record the day and time after each message received. This feature greatly increases the usefulness of an answering machine. Often, the meaning and urgency of a message depends upon when it was left, but you're fortunate to get a message from most callers; very few include the time and day they called in their messages.

The same voice that records the time and day on the message tape is accessible through a front-panel button so that the 7200 can also function as a "talking clock." One 9-volt battery provides back-up to maintain the clock's setting during a power failure. When appropriate, the synthesized voice will also inform incoming callers that, "Sorry, the message tape is full." The "voice" is quite understandable and of higher quality than many of the synthesized voices I've encountered in other equipment.

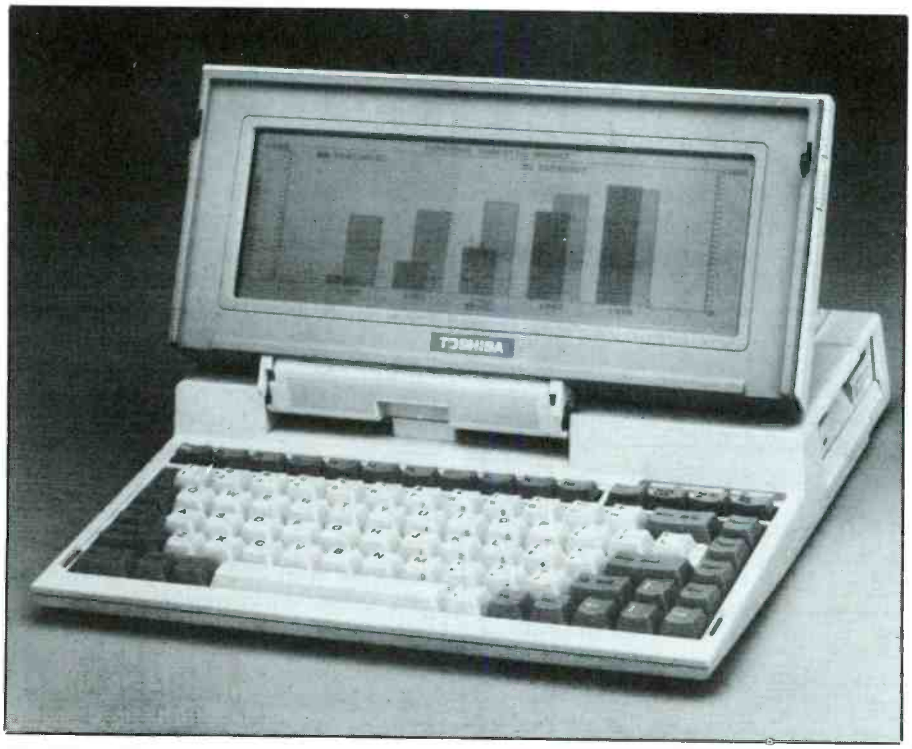
Recording the outgoing message works about the same as every other answering machine. You press a button to record, speak into the microphone, and release the button when you've finished speaking your message. The 7200 has a built-in mike, but it doesn't have a provision for an external mike. I tried to use some messages I had recorded on an old (1980 vintage) PhoneMate, but there seemed to be some compatibility problem. Two of the old tapes worked, three didn't. All of them continued to work in the ancient PhoneMate, though.

It's in the retrieval messages that the many features of the 7200 come into play. A flashing green LED on the front panel indicates that you have messages waiting. However, this LED is dimmer and less noticeable than the red message-waiting LEDs on my other two answering machines. In fact, the first time I had a message waiting, I walked to the new PhoneMate several times before I noticed that the green LED was flashing.

When you press the "Play Messages" button, the synthesized voice announces how many messages have been received, which is a nice touch. After each message, the voice announces the time and day it was received. Furthermore, when the message tape stops, it announces, "That was your last message." A "Search" button allows you to fast-forward or rewind the tape during playback. The messages can be saved, or the PhoneMate will automatically rewind and record over them.

All of these functions can be accessed remotely. Since the 7200 features *beeperless* remote control, there's no beeper control for you to remember to carry (and possibly misplace). The remote-control functions *do* require a Touch Tone phone for access, and the Touch Tone phone must be capable of sending a tone continuously for 2 seconds. This may sound simple, but an office I've worked out of recently has a NEC digital PBX, and all of its tones are momentary. Therefore, I couldn't access the 7200's remote features from these office phones without using an external Touch Tone generator (something like the "pocket dialers" you may have seen advertised or used by others).

When accessing the answering machine remotely, the feedback from the synthesized voice gives is invaluable. In older answering machines, the user had to remember a series of beep codes to know what the machine was doing. Here, the voice guides you through every step. In addition to playing, rewinding, saving and erasing messages, the PhoneMate allows for the outgoing message to be re-recorded remotely. Even if you accidental-



Toshiba's T1000 is the smallest and lightest laptop computer. Though built around a "dated" 8088 microprocessor and sporting just one disk drive, this machine is more than adequate for most on-the-go computing.

ly leave the machine off, calling in and letting the phone ring 10 times will cause the PhoneMate to answer and remain on.

There is a function called "Tollsaver" that can save you phone-call money when you call remotely. It allows you to set the 7200 to answer on the second ring if there are new messages and on the fourth ring if there are no new messages. Consequently, with this feature, you can determine that there are no new messages before the unit answers and the phone toll is incurred.

Rounding out features on the PhoneMate 7200 are call screening, where you can listen to determine the identity of a caller before answering the phone; a memo recording function that allows the unit to be used like a regular cassette recorder; and the ability to record a phone conversation as it is taking place.

The "list price" for the PhoneMate 7200 is $180, but the "street price" runs $100 to $130. PhoneMate builds good, solid equipment, and this unit certainly deserves your consideration if you're looking for an answering machine. But no matter what brand you buy, be sure to get a machine with the Day/Time stamp function. This one feature provides a quantum leap in answering-machine usefulness.

The Toshiba T1000

The trend today in laptop computers seems to be toward more-powerful, more-expensive and (unfortunately) heavier machine. Bucking this trend is the Toshiba T1000 laptop.

The T1000 features an 8088 microprocessor running at 4.77 MHz with 512K bytes of RAM standard and one disk drive. These stats aren't going to make anyone's heart beat faster . . . it's a relatively slow machine, as state-of-the-art goes. But consider that it weighs less than 7 pounds and is thin enough to fit into a briefcase with room left over for books and papers. And since, for most of us, a laptop is used primarily for word processing, communication (via modem) and running light speadsheet or calculation programs, who needs fast and heavy? For most portable computing purposes, an 80286 or 80386 processor is not really needed. The T1000 runs all our favorite and familiar PC software, so even on the road we have almost all of the working comforts of home.

A couple of implications of its small size are of special note. First of all, despite its small size, the T1000 has an excellent keyboard. I've used it for several hours with no more fatigue than would have occurred with a regular keyboard.

The computer's display is a good SuperTwist LCD, but it does need to be backlit. Even though backlighting would certainly quicken the T1000 battery's discharge rate (and result in shorter operating time), it would be a most welcome improvement. The greatest problem I had with the T1000 was orienting it so that its display would be readable in low-light situations, such as occurs on airplanes and in many motel rooms where lighting is more for "atmosphere" than productivity.

