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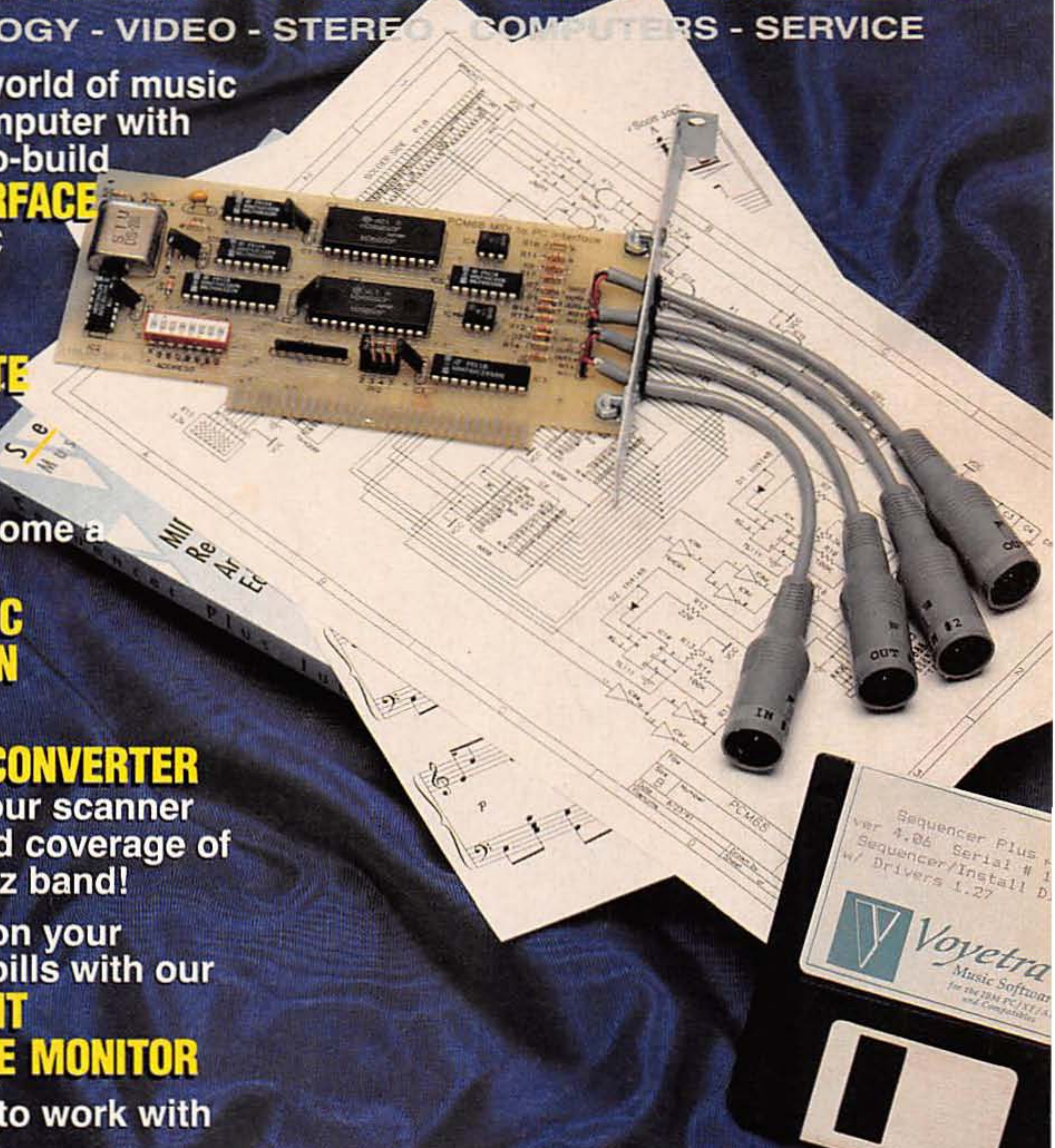
Radio-Electronics

MARCH 1992

TECHNOLOGY - VIDEO - STEREO - COMPUTERS - SERVICE



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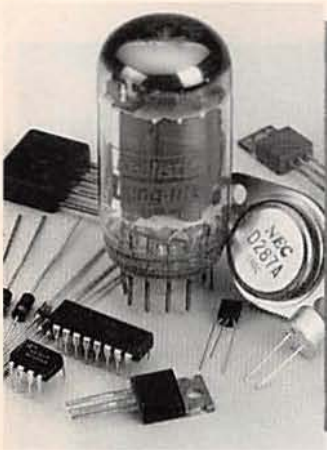

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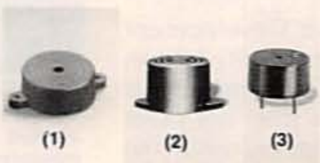

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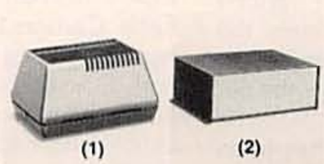

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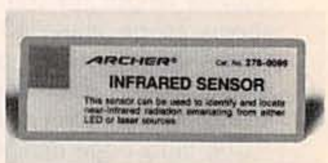

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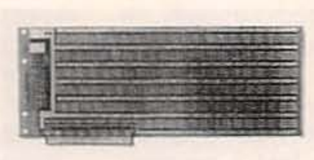