Interestingly, I'm typing this column at 35,000 feet, *in coach!* The primary problem with using the Toshiba computer under these conditions is, again, lack of light. The seat lighting on this model of airplane (M80) isn't adjustable; so I'm forced to set the computer at an unusual angle from my aisle seat toward the middle seat to scavenge every bit of available light. I'd easily forego an hour or so of operating time for a backlit screen now!

There really is no problem with space and the size of the T1000, though. I am 6 feet 1 inch tall and possessed of more than ample girth, but there's plenty of room to type without bothering my neighbor. If I just don't go blind trying to see this dark screen, I'll be okay.

The display also has an aspect ratio that is wider than that of typical PC screens. This made pie charts look like "football" charts, but it was quite tolerable. When some friends ran Chuck Yeager's flying program on the computer, however, Chuck (whose picture appears on an opening screen) looked like he'd landed a bit too hard.

With the exception of needing a backlighted display, the T1000 is a superlative machine. I lugged it on airlines as both checked and carry-on luggage at different times, took it on a fishing trip to the Gulf Stream, and hauled it around in the back of my car through hot and cold weather. And it performed flawlessly!

The Toshiba T1000 laptop computer lists for $1,249, but it's routinely discounted to less than $900. For most purposes, the 768K nonvolatile RAM option is needed since there's no second disk drive, which will add $250 to $300 to the price of the computer. It's got plenty of power for most of us who don't like lugging around extra weight (who does?) and don't want to spend much money.

Your comments are welcome. You can contact me through The Source (BDK887), Delphi (CURTPHIL), CompuServe (73167,2050) or at P.O. Box 678, Garner, N.C. 27529. ME

How to Draw Schematics and Design Circuit Boards With Your IBM PC by Steve Sokolowski. (Tab Books. Soft cover. 179 pages. $13.95.)

This book offers an inexpensive way of getting started in computer-aided engineering (CAE). It is written around "Electronic Schematic Designer" and "PC Board Designer" programs (both in interpreter BASIC) that offer the "flavor" of commercial drawing software for the IBM PC and compatibles environment. No graphics card is needed. Two extensive chapters give complete program listings and detailed instructions on their use. Though the programs can be keyed into a computer by hand, saved to disk and be recalled as needed, an optional $25 disk containing both programs eliminates the laborious task of hand keying.

The programs can be used to draw lines, circles and schematic symbols, using BASIC's graphics commands. With a few strokes at the computer's keyboard, the user can draw schematics or/and pc guides, the latter to exact scale. The schematic program has 30 preprogrammed electronic symbols that can be called as needed. Though hardly sufficient for drawing complex schematics, these symbols can be augmented by user-drawn symbols that can be called from a symbol library when needed.

The even more limited pc-guide program's symbol library consists of DIP IC pad patterns for 6- to 18-pin devices, a termination point and a circle. Not much more than these and the basic line-drawing function are needed, though, and the program does permit other often-used symbols to be drawn and added to the library. A limitation of this program is that all DIP ICs must be laid out horizontally to assure accurate 0.1-inch spacing of DIP IC pads. This should not prove to be a hardship in most cases.

Practical hands-on experience with the programs is given in an example that shows how to use the programs to draw the schematic and its pc board layout for a simple power supply. Information is given for converting the pc guide into a finished board. Also included are two more chapters that provide screen displays generated by the programs, a list of reserved words, error messages and their meanings and other useful reference material. Appendices summarize the CAE commands and provide information on making back-up copies of the optional program disk. Rounding out the book are a glossary of technical terms and a postage-paid order card for the program disk.

Just a few keystrokes are needed to execute each step in both programs. Additionally, on-screen prompting makes the program easy to use even for someone who has no experience in CAE or computing. These programs are not as developed as those sold commercially. Many of the bells and whistles of commercial programs and much of their flexibility are lacking. For the occasional user, these limitations are more than compensated for by the low cost of the book (and its optional program disk).

Building Speaker Systems by Gordon McComb. (Radio Shack. Soft cover. 128 pages. $5.95.)

Audiophiles will find this book a fascinating adventure in the build-it-yourself aspect of the hobby. This is not simply a book of speaker projects. It begins with a general sound/speaker theory chapter and two "Close Look" chapters devoted to speakers and enclosures. The first of these chapters covers such topics as the audio frequency spectrum, loudness, direct-versus-reflected sound energy, how speakers work, etc. The next covers frequency response, dynamic range, sound dispersion, sensitivity, damping, distortion, power rating, driver types, how to read and interpret speaker specifications. The third deals with enclosures types, driver selection, estimating enclosure volume, calculating enclosure size, driver layout, port and duct details, box tuning, damping, and enclosure construction.

Chapters 4 and 5 deal with construction and finishing techniques and contain a wealth of basic shop information for the beginning wood worker. Chapter 6 details wiring and introduces crossover networks, L pads and speaker protection and how to implement them into your designs. Chapter 7 deals with testing procedures, has a troubleshooting table for quickly isolating and dealing with problems and discusses speaker placement for best sonic effect.

Chapter 8 gives complete construction details for four speaker projects: single-driver compact bookshelf speaker, two-way bookshelf, three-way floor-standing, and medium-size three-way ported.

Each is accompanied by detailed numbered step-by-step construction details, drawings, and full parts lists.

The book closes with Design Equations and Enclosure Dimension Tables appendices and a comprehensive glossary. With the wide range of information provided in it, this modestly priced book can serve as a primer on sound theory and speaker system design. For the serious audiophile, it can also serve as a valuable reference.

McGraw-Hill Dictionary of Scientific and Technical Terms, Fourth Edition, edited by Cybil P. Parker. (McGraw-Hill Book Co. Hard cover. 2,137 pages. $95.)

Think of a scientific or technical term—any term—that existed before this book went to press and chances are you will find it listed and defined in this massive book. Contained herein are more than 117,000 definitions, more than 7,600 of them new to this edition, representing 102 disciplines. Listings are strictly alphabetical without regard to discipline, making locating a specific one as simple as looking it up by its spelling. The Dictionary is thumb-indexed for ease of use and new with this edition is a pronunciation guide for each listed term.

More than 3,000 photos, drawings, tables and diagrams illustrate the listings. The definitions are written in layman's terms, making the contents usable by non-specialists as well as specialists. Included are helpful appendices that present such data as SI conversion tables, the periodic table of elements, electronic schematic diagram symbols, scientific and technical organizations, mathematical signs, symbols and notation, and more. With the wealth of information contained between its covers, this book deserves a home in every technical, scientific and engineering library—whether in a college, university, business office or home office.

NEW LITERATURE

Metal-detector Catalog. A new 12-page, full-color catalog from Fisher Research lists, pictures and fully describes the company's full line of "m-scope" metal detectors. Instruments for all purposes, from economy models used by beachcombers to expensive professional units designed for deep hunting are listed. Each entry contains a non-technical description of the product and a list of features. A handy table on the inside rear cover provides a quick reference to all detector models listed, and the rear cover lists and describes optional accessories. Except for prices, information is complete. For a copy, write to: Fisher Research Laboratory, 1005 I Street, Dept. ME, Los Banos, CA 93635-4398.

Software Engineering Tools Catalog. A 14-page catalog that lists and describes MS-DOS/PC-DOS engineering software tools for the IBM PC and compatible computers is available from BSOFT Software. Among the offerings listed and fully described are computer-aided mathematics, waveform-viewer and circuit-design programs, plus a logic circuit emulator program, each selling for $49. Other offerings listed and briefly described, and selling for between $12 and $29, include ac and dc network analysis, an electronics calculator and circuit-analysis programs. For a free copy of the catalog, write to: BSOFT Software, 444 Colton Rd., Columbus, OH 43207.

Test & Instrumentation Product Guide. The hard-bound 1989/1990 product guide from United States Rentals provides information on more than 5,000 different models from more than 170 major manufacturers of electronic test and measurement instruments, data-processing equipment and telecommunications test devices for rent, lease and sale. This is a comprehensive one-stop reference that contains descriptions, specifications, photos and other technical data on a broad range of product categories that are indexed both by product and manufacturer. Among the types of products listed are analyzers, CAE/CAD equipment, signal generators, meters, recorders, oscilloscopes, signal processors, microcomputers, and telecommunications test equipment. For a free copy, write to: United States Instrument Rentals, 2988 Campus Dr., Dept. ME, San Mateo, CA 94403.

or more. At 9,600 baud, communicating range increases to 5 miles. The user has a choice of terminations for the twisted-pair cables that link together the modems. Built-in solid-

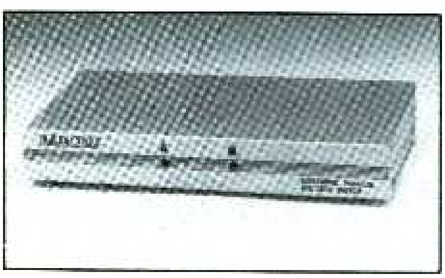
state surge protection is claimed to make the modems immune to surges and transients that may be impressed on the twisted-pair lines.

Included on the Model 201 is a DTE/DCE switch that permits the connections to pins 2 and 3 of the RS-232 connector to be transposed to accommodate the specific needs of computers, terminals and printers. The device is available with a choice of male or female connector. $72.

CIRCLE NO. 108 ON FREE INFORMATION CARD

Automatic Printer Switch

New from Data Spec (Chatsworth, CA) is an automatic switching device that lets two personal computers share a single parallel printer. The Model ADS2500 electronic data switch is compatible with IBM PC,



XT, AT, PS/2 computers and compatibles. When the switch detects that either computer connected is sending data to be printed, it automatically switches off access for the other computer. When the printing operation is complete, the switch automatically resets itself to wait for the next signal that either computer wants to print a document or other information.

This compact data switch features electronic switching (there are no buttons or other controls), full shielding that exceeds FCC requirements and long-life gold-plated connector contacts. $99.

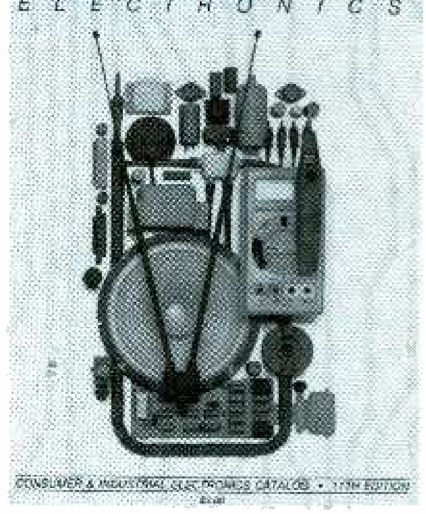
CIRCLE NO. 109 ON FREE INFORMATION CARD

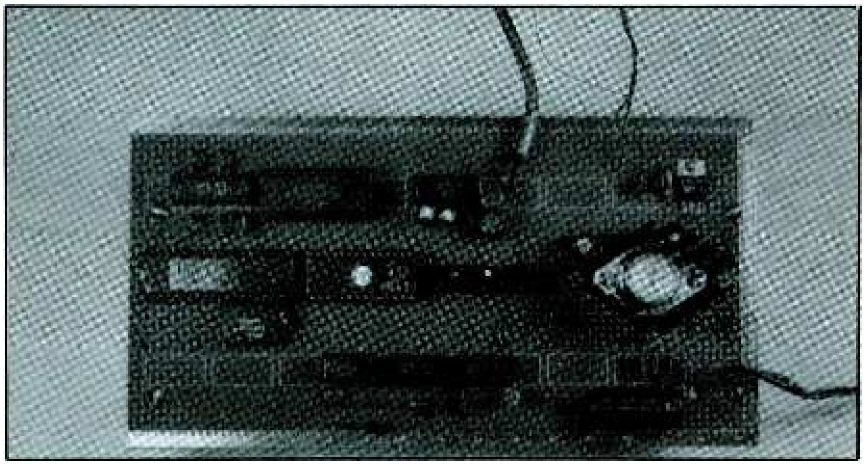
Telephone/Data-Line Surge Suppressor

The Electra Guard® 3111 (EG 3111) from CPS Electronics, Inc. (Clearwater, FL) offers surge suppression to protect telephone/data and power lines. It is designed to protect home answering machines, facsimile machines and modems from transient over-voltages and emi/rfi interference. Two separate units are contained inside the EG 3111—a surge

suppressor for the power line and a data line protector for the telephone line. The surge suppressor guards against voltage surges on the hot, neutral and ground lines, and noise and induced surges on the phone lines are eliminated with a data line protector, which is claimed to provide full protection for the tip, ring and ground conductors. Response of the EG 3111 is rated at less than 1 nanosecond. The EG 3111 is UL listed and exceeds IEEE Specifications #587 Category A. $40.

CIRCLE NO. 110 ON FREE INFORMATION CARD





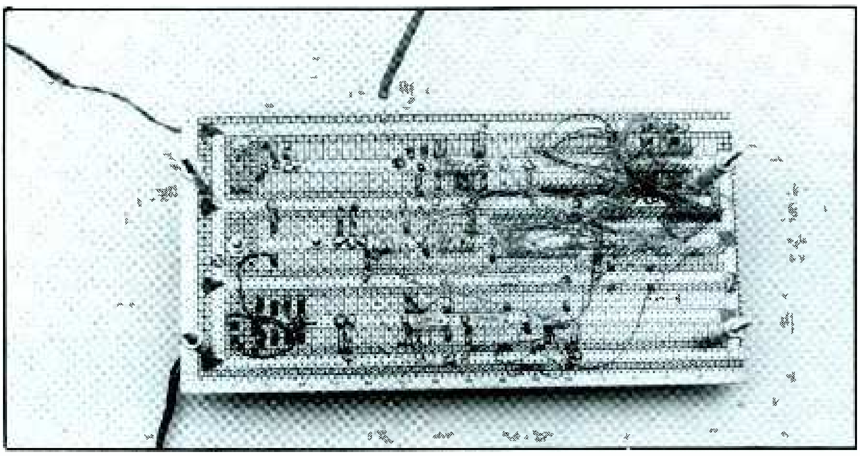


Fig. 4. Microsys components can be mounted on perforated board (upper photo) and be Wire Wrapped together (lower photo).

board connections to *T1*, *S1*, and *F1* will be added later.