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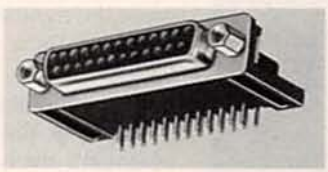

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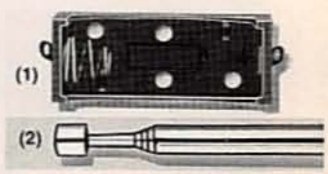

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WHAT'S NEWS

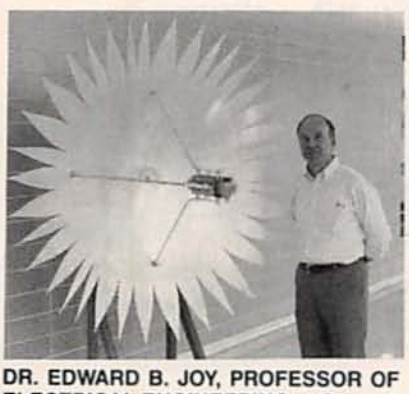
A review of the latest happenings in electronics.

Petal power?

Electrical engineers at the Georgia Institute of Technology (Atlanta, GA), with support from the U.S. Joint Services Electronics Program, have discovered that adding serrations shaped like flower petals to the outer edges of satellite dishes can significantly improve their performance by reducing unwanted "sidelobe" radiation—energy that is unintentionally scattered by the dishes. Reducing it minimizes the chance that antennas will interfere with each other or send signals in undesired directions, both of which could cause problems for future telecommunications satellites that will be placed much closer together in geosynchronous orbit.

The edge treatment, for which Georgia Tech has applied for a patent, allows designers to customize the serration design for specific applications, taking into account such factors as how much gain will be lost to reduce the sidelobe levels. The optimal length for the serrations seems to be about 10 times the wavelength the dish is designed to reflect. It isn't necessary for the petals to be of uniform size.

The petal-edge design has been incorporated in an outdoor compact range recently build for the U.S. Army's Electronic Proving Grounds at Fort Huachuca, AZ, and at least one manufacturer of compact antenna ranges has already adopted the technology. The edges will add little to the manufacturing costs of dishes, and could even be retrofitted onto existing dishes, although such modified dishes would require alterations to the feed systems.



DR. EDWARD B. JOY, PROFESSOR OF ELECTRICAL ENGINEERING at Georgia Tech, shows antenna dish with flower petal edges that improve the antenna's performance.

Harder than diamonds?

High-resolution x-ray measurements performed by scientists at Ford Motor Company (Dearborn, MI), show that gem-quality diamonds synthesized by scientists at GE Research and Development Center (Schenectady, NY) contain more atoms per cubic centimeter at room temperature than any other solid known to exist on earth. The diamonds, which are composed almost totally of the isotope Carbon-13, are of greater crystalline perfection than any found in nature, and range up to three carats.

Carbon exists as two stable isotopes: Carbon-12 and Carbon-13. Each Carbon-13 atom is slightly heavier than its Carbon-12 counterpart. Diamond is composed of carbon atoms arranged in a regular lattice, with each atom at the same small distance from its neighbors. The regular lattice, small distance between atoms, and very strong carbon-to-carbon bond, account for diamond's unsurpassed hardness. Natural diamonds contain 99% Carbon-12 and only 1% of Carbon-13, while the synthesized diamonds are made of 99% Carbon-13 and 1% Carbon-12.

A proprietary two-step process invented in the late 1980's by GE scientists involves, first, a low-pressure chemical vapor deposition technique to produce aggregates of small diamonds with the desired isotopic composition, and second, dissolving and recrystallizing the aggregate into gem-quality diamonds weighing a carat or more.

The Ford experiments showed that, as Carbon-13 interaction is increased, the interatomic distance, or lattice constant, decreases slightly. Some scientists speculate that the smaller lattice constant could make the GE diamond even harder than natural diamonds.

GE RESEARCH AND DEVELOPMENT Center scientists examine a model of the atomic structure of a diamond synthesized from 99% Carbon-13. The diamonds, shown in the foreground, could turn out to be harder than natural diamond, currently the world's hardest material.

Also revealed by the Ford experiments is that the GE diamond's crystal quality approaches that of the best man-made semiconductor crystals. Because improved crystal quality translates to improved electronic properties, that discovery is expected to stimulate the development of electronic devices based on diamonds. Laboratory studies have shown that synthesized gem diamonds can be electronically "doped" by the incorporation of small amounts of boron, which transforms it from an insulator into a semiconductor.

GE manufactures diamond heat sinks for the electronics industry as well as diamond abrasives for machining, grinding, sawing, and drilling applications. **R-E**

VIDEO NEWS

What's new in the fast-changing video industry.

DAVID LACHENBRUCH

• "Use it or lose it." Anticipating the arrival of HDTV, the FCC is preparing new allocation of TV channels to permit broadcasters to simulcast in standard NTSC and HDTV during a long transitional period. The FCC has found that there will probably be enough channels in most markets to allot those extra frequencies to broadcasters who are planning to transmit in HDTV. However, there is some fear that broadcasters, hesitant because of the expense of converting to HDTV, might merely sit on the extra channels. Thus, the Commission's chairman, Alfred Sikes, has warned that broadcasters won't be allowed to dally and that the UHF spectrum space that broadcasters don't use after a respectable period of time could well be turned over to land mobile services. The FCC is asking a number of questions to prepare for HDTV, including how long stations should continue broadcasting in NTSC after the arrival of high definition.