Next, wire the + 12.5-volt supply, marking off each component and conductor run as you make it on the photocopy of Fig. 2. Mount *IC8* on the circuit board by bending its legs 90 degrees backward (toward the metal tab) and inserting them so that the mounting hole on the IC lines up with the prepared hole in the circuit board. A small machine screw and nut through the IC's mounting hole secures the IC to the board. Then wire into the circuit *IC8*, *C13*, *C14*, *R2*, and *R3*.

Slip a 1-inch length of small-diameter heat-shrinkable tubing over the red-insulated lead of one battery snap connector. Twist together this lead and the black-insulated lead of the other connector. Solder the connection and then slide the tubing over the connection and shrink it solidly into place. Solder the free red-insulated lead on the connector pair to the IN of *IC8*; solder the remaining free black-insulated lead to a ground point on the circuit board.

Now wire the rest of the Microsys. Following your preliminary layout, install and solder into place the sockets for *IC1* through *IC7*, *IC9*, and *IC10*. (Do *not* install the ICs in their respective sockets until you've wired the entire circuit and checked for proper voltage distribution with the power supply turned on.)

Use self-adhering or socket-identification labels to identify the number of the IC and indicate the location of pin 1 in each case on the wiring side of the circuit-board assembly.

Connect the power-supply and ground pins on the sockets to the power and ground buses on the circuit board. Be aware that the *IC1* socket is the only one with unconventional V+ or ground pin locations. In this case, pin 15 is to be grounded and pin 16 is to be at + 5 volts. For all other sockets, ground is at the lower-right pin and V+ is at the upper-left pin on the wrap side of the board (pins 7 and 14 of a 14-pin socket, pins 8 and 16 for a 16-pin socket, and so on).

Install and solder into place bypass capacitors *C8* through *C12* at roughly even intervals between the + 5-volt and ground buses on the circuit board. Then use Fig. 1 and Fig. 2 as guides as you continue wiring the circuit. As necessary, insert and solder *XTAL1*, *Q1*, *R1*, *R4* through *R16*, *D1*, *D2*, and *C4* through *C7*. Observe proper orientation for *XTAL1*, *Q1*, *D1*, *D2*, *C1* through *C5*, and *C12*.

At *IC1*, notice especially the orientations of *C6* and *C7*. In a properly wired circuit, pin 6 of *IC1* will be at – 10 volts; so the positive (+) lead of *C7* must connect to ground. Similarly, pin 2 will be at + 10 volts; so the negative (–) lead of *C6* must connect to + 5 volts on the circuit board.

Select an enclosure for the project that is large enough to accommodate the circuit-board assembly and off-the-board components without crowding. Make certain that the enclosure is deep enough to ensure that the Wire Wrap socket pins on the circuit-board assembly will not contact the floor panel.

Begin preparing the enclosure by planning parts placement. This done, drill mounting holes in the floor panel for mounting the circuit-board assembly, power transformer *T1*, and two 9-volt battery clips. Drill a hole through the back panel for the ac line cord and cut the slot for the serial-port connector. An opening for a D-type serial-port connector can be made by first drilling a ⅜-inch starter hole and then using a nibbling tool to complete the task. Two small holes are also required for the D connector's mounting hardware.

Drill a hole through the front panel for POWER switch *S1*. Locate this hole to one side of the panel to leave room for adding more controls and displays later as needed.

Next, wire *T1*, *S1*, and *F1* into the circuit, using heat-shrinkable tubing to insulate all exposed connections. Connect the two prepared 8-inch-long wires to the primary leads of *T1*. Twist each pair of wire ends together, solder the connections and insulate them with heat-shrinkable tubing. Slide another length of tubing over each wire, solder connections to *S1A* and *S1B*, and shrink the tubing over the switch terminals.

Insert a rubber grommet into the ac line cord's hole. Feed the free end of the line cord through the grommet into the enclosure and tie a strain-relieving knot in it several inches from the inside end. Tightly twist together the fine wires in each line-cord conductor and sparingly tin with solder. Then solder the in-line fuse holder's leads to a terminal of *S1A* and to the "hot" conductor of the ac line cord. Solder the free end of the other line cord conductor to the remaining lug on *S1B*. Use heat-shrinkable tubing to insulate all connections.

Crimp and solder the unconnected wires at the two-pin locking connector to the junctions of *D3/D4* and *D5/D6*.

Three wires connect the Microsys to its serial-port connector. Solder the wires on one of the prepared three-pin locking connectors to the appropriate pins on the serial-port connector, using either Fig. 1 or your own configuration as a guide. Solder the three wires on the matching connector to pins 7 and 8 of *IC1* and to ground on the circuit board, as appropriate.

Carefully check over your wiring. If you're satisfied with your work, mount the circuit-board assembly in place, using suitable-length spacers and machine screws. Then mount into place the battery clips, serial-port connector, *T1*, and *S1*. Install *F1* and connect the locking connectors.

Checkout & Use

The first step in circuit checkout is to verify power-supply operation. Plug in and turn on the +5-volt supply and verify that its output is within 0.2 volt of +5 volts. Also check for +5 volts between the V+ and ground pins of each IC and for +12.5 volts at the output of IC8. If your Microsys fails any of these tests, locate and rectify the problem before proceeding.

When everything looks okay, turn off the power supply and allow the charges to bleed off the electrolytic capacitors. Then install the ICs in their respective sockets. Make sure you plug each IC in the correct socket and in the proper orientation and that no pins overhang the socket or fold under between IC and socket.

Connect the Microsys' serial port to your terminal's or computer's serial-port cable. Turn on the terminal or computer and configure it for operation with 8 data bits, no parity, and one stop bit. Baud rate used is your choice. On boot-up, the 8052 senses the transmission rate and matches it. A good initial selection is 1,200 bits per second. (If you use Procomm communications software, these parameters are set in the Line Settings menu, with selection #8.)

Turn on the Microsys, and press the space bar at your terminal or computer. If everything is okay, the sign-on message:

```
*MCS-51(tm) BASIC V1.1*
READY
```

will appear on-screen. This indicates that you can now use the project. If you don't see the sign-on message, don't despair. It just means it's time to troubleshoot.

First off, the space bar at the keyboard *must* be the first key you hit after powering up the Microsys. If you don't hit the space bar first, the project will not respond properly. However, if you should press any other key first, turn off the Microsys, wait 10 seconds, and turn it back on. Press the space bar. If you still don't see the correct sign-on message, check to make sure the terminal or computer is configured correctly and that the serial connector is wired correctly.

Recheck the other wiring in the Microsys. Be sure all connections are made correctly and that no inadvertent short circuits or open connections have crept into the project. Verify that no connections have been left out. With persistence, you'll soon find the cause of the problem that's keeping your system from booting up and repair the situation.

When the system has booted to BASIC, a few simple tests will verify that your Microsys is functioning properly.

After seeing the sign-on message, key in:

```
PRINT MTOP
```

and press RETURN. The terminal or computer should respond with:

```
8191
```

which tells you the amount of user RAM available. Following this, key in:

```
XTAL=4915200
```

and press RETURN. (From here on, each line you key in is to be followed by a RETURN, and a RETURN is to be used at the end of each entry.) This tells the 8052 the frequency of the crystal installed in your Microsys. The 8052 uses this information to time signals such as its real-time clock and EPROM programming pulses.

Type:

```
PRINT XTAL
```

The terminal should respond with:

```
4915200
```

Listing 1. Sample BASIC Program

```
1     REM Program 1, for-next loop
10    FOR I=1 TO 10
20    PRINT I
30    NEXT I
40    END
```

which shows that your previous message was received. Now try typing in and executing a program. Listing 1 is a simple program you can type in at the keyboard, then run on the Microsys.

Key in Listing 1. If you make an error while typing in a line, whether on this or any other program, erase characters with the DELETE key. Once you press the RETURN key, however, the line can be changed only by retyping it completely. To execute the program, type:

RUN

The terminal should respond by listing the numbers from 1 to 10. If the program doesn't run properly, type:

LIST

to review the program entered. Retype the entire line that has an error in it. Then type:

LIST

again to ensure that it's correct. If it is, type:

RUN

to execute the corrected program.

The command "NEW" erases all lines previously entered for the current program and allows you to begin fresh.

The program in Listing 2 prompts you to enter a temperature in Fahrenheit degrees and then converts it to Celsius and displays both on-screen. Type in this listing and run the program as you did for Listing 1.

Listings 3, 4, and 5 are more sample programs. The program in Listing 3 lets you read or write data to a location in RAM.

Program 3 first asks you if you want to read or write. It then jumps to the appropriate subroutine and prompts you for the information needed. If reading is selected, the special operator XBY in line 80 reads the data stored at the address requested, and line 90 displays the data read on-screen. If writing is selected, line 140 writes the data into the address requested.

Writing to addresses below 1000 isn't advised, as you might over-write the program you're executing or other essential data required by the system. This could "crash" the system. If you do inadvertently cause a system crash, power down momentarily, then power up and press the SPACE bar to reboot.

Listing 4 shows the somewhat unconventional way that MCS BASIC-52 handles string, or text, variables. The STRING statement in line 10 sets aside a portion of memory, and is required if string variables are to be used. The second number in the STRING statement is the maximum length of string variables allowed plus one. The first number is the number of string variables allowed plus one, multiplied by the second number. Line 10 allocates space for one eight-character string variable, which is declared in line 20. Line 30 displays the string on the screen, and lines 40 through 60 select each character in the string individually and display each on a separate line on the screen.

Listing 5 uses the 8052's real-time clock that creates a 60-second timer on the terminal's or computer's screen. Line 20 turns on and initializes the clock, which automatically counts seconds in 5-millisecond steps and stores the count in the variable TIME. The ONTIME statement in line 50 causes an interrupt when TIME is equal to or greater than 1 second. The program then jumps to line 80, where it subtracts one from TIME, increments the seconds count, and displays the count on the screen. The program then returns to the main loop at lines 40 through 60. The program ends after 60 seconds have been counted.

These sample programs illustrate that MCS BASIC-52 is in many ways similar to other BASICs. There are some differences, of course: MCS

Listing 2. BASIC Temperature-Conversion Program

```
1     REM Program 2, Fahrenheit to Celsius
10    DO
20    INPUT "Enter a Fahrenheit temperature (Ø to quit):  ",FTEMP
30   CTEMP=(FTEMP-32)*5/9
40    PRINT FTEMP," degrees F = ",CTEMP," degrees C"
60    UNTIL FTEMP=Ø
70    END
```

Listing 3. BASIC Program For Writing/Reading Data to a RAM Location

```
1     REM Program 3, read and write to RAM
10    DO
20    INPUT "Enter Ø (read), 1 (write), or 2 (quit):  ",RW
30    IF RW=Ø THEN  GOSUB 70
40    IF RW=1 THEN  GOSUB 120
50    UNTIL RW=2
60    END
70    INPUT "Enter an address to read (Ø-8191):  ",ADDRESS
80   BYTE=XBY(ADDRESS)
90    PRINT BYTE," is stored in address ",ADDRESS
100   PRINT
110   RETURN
120   INPUT "Enter an address to write to (1000-8191):  ",ADDRESS
130   INPUT "Enter data to be written (Ø-255):  ",BYTE
140  XBY(ADDRESS)=BYTE
150   PRINT BYTE," has been written to address ",ADDRESS
160   PRINT
170   RETURN
```

Listing 4. BASIC Program That Shows Unconventional Way MCS BASIC-52 Handles Text Variables

```
1       REM Program 4, string variable
10      STRING 18,9 :  REM reserve string space in memory
20     $(0)="MICROSYS" :  REM create string variable
30      PRINT $(0) :  REM display string
40      FOR I=1 TO 8 :  REM display each character separately
50      PRINT CHR($(0),I)
60      NEXT I
70      END
```

Listing 5. BASIC Program For On-Screen 60-Second Timer

```
1       REM program 5, real-time clock
10     XTAL=4915200
20      CLOCK 1 : TIME=0 :  REM start and initialize timer
30     SEC=0 :  REM initialize seconds
40      DO
50      ONTIME 1,80 :  REM when time=1 second, go to line 80
60      WHILE SEC<60
70      END
80      REM increment time subroutine
90     TIME=TIME-1 :  REM decrement time
100    SEC=SEC+1 :  REM increment seconds
110     PRINT SEC
120     RETI  :  REM return to main program
```

BASIC-52 is in some ways more limited, and in other ways, more powerful, than other BASICs.

Enhancements include the specialized statements and commands that allow you to check for interrupts, read and write to memory and I/O ports, and program EPROMs. Limitations of the language are mainly due to the fact that the entire BASIC interpreter must fit into the 8k bytes of ROM available in the 8052.

We don't have enough space here to give more than give a few examples of MCS BASIC-52 programs. The User's Manual describes the language fully and is essential for serious experimenting with the Microsys.

When you want to save a program, you can store it (and up to 254 other programs, space permitting) in the EPROM. The BASIC command PROG writes the program currently in RAM to the EPROM. To save the program that you've just run, install *B1* and *B2* in the project via the two battery snap connectors and then type:

PROG

Microsys will then program the EPROM with the program currently in RAM. The terminal or computer displays a "1" to show that this is the first program to be stored in the EPROM. When programming is done, you'll see the READY prompt at the terminal.

The 8052 has two modes of operation. In RAM mode (the default), the RUN command executes the current program in RAM. In ROM mode, the RUN command executes the requested program in EPROM. To specify the mode, type "RAM" or "ROMn," where *n* is the number of the EPROM program wanted.

To execute the program now in EPROM, type:

ROM1
RUN

This switches to ROM mode, selects the first ROM program (the only one, so far), and executes it. To return to RAM mode, type:

RAM

Powering down doesn't affect the programs saved in EPROM. On powering up again, you can run any program saved in EPROM by switching to ROM mode with the appropriate program selected.

Perhaps you'd like to make changes to the program stored in EPROM. The information in the EPROM can't be changed (except by erasing *everything* programmed into the chip's ROM section), but you can edit a stored program if you transfer it back into RAM. To do this, type:

ROM1
XFER

This selects program 1 in the EPROM, transfers it to RAM, and switches to RAM mode.