• Two-lens camcorder. One of the last holdouts against the 8mm video format—Sharp Electronics—has come into the fold in a big way. It has introduced two camcorders with dual-lens systems. Each of the compact, palm-sized models are virtually two cameras in one. One lens provides a fixed-focus, wide-angle picture, the other an 8:1 zoom system. The wide-angle lens gives a 62° filed of view, and switching from one lens to the other provides "instant 12:1 zoom," according to Sharp. The system provides a number of special effects. It can be used for picture-in-picture, with both lens and CCD operating systems operating at the same time, or the user can "wipe" from one lens to the other. The basic model has monophonic sound and a monochrome viewfinder, while the higher priced model has stereo audio and a color LCD viewer.

With Sharp's addition of 8mm (it will continue to offer VHS camcorders as well), only JVC—the inventor of VHS—has no involvement with 8mm, among all major camcorder makers. Even Matsushita Electric, which doesn't offer 8mm camcorders under its own brands (Panasonic, Quasar, and National), manufactures 8mm camcorders on a private-label basis of other brands.

• Home multimedia. Nobody has really defined the word "multimedia," which is largely used to describe CD-ROM computer products to which interactive video has been added. Those offering non-computer items with similar attributes have generally avoided the word. The question for the future is whether multimedia will enter the home as a computer or as an attachment for the common TV set. Although there are many approaches to multimedia via the computer, so far only two systems have been introduced that use the family TV. Those are Commodore's CDTV, which is based on the Amiga computer but has no keyboard, and Philips' CD-I, launched with great fanfare (**Radio-Electronics**, February 1992) reportedly is selling well. Philips recently announced agreement with Motion Picture Experts Group (MPEG), a standards-setting body, on a standard to add full-motion video to CD-I. All CD-I players have a port for the addition of a chip to provide full-motion, full-screen video. Philips promises the plug-in chip by mid-year.

While Philips is attempting to appeal to the entire family with its CD-I programming—including children's activities, adult games, and reference materials—Commodore says it will begin next year to offer special-interest interactive packages, including MIDI (musical instrument digital interface) selections for audio enthusiasts and titling and captioning software for videomakers. Commodore also plans to bridge the gap between TV-based and computer-based multimedia by offering a CDTV drive to the 750,000 Amiga computer users in the U.S.

• Full HDTV schedule. High-definition broadcasting is now on a regular schedule in Japan, the satellite-delivered Hi-Vision signal being transmitted for eight hours daily, although the broadcasts are still billed as "experimental." So-called "regular" HDTV broadcasting is still three years off. Japan's analog HDTV system has been under development for more than 20 years. TV sets to receive and display the broadcasts in full HDTV still cost about $30,000, and HDTV VCR's are around $115,000, although costs will come down. Already some private broadcasters in Japan (as opposed to the public NHK network, which developed Hi-Vision) are calling the Japanese system an "interim" measure until a truly digital system is developed.

• Bigger S-VHS push. Although more than 20% of all VCR's sold in Japan are in the Super-VHS format, the proportion in the U.S. continues to hover around 2%. Panasonic now plans a major campaign around S-VHS, with lower prices—a strategy already being followed by JVC, which is now shipping an S-VHS deck carrying a "nationally advertised price of $799," about $500 less than the cheapest model last year. Although Panasonic's pricing hadn't been revealed at our press time, it is expected to be at least in line with JVC's. In addition, Panasonic will bring S-VHS into more complete VHS compatibility by making its entire VHS line S-VHS "playback compatible"—meaning that its standard VHS decks will be able to play S-VHS tapes as well as standard VHS (although with only standard VHS resolution). **R-E**

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VIDEO FADER

I'm interested in learning how to design video hardware and I have been working on a circuit that would cause a video image to fade as I turn a potentiometer. I've tried several ideas but keep running up against the same problem. As I cause the signal to fade, it always starts to mess up horizontally and vertically before the image disappears completely. I'm not asking you to design the circuit for me, but I sure could use some advice. Do you have any idea what I'm doing wrong?—D. Koetting, St. Louis, MO

It's always a pleasure to answer a letter from someone who understands that the only way to learn is to make mistakes and work out the answers with a minimum of help and a maximum of brainwork.

I've studied your schematics and you've been making the same mistake each time. Each design you've done assumes that the video signal is similar to audio in that all the information contained in the signal is spread equally throughout the signal's entire voltage range. The video signal is extremely complex and different parts of it are reserved for different purposes. A typical line of video is shown in Fig. 1. Notice that the line is divided horizontally between the picture information (want to fade), and the control information (want to leave alone).

The only thing wrong with the designs you sent me is that they all treat the two parts of the video signal equally. By dropping the voltage level of the entire line of video, you're cutting the level of the control information in the horizontal interval as well. For your designs to work properly, your circuit must distinguish electronically between the picture and the control information in the horizontal interval.

This is the same problem that every television has and, as you would expect, there are one-chip solutions to the problem. National Semiconductor and other manufacturers have a range of chips available that can separate picture and sync. If you want to build something of your own to handle this problem, the answer will become evident when you realize that in a standard NTSC signal (1 volt peak-to-peak), the picture data lives above 300 millivolts and the sync information lives below that. You didn't ask for a specific design, but remember that in 5-volt TTL land, the picture information will be seen as a high and sync will be seen as a low.

Once you work out that part of the problem, you have to use the sync signal to gate your fade circuit. Reducing the picture to 300 millivolts will make it disappear completely, and passing the whole signal during the sync interval will steady the image as it fades away on the screen.

EGA-VGA ADAPTER

I have an AT clone and recently I upgraded my video card from EGA to VGA but I am still saving to buy myself an analog VGA monitor. The problem I'm having at the moment is that my old EGA monitor has a nine-pin connector and the VGA card has

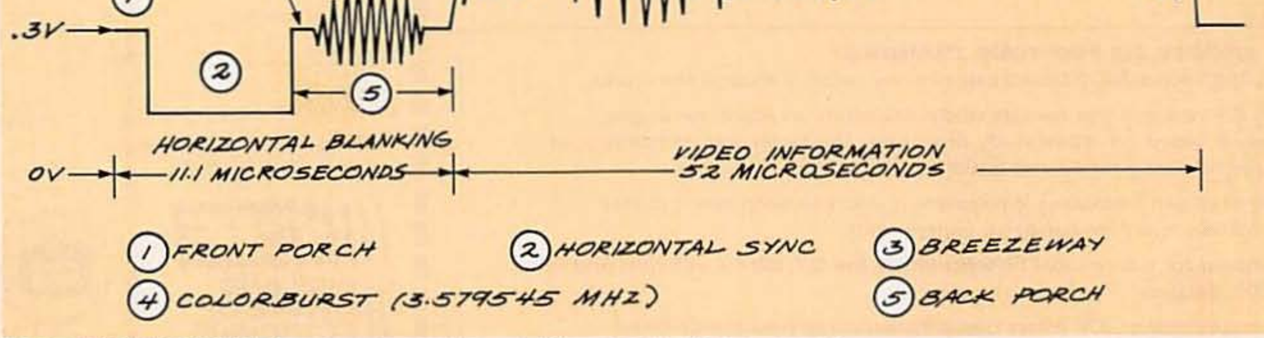

FIG. 1—THE VIDEO SIGNAL is extremely complex and different parts of it are reserved for different purposes. A typical line of video is divided horizontally between the picture information and the control information.

TABLE 1
IBM 15-PIN VGA CONNECTOR PINOUTS

Pin #	Function
1	Red Video
2	Green Video
3	Blue Video
4	Not Used
5	Ground
6	Red Ground
7	Green Ground
8	Blue Ground
9	No Pin
10	Sync Ground
11	Monitor ID (not used)
12	Monitor ID
13	Horizontal Sync
14	Vertical Sync
15	Not Used

Monochrome VGA monitors get their signal from Green Video on pin #2 and connect pin #12 to ground. Color VGA monitors leave pin #12 open. This allows the VGA card to detect the type of monitor it's driving when the computer is first turned on.

TABLE 2
PINOUTS OF THE NINE- TO FIFTEEN-PIN IBM VIDEO ADAPTER

Nine Pin Connector		Fifteen Pin Connector	
Pin #	Function	Pin #	Function
1	Red Video	1	Red Video
2	Green Video	2	Green Video
3	Blue Video	3	Blue Video
4	Horizontal Sync	13	Horizontal Sync
5	Vertical Sync	14	Vertical Sync
6	Red Ground	6	Red Ground
7	Green Ground	7	Green Ground
8	Blue Ground	8	Blue Ground
9	Sync Ground	10	Sync Ground
		5	Ground

a fifteen-pin connector. I know I can't see VGA-quality video on my monitor, but is there a standard for making an adapter to go from the fifteen pins on my card to the nine pins on my monitor?—F. Gisher, Benjamin, IN

At the risk of sounding completely mysterious, I have to tell you that the answer to your question is yes (maybe), and no (sort of). Even though VGA is an established standard, there are some important parts of it that aren't standardized.

Nine-to-fifteen pin adapters are sold by a lot of people. The pinout for the VGA's fifteen-pin connector is shown in Table 1, and the nine-to-fifteen pin adapter pinouts are shown in Table 2. Making one of these adapters is easy but the fifteen-pin connectors are a pain in the neck to work with. If I were faced with your problem, I'd spring for a ready-made adapter.

While the adapter is standard, there's no guarantee that you can use it safely in your system. The EGA monitor you have is probably designed to handle only the standard EGA-level signals, and the VGA card you bought can probably drive only VGA-type analog monitors. Even if you were able to get past the problem with signal levels (and type), you'd still be left with the problem of the scan rate.

The standard EGA horizontal scan rate is about 21 kHz, while the regular VGA scan rate is considerably higher—about 31 kHz—and this is root of the problem. Trying to drive a monitor designed to scan at 21 kHz with a horizontal frequency 10 kHz higher will undoubtedly damage the horizontal deflection circuitry in the EGA monitor.

Some VGA cards—such as the ones from ATI—have hardware on them specifically designed to drive everything from monochrome to CGA to EGA monitors. In essence, while they look like a VGA card to both your computer and software, they can look like a variety of video cards to your monitor. Read your VGA card manual carefully and, if it doesn't specifically state that it can drive an EGA monitor, forget the idea and buy a VGA monitor.