You can now make any changes you wish to the program by adding, deleting, or re-entering program lines. To save the new, edited program to EPROM, type:

PROG

The terminal or computer will display a "2" to show that this is the second program to be stored in the EPROM.

To run the new program from EPROM, type:

ROM2
RUN

To return to RAM mode, type:
RAM

Closing Remarks

Your complete, functioning Microsys allows you to write programs, save them to EPROM, and run them from RAM or from EPROM. Feel free to experiment by writing and running your own programs on the Microsys.

Next month, we'll show you how to add such "real-world" inputs and outputs as sensors and displays, as you transform the Microsys into the Tempwatch smart thermometer. Of course, the Tempwatch is just one example of what you can do with the Microsys. The Microsys has wide capabilities, yet it is user-friendly, providing a good introduction to the topic of microprocessor control. ME

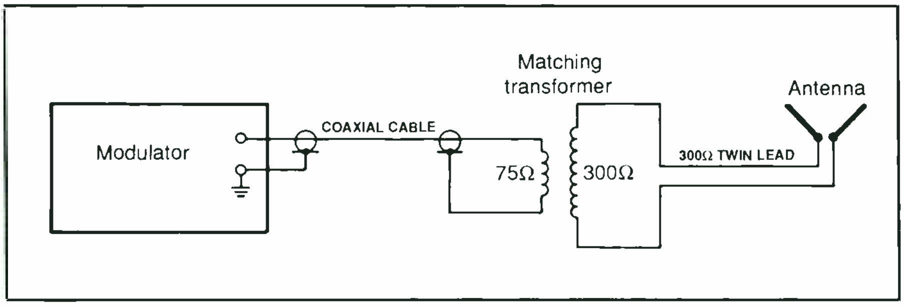


Fig. 5. How to use 75-to-300-ohm transformer to match project to 300-ohm twin-lead line that goes to radiating antenna.

rangement and are connecting the cables directly into the circuit-board assembly, save connection of these cables to the circuit-board assembly until after you've machined the project's enclosure. However, you can prepare the two cables needed using standard audio or video cables terminated in phono jacks. These cables should each be 36 to 42 inches long. Clip away the plug from one end of each cable. Then prepare the cut ends as described above.

Plug one end of one of the cables into the holes labeled J1, inner conductor into the hole near *R8* and shield into the hole near *R7*, and solder both into place. Similarly, plug one end of the other cable into the holes labeled J2, inner conductor into the hole near *R9* and shield into the hole near *R7*, and solder both.

This completes wiring of the circuit-board assembly. Now very carefully inspect the assembly. Check for components installed in the incorrect locations and/or wrong polarities. Also check for poorly soldered connections and connections that have solder bridges, the latter especially between the closely spaced IC pads. Reflow the solder on any questionable connection and use desoldering braid or a vacuum-type desoldering tool to remove any solder bridges.

Now use a magnifying glass to check all component leads that pass through holes that should not be at circuit ground on the ground-plane side of the board. Make certain that none of these leads makes contact with the ground plane. If you don't have a magnifying glass, use an audible continuity checker or ohmmeter set to a low-resistance range to ascertain that no lead that shouldn't be is touching the ground plane.

You can use any enclosure that will comfortably accommodate the circuit board assembly as the project's enclosure. This enclosure should preferably be all-metal. Machine the enclosure as needed. That is, drill mounting holes for the circuit-board assembly, fuse holder and switch and entry/exit of the ac line cord, AUDIO INPUT and VIDEO INPUT cables (or jacks *J1* and *J2*) and the wire or cable that connects to the antenna.

Temporarily mount the circuit-board assembly inside the box, using ½-inch spacers and ¾-inch machine screws and nuts. Then very carefully ascertain where to drill the holes for access to the adjustment slots on trimmer capacitor *C9*, variable inductor *L2* and trimmer resistor *R12*. Dismount and set aside the circuit-board assembly and then drill the holes in all three locations.

Deburr all holes. Then line all cable entry/exit holes with small rubber grommets. Mount POWER switch *S1* and the holder for fuse *F1* in their respective locations. Pass the free end of the ac line cord through its rubber grommet into the enclosure. Tie a strain-relieving knot in the cord about 8 inches from the free end inside the enclosure. Tightly twist together the fine wires in each line-cord conductor and sparingly tin with solder. Solder the center conductor directly to the circuit-board assembly's ground plane. Then crimp and solder one of the remaining conductors to one lug of *S1B* and the other one to one lug of the fuse holder.

Cut to length a hookup wire and strip ¼ inch of insulation from both ends. Crimp and solder one end of this wire to the free lug of the fuse holder and the other end to one lug of *S1B*. Locate the two wires coming from the S1 holes on the circuit-board assembly. Crimp and solder one wire to the remaining *S1A* lug and the other wire to the remaining *S1B* lug.

If you've decided to directly connect the INPUT cables to the circuit-board assembly, route the free ends through their respective grommet-lined holes into the enclosure and tie strain-relieving knots in each about 6 inches from the free ends inside the enclosure. Plug the free end of the AUDIO INPUT cable into the holes labeled J1 and solder into place. Then do the same for the free end of the VIDEO INPUT cable and the J2 holes. See above for inner-conductor and shield connection points.

Mount the circuit-board assembly inside the enclosure, using the ½-inch spacers, this time using lockwashers with the hardware. If you decided to use jacks for the AUDIO INPUT and VIDEO INPUT connections, mount the jacks in their respective holes. Crimp and solder the free ends of the cables coming from the J1 and J2 holes to the appropriate lugs of these jacks. Without tying a knot in it, route the free end of the R-F OUT wire or cable through its rubber-grommet-lined hole. Place a ½-ampere slow-blow fuse in the holder.

Checkout & Use

With *IC1* still not installed in its socket, plug the project's line cord into an ac outlet and set the POWER switch to ON. Connect the common lead of a dc voltmeter or multimeter set to measure dc voltage to circuit ground. Touch the "hot" probe to the positive (+) side of *C3*. You should obtain a reading of at least +16 volts at this point. Next, touch the "hot" probe to the + side of *C1*, which should now yield a reading between +11.5 and +12.5 volts.

Now touch the probe to pin 13 of the *IC1* socket while adjusting the setting of *R13*. This control should give you an adjustment range of between about +5 and +10 volts. If so, set *R13* for a reading of +8 volts. At pins 2, 3 and 4 of the *IC1* socket, your readings should all be +6 volts, while at pins 6, 7, 10, 11, 14, 15 and 16 of the socket the readings should all be +12 volts.

If you fail to get the above readings at any given point power down the project, unplug it from the ac line and troubleshoot it. Rectify the problem before proceeding.

If your project meets all the above criteria, power it down and allow the charges to bleed off the electrolytic capacitors in the power supply. Then plug *IC1* into its socket. Make certain that the IC is properly oriented and that no pins overhang the socket or fold under between IC and socket.

To make the following adjustments, you need a TV receiver and VCR. You can use the receiver that's normally used with the VCR or a second TV receiver placed in close proximity to it. Be sure the receiver's color controls are properly adjusted before you begin.