By the way, the nine-to-fifteen-pin adapters are normally used for multisync monitors that can handle both analog (VGA) and TTL video signals. **R-E**

LETTERS

Write to Letters, Radio-Electronics, 500-B Bi-County Blvd., Farmingdale, NY 11735

A REAL SOAP OPERA

Radio-Electronics readers might be interested to know that radio musical comedy is still alive and well in the 1990's. ZBS Foundation has produced "Dishpan Fantasy," a modern comic opera that is available to public radio stations as two half-hour programs. The format might be reminiscent of the past, but the plot and production methods are strictly contemporary. The story line blends bits of feminism with fantasy, comedy, love, and self-discovery. The music ranges from classical to rock'n'roll, from 50's cocktail lounge songs to African drums and whistles. The voices of two opera singers were used to create the seven characters in the opera. By running the singers' voices through a processor, the producer, Tim Clark, was able to create a cartoon-like quality. Using samplers and synthesizers, sound effects and environmental background noises were added. The "Finale" music-writing program was used for composing the opera, and the "Performer" program was used for the preliminary rough mix that allowed the singers to hear their parts with full orchestration. After the voices were recorded on a multitrack, Clark went back and added the music that was in the computer in the Performer program. Besides simplifying production, computer technology offered one big plus: Listeners can hear every word. Clark was able to rearrange the vocals and instrumentation so that the singers' words were always clearly understood. Check local public radio programming schedules for broadcast times of "Dishpan Fantasy."

KATHY GRONAU
ZBS Foundation

If "Dishpan Fantasy" isn't being broadcast in your listening area, you can order it on a 72-minute audio cassette for $12.95 directly from ZBS Foundation, RR#1 Box 1201, Ft. Edward, NY 12828-9713. Their phone number is 800-662-3345.—Editor

ONE READER'S OPINION

I'm writing to let you know that you're doing a great job. I work as an electrical engineer in the automotive field at a major R&D outfit during the day, and work towards my masters in E.E. at night. My job requires that I stay on the leading edge of technology and be informed on the latest techniques, applications, and discoveries. **Radio-Electronics** has been a great help in meeting those requirements. I can't emphasize enough that education is a priority for success and must be a lifetime commitment. I've always preached to other electronics students that **Radio-Electronics** is an excellent source of information. I love to study the "Build This" projects, admiring some of the designs—and catching some of the errors. The technology articles provide an excellent review. The various departments keep getting better, and I hate it when I don't have time to read them all.

One suggestion for improvement: I'd like to see a section in **Radio-Electronics** devoted to testing your electronic skills. Perhaps it could be a one-page test, covering a different topic each month, that readers could take to quiz themselves. Taking such tests really keeps you on your toes.

Keep up the good work!
J. KEITH DAVIS
San Antonio, TX

ADC FOR YOUR PC IMPROVEMENTS

The surface temperature probe in "Experimenting with ADC for your PC" (**Radio-Electronics**, January 1992) should not have its handle filled with epoxy or silicone, as that will increase heat transfer between the sensor and the handle, thus increasing response time and decreasing accuracy. The top of the TO-92 case should also be filed flat to increase contact area and heat transfer between the sensor and the measured surface.

At the low-temperature data-gathering point, be sure not to record the voltage until the ice cube is wet from its own melting. An ice cube just out of a freezer could have a temperature well below 0°C.

At the high-temperature data-gathering point, the probe should not be immersed if it's to be used as a surface probe. Place it against an outer flat side of the container of boiling water, just below the water level. Bring the water to a rolling boil, reduce the heat slowly, and record the voltage just as active bubble production ceases.

A rolling boil can be more than 1°C above the true boiling point—which is also greatly affected by the barometric pressure. Pure water will boil at less than 95°C in Denver under the influence of a low-pressure system, and at more than 101°C at sea level under the influence of a high-pressure system.

The current uncorrected barometric pressure can be obtained from your nearest airport or weather bureau. For every 0.1 inch of mercury above or below 29.92 inches, adding or subtracting 0.1°C from 100°C will be quite close.

For immersion probe construction, on the other hand, thermal isolation of the sensor from the handle is of little concern, but moisture proofing is important. For the low-temperature point, immerse the probe in a constantly stirred slurry of chipped ice and water using +0.3°C instead of 0.0°C as the temperature. At the boiling point, don't pour the water into another container. It will lose several degrees in the process. Immerse the probe to just above the bottom of the container, making temperature corrections and voltage recordings as outlined above.

DAN A. NIEMI
Gwinn, MI

SCRAMBLER/DESCRAMBLER REQUEST

It has been several years since my service training in electronics. As a matter of fact, my education was very complete—on tubes, that is. I've just recently regained my interest in electronics as a hobby for my golden (silicon?) years. After making a bunch of doo-dads directly from simple schematics, I would like to get back into designing my own circuitry as I did in days of yore.

In the meantime, while my knowledge is getting modernized, I would greatly appreciate plans for a simple solid-state scrambler/descrambler. The parameters could be very limited, since it only has to be variable to give four or five "channels" and an audio band (even just the frequencies of the human voice).