Whichever TV receiver you decide to use for aligning the project, disconnect all wires that feed its vhf antenna input terminals and connect the project's R-F OUTPUT lead or cable to the 75- or 300-ohm vhf antenna input terminals, as in Fig. 4.

Plug the VIDEO INPUT and AUDIO INPUT cables into the respective outputs on your VCR (don't mix up the two). Turn on the TV receiver and set it to unused channel 3 or 4 in your area and ascertain that there is no picture pickup on this channel. Then set the project's POWER switch to ON and turn on your VCR and set it to play either a tape or tune it to any active TV channel.

Use an insulated alignment tool to very slowly adjust trimmer capacitor *C9* until the TV screen fills with some sort of video. Don't pay any attention to the sound at this point. The picture may be severely distorted or even totally black. Adjust the setting of *R12* for best possible picture. Then very carefully readjust *C9* to tune the VCR Modulator or fine-tune the TV for best picture.

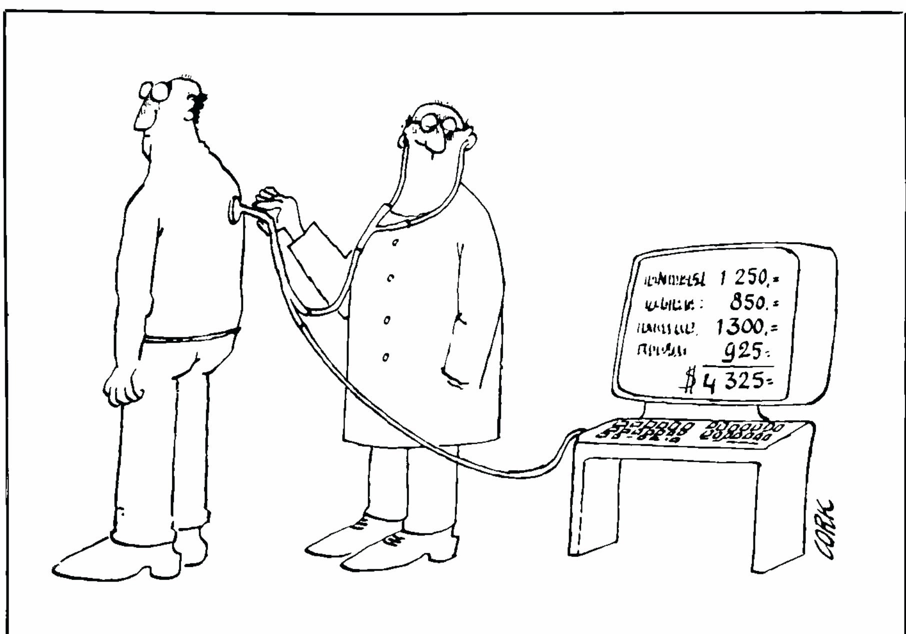
Proper tuning will be near the point where the picture changes from black and white to color. Adjust *R12* for correct color balance by observing known white objects in the picture or skin tones.

Finally, adjust the slug in *L2* for clearest sound. This may be a fairly critical adjustment, so tune very slowly. When the sound is at its clearest, with no indication of "buzzing," *L2* is properly adjusted. Your VCR Modulator is now aligned and ready to be put into service.

The TV receiver with which you normally use your VCR can be restored to its original connection to the VCR if it was used to align the project. The Modulator can be used to feed the vhf antenna input of a second TV receiver, which will now receive the video and audio signals developed by the VCR.

If you're able to operate your project with a direct connection to the second TV receiver, nothing further needs to be done. However, if your setup precludes direct connection, you can experiment by connecting one length of wire to the vhf antenna input and another to the R-F OUTPUT of the VCR Modulator and determining if the TV receiver receives sufficient signal level to assure good picture and sound reception. This will depend on distance between project and receiver and your receiver's sensitivity.

Signal strength will depend upon how good the impedance match of the output from the project is. You can experiment further by connecting a 75-to-300-ohm matching transformer to the project, as illustrated in Fig. 5. This arrangement will allow you to connect ordinary 300-ohm twin-lead cable to the output of your VCR Modulator and may improve the "sensitivity" of the TV receiver.



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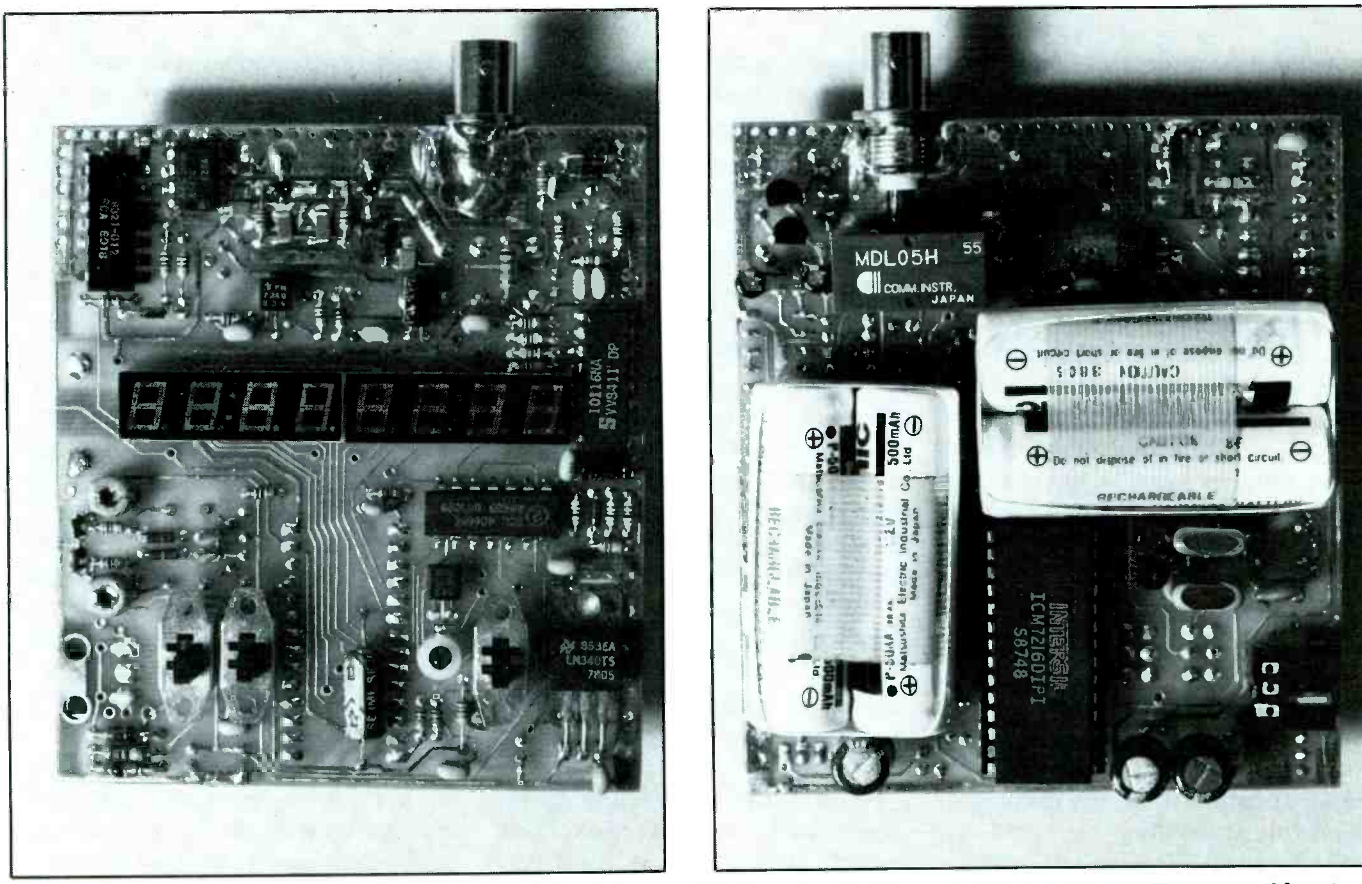

Fig. 5. These photos show fully wired circuit-board assembly from top (left) and bottom (right) perspectives. Note in both photos how BNC connector mounts on board with its threaded section straddling both sides.

28-pin DIP socket in the U1 location. Then exercise the same handling technique for MOS devices to install *U1* in the socket. Make sure you properly orient the IC in the socket and that no pins overhang the socket or fold under between IC and socket during installation.

Pictured in Fig. 5 are both sides of a fully assembled frequency-counter circuit-board assembly just prior to installation in its enclosure. The photo on the left is of the top, the one on the right the bottom of the board.

Any enclosure that will comfortably accommodate the circuit-board assembly can be used to house the counter. An all-metal enclosure that measures 3¾ × 3⅜ × 1 inches should do just fine. Otherwise, as mentioned above, you can build the project into an existing piece of equipment and use it as you would a panel meter.

Machining of the enclosure can be a tedious task. Four rectangular slots must be cut and three holes must be drilled in the front panel. One slot is the long and narrow display window that goes almost clear across the front panel; the three other slots are small enough only to permit normal operation of the three switch slides. The drilled holes are for mounting the LED and accessing the tuning slots of the trimmer capacitors.

A large hole for the BNC connector to exit the enclosure must be drilled in the top panel, and a suitable hole for the ac adapter/charger's jack must be drilled in the left side panel. No holes need be drilled for mounting the circuit-board assembly in place. When the enclosure has been machined, paint it if you wish and then use a dry-transfer lettering kit to label the front panel (see lead photo for details). Spray two or more light coats of clear acrylic over the lettering to protect it from wear. Allow each coat to dry before spraying on the next. Then cement a transparent red plastic lens over the display window inside the enclosure.

You can eliminate having to do all this metal work, of course, by purchasing a machined, painted and silk-screened enclosure with plastic window from the source given in the Note at the end of the Parts List.

Checkout & Calibration

Now that your counter is completely assembled, give it a thorough visual inspection. Check to make sure that all components are installed in their respective locations and that those that are orientation-sensitive are installed properly. Also check your soldering. Solder any missed connections, reflow the solder on any connection that appears questionable and use desoldering braid or a vacuum-type desoldering tool to remove inadvertent solder bridges.

When you are confident that everything is okay, plug the ac adapter/charger into the jack on the side of the instrument and into an ac outlet. Setting the PWR switch to AC-CHG should cause some if not all of the digits in the display to come on and the GATE LED light to light. If everything is okay, you will note that the 7805 voltage regulator at the lower-right on the top side of the circuit-board assembly runs warm to the touch. This is the normal operating condition for this regulator.

After proper operation is verified, set the RANGE switch to position A and feed a signal in the low A range into the input of the frequency counter, using a precision reference source and note the displayed frequency. If this frequency does not agree with the rated precision reference frequency, adjust the setting of trimmer capacitor *C35* until it does. Use a non-metallic tuning tool to make the adjustment.

Set the RANGE switch to position B and feed another precision reference frequency in the range between 10 MHz and 2.2 GHz into the counter and note the reading in the display. If this reading does not agree with the specified reference frequency, adjust the setting of trimmer capacitor *C34* until it does. Again, use a non-metallic tuning tool to make the adjustment.

Now that your frequency counter is ready to be put into service, there are many new applications that you can find for this very sensitive wide-range portable instrument. Next month, we will explore some of the many possible uses for this counter and show you some useful techniques to use for making measurements. We will also include counter surveillance, troubleshooting, servicing of two way radios, obtaining scanner frequencies and other topics. **ME**

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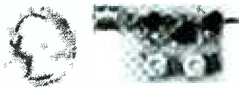

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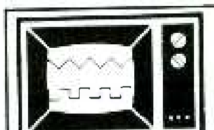

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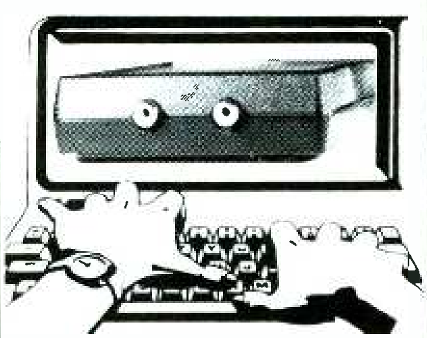

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Midi Music *(from page 33)*

The author at work in Solar Wind Studios, a small San Francisco Bay Area recording studio that specializes in MIDI sequencing and recording. An Atari 1040ST computer controls up to 32 tracks of MIDI's instruments simultaneously.

Typical Applications

Now that you have a basic understanding of how MIDI works, let's look at some of the ways musicians use MIDI on-stage and in the studio. The simplest application was illustrated in Fig. 1, where a master instrument controls a slave instrument. The combined sounds are "thicker" and more complex than either instrument would produce by itself. Many of the sounds used in today's music employ this method, which is known as "layering."

A variation of this technique is illustrated in Fig. 2. Here, a master controls a number of slaves using the MIDI Through box. By assigning each module to a different channel, different modules can be selected simply by changing the controller's channel.

Since a number of instruments have been designed to serve as master controllers, these allow multiple-channel data to be sent at one time or allow the musician to set up specific areas of the keyboard to transmit data on different channels. This is especially useful in concert work, where a musician might need to access a variety of different sounds while playing a single song.

Adding a computer or software sequencer greatly increases the musical possibilities of the system illustrated in Fig. 3. Here, the controller can be used to play the sound modules directly or to input data to the sequencer. The recorded data can then be edited as already described, and individual parts can be assigned to various modules. This leaves the performer free to play along or improvise against the sequenced parts, thus creating a true "one-man band."

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(The VHF converter options must be used in the R-5000 and R-2000.)

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R-2000

The R-2000 is an all band, all mode receiver with 10 memory channels and many deluxe features such as programmable scanning, dual 24-hour clocks with timer, all-mode squelch and noise blankers, a large, front-mounted speaker, 110 volt AC or 12 volt DC operation (with the DCK-1 cable kit), and 118-174 MHz VHF capability with VC-10 option.

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Optional Accessory
- **PG-2N** Extra DC cable

Optional Accessories

R-2000:
- **VC-10** VHF converter
- **DCK-1** DC cable kit for 12 volt DC use.

R-5000:
- **VC-20** VHF converter
- **VS-1** Voice module
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