It's hard to believe the changes that have come to pass. Picking up my first subscription copy since dropping out years ago is like starting to learn a foreign language that your distant relative spoke in your youth. In any case, it is satisfying to see that the quality of **Radio-Electronics** has not suffered.

LEN BOULTER
Prince Rupert, B.C.
Canada

Keep reading—we're working on just such a project!—Editor R-E

MARCH

LARRY STECKLER, EHF/CET, Editor-in-Chief

IF YOU MAINTAIN, REPAIR OR UPgrade electronic equipment you should become a Certified Electronics Technician (CET). Here's how you can become someone special.

On behalf of its more than 32,000 Certified Technicians, Ernie Curtis, CET, Chairman of the International Society of Certified Electronics Technicians, has declared Tuesday, March 10, 1992, "Electronics Technicians Day."

"The electronics technician," stated Curtis, "is responsible for keeping today's electronics-dependent society operating. Without this highly-skilled and specially-trained corps of electronics technicians, breakdowns in modern complex electronics would quickly bring our world to a sparking halt. Our intention," Curtis continues, "is to focus international recognition on the high standards of performance and excellence maintained by professional electronics technicians."

Over 100 ISCET Certification Test Administrators have volunteered to give tests during the week of March 8 through 14, 1992 to honor Electronics Technicians Day. The complete list of all of these test sites is published in the pages that follow this article. In 1991, the 30,000th CET, Robert Bruce Bottoms, CET was an ISCET member who used T-Day 1991 to upgrade from Associate to Journeyman. Bottoms, an employee of United Parcel Service, attended the 1991 ISCET convention in Reno, Nevada, and addressed an enthusiastic audience about his desire to represent a new generation of CET's.

AT THE ISCET CONVENTION, the current ISCET chairman, Ernie Curtis, CET (left) accepts the gavel from outgoing chairman, Leonard Bowdre, CET.

What is ISCET?

As the proud electronics technicians division of the National Electronics Sales & Service Dealers Association (NESDA), ISCET was founded in 1970 by a committee of Certified Electronics Technicians, whose main purpose was to foster respect and admiration for their profession. By maintaining rigorous standards in its certification program, ISCET is able to separate the highly skilled and knowledgeable technicians from those with less experience. ISCET's main functions include direction and administration of the CET program, the national apprentice and training program, the technical information training and upgrading programs, and the serviceability programs.

The CET program was designed to measure the degree of theoretical knowledge and technical proficiency of practicing technicians. A technician with a CET certificate is thought of in the industry as one who possesses the training and expertise necessary to perform his job with professional competence. Since its inception, the CET program has continued to gain acceptance by technicians, manufacturers, and consumers. Many organizations encourage, and often require, their technical employees to be certified by ISCET.

Technician skills

Just keeping up with the changes that seem to occur daily in new equipment is a full-time task. To be able to service the latest electronics equipment with its new circuitry, new components, and new principles is a difficult challenge. Today's electronics technicians must constantly learn, constantly aquire new theoretical and practical skills, and constantly develop new techniques. They must become familiar with new

10: ELECTRONICS TECHNICIANS DAY

kinds of test equipment and new servicing techniques to repair the latest electronics engineering marvels.

Perhaps this was best summed up by Leonard Bowdre, CET, ISCET's Immediate Past Chairman, when he said, "I marvel at the exponential changes in electronics since my introduction to it in 1946. The new techniques, devices, and technology that have appeared in the last two years alone are mind-boggling. With what today's technicans must know, I think they must be the most qualified, most underpaid, and the least recognized in the world's work force."

The CET exam

To become certified by ISCET, the electronics technician must pass both a 75-question Associate-level CET test, and a 75-question Journeyman-level test. To pass, the candidate must score a grade of 75% or better. An electronics technician or student with less than four years of experience may apply for the Associate-level exam only, which covers the following subjects:

- Basic Mathematics
- DC Circuits
- AC Circuits
- Transistors and Semiconductors
- Electronic Components
- Instruments
- Tests and Measurements
- Troubleshooting and Network Analysis

A fully certified technician must have four or more years of education or experience in electronics and must pass, in addition to the Associate-level test, one or more of the Journeyman options available in specialized fields of electronics. The Journeyman options that are available are:

- Consumer—Subjects covered include antennas and transmission lines, digital and linear circuits in consumer products, TV and VCR servicing problems, and the use of test equipment.
- Industrial—Subjects include transducers, switches, power factor, differential amplifiers, closed-loop feedback, basic logic circuits and functions, elements of numeric control, thyratrons, and SCR controls.
- Communications—This test covers two-way radio transceiver theory and servicing, receivers, transmitters, basic communications theory, deviation sensitivity, quieting, and troubleshooting.
- FCC Legal—This is a 25-question optional exam covering FCC regulations. Applicants who take the associate exam, the Communication option, and the FCC Legal exams will receive a general radio-telephone license.
- Computer—This test covers operation of computer systems with basic emphasis on hardware. Subjects covered include basic arithmetic and logic operations, computer organization, input and output equipment, and memory and storage. Some knowledge of software and programming is required, and the ability to explain troubleshooting procedure is also required.
- Audio—Products covered in this option include turntables, tape decks, compact discs, and

TRAINING NEVER STOPS for electronic technicians. Here Ernie Curtis, CET and other ISCET Members learn about the latest developments in digital electronics.

radios. The exam consists of both digital and analog sections, amplifiers and sound quality, system set-up, speaker installation, and troubleshooting audio systems.

• Medical—The priorities of this option are electrical safety and accuracy of calibration for electromedical instruments. The technician must be familiar with the basic vocabulary of medical instrumentation, telemetry, measurements, and differential and operational amplifier applications.

• Radar—A general knowledge of both pulsed and continuous-wave radar is necessary to take this Journeyman option. The test covers transmitters and receivers, CRT display systems and their power supplies, and antennas, transmission lines and their characteristics.

• Video—The rapidly growing field of video is covered by this exam. The technician needs to know NTSC standards, video basics, test signals, and the operation of both the electronic and mechanical systems in VCR's. Also covered are 8mm video, camcorders, cameras and monitors, and the microprocessors used in video products

Fees and difficulty

The fee for the CET exam is $25.00, which includes both the Associate exam and any one Journeyman option, if taken in one sitting. If the Journeyman option is taken separately from the Associate exam, each test is $25.00. Each additional Journeyman option is $25.00. If you fail any portion, the first retake is free, after a 60-day waiting period. The fee for any additional retake is $12.50. If you choose to take the FCC Legal exam after you have successfully completed the Communications option, there is an additional fee of $10.00. Don't underestimate the difficulty of the CET exam. Every year only 30% of those who take a CET test pass—it is not an easy test!

The best way to prepare for this exam is to study diligently. Tab Books publishes *The CET Study Guide* by Sam Wilson, which will help you prepare for both tests. ISCET also has additional study guides available for a nominal fee.

If after reading this article you're interested in taking the CET exam and joining the growing ranks of Certified Electronics Technicians, contact any one of ISCET's volunteer test administrators listed in this article for details. The exams are scheduled to be given during the week of March 8 through 14, 1992. For any additional information you might need, contact ISCET at 2708 West Berry St., Fort Worth, TX 76109; phone 1-817-921-9101.

Join the professionals

You're already competent in electronics or you wouldn't be reading this magazine and this article. You need to gain the recognition you deserve. To do so, take the CET challenge and join 32,000 other electronics professionals. Become a CET. It's worth the effort and you deserve the recognition. R-E

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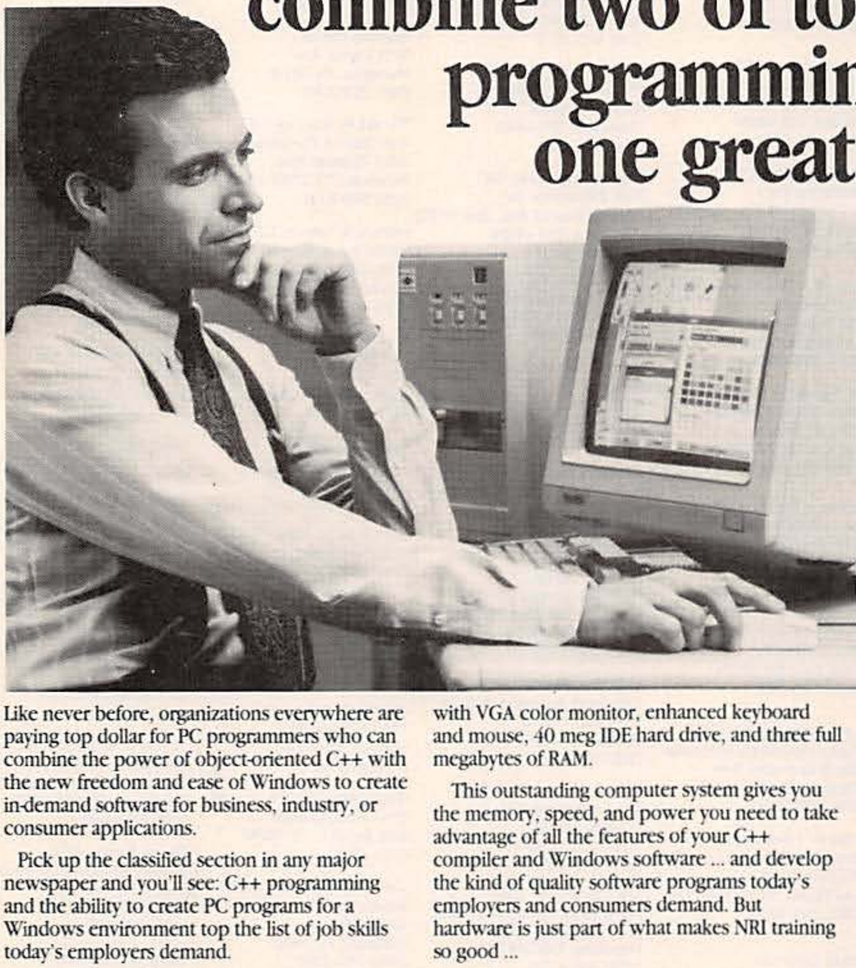

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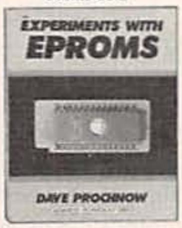

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Dallas Semiconductor Touch Memory Starter Kit

The electronic equivalent of the Post-It note.

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People were once naive enough to believe that computers and other office-automation equipment would bring about the "paperless office." We haven't heard anyone suggest such a thing for some time, but Dallas Semiconductor (4401 South Beltwood Parkway, Dallas, TX 75244) might have come up with a way to replace a good deal of paper with silicon chips. Their DS199x *Touch Memory* devices are non-volatile memory packaged in a button-shaped can. They can be read or written with a momentary contact. We recently had the opportunity to examine the devices and see how they work, using Dallas Semiconductor's *DS9092K Touch Memory Starter Kit*.

Touch Memory is available in two main configurations: One is ROM only, the other is a combination of ROM and battery-backed RAM. The ROM-only device would be used primarily for electronic identificaion. If attached to an employee ID badge, for example, it could be used to permit access to secure areas of a building. The ROM/RAM device could be used for a good deal more. In manufacturing, for instance a Touch Memory could be attached to the device being manufactured. It could contain proper calibration settings for the assembly technician to read. The technician could then in put the results of the calibration tests into the Touch Memory, along with his identification and a date stamp.

The potential applications aren't limited to electronics and manufacturing. Imagine if your checked airline baggage was identified by a small Touch Memory tag that not only contained your destination, but your name, address, flight itinerary, and the name of each baggage handler who handled your luggage—including the one who put your bags on the flight to Bogata instead of Boston.

The Touch Memory Starter Kit is a good way to get a feel for what Touch products can do. It includes five assorted Touch Memories, a Touch Memory probe (for reading and writing the devices) an adapter that lets you attach the probe to the serial port of a PC, and a floppy disk that contains the interface software.

Three of the five included Touch Memory devices are DS1990 "Touch Serial Numbers." They contain a 64-bit ROM into which is written an 8-bit family code, a 48-bit serial number, and an 8-bit CRC (cyclical redundancy check). One of the devices is mounted to a key fob, while the other two are mounted on a "peel and stick" sheet. Two DS1991 touch memories are also provided. They contain 3 384-bit blocks of non-volatile RAM and a 64-bit ROM.

The probe included with the evaluation kit is is strictly for evaluation—it's not packaged with any handle or base, and instead, hangs on the end of a pair of wires. The other end of the wire is terminated in a RJ-11 modular telephone jack. That, in turn, plugs into an adapter that converts the RJ-11 jack to a 25-pin D-type connector for a PC serial port, as well as converting the computer's RS-232 interface into a single, bi-directional data line.

The probe doesn't have to look good to get across its strong points, however. Most important, it's very forgiving of how it's positioned on the memory. One of the reasons the memory is packaged in a round "MicroCan" is becuase the curved edges can guide the probe for self-alignment. The one-wire data transfer is what helps to make Touch Memory rugged. The top of the can is the data connection, while the edge and bottom is ground. Data is transferred at speeds up to 16.6 kilobits per second, which seems instantaneous for small memories.

Even with fast data rates, it's likely that a momentary contact will be interrupted before a data tramsfer is complete. However, the Touch Memory uses two verification techniques to ensure data integrity. First, data is written to a scratchpad memory and verified before it is transferred to memory. If the connection is broken early, the scratchpad contents won't be transferred to the main memory, so the integrity of the previous memory is maintained. A CRC check is also performed on data.

The non-volatile memory will last for five or ten years—the life of the built-in lithium battery. The stainless-steel case is resistant to corrosion from moisture, acid, and plain old dirt.

From what we've seen of this self-stick data carrier, we think that we may be seeing fewer bar codes, and a bit less paper. If you'd like to get an idea of how they work, the Touch Memory Starter Kit is available for $75. **R-E**

NEW PRODUCTS

Use the Free Information Card for more details on these products.

HANDHELD DIGITIZING SCOPE. According to Tektronix, its *Model 224* 60-MHz handheld digital oscilloscope is the fastest in the industry. It allows electronic service technicians to troubleshoot high-speed TTL circuits with a battery-operated unit, avionics technicians to get the power of a digitizing scope in the cockpit, and military-maintenance personnel to perform accurate equipment servicing in remote land or under-sea operations. The *224's* TV triggering capabilities allow video repairmen to monitor and troubleshoot a wide range of imaging systems. The unit weighs just 4.4 pounds, and two rechargeable batteries provide three hours of reliable operation.

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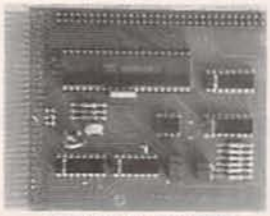
The *224's* dual-channel design allows input-to-output comparisons and its unique "Isolated Channel" architecture, in which each channel is isolated from the other channel and from earth ground, makes truly safe floating measurements (as opposed to other handhelds that claim safe floating measurements simply on the basis of their plastic cases). True floating measurements can be made up to 400 volts per channel or 800 volts peak-to-peak, without risk to the operator or to the device under test.

Like the other members of Tektronix's popular 222 family of portable digitizing oscilloscopes, the *224* features a clear, bright CRT display; ease of use; and PC compatibility. AutoSet and Autolevel Trigger allow effortless acquisition and display of signals. Up to four front-panel setups can be defined and stored in memory, then recalled at the touch of a button. Four waveforms can be stored as reference templates or for future analysis. The *224* is 100% programmable from the RS232C port. When linked by modem, the 224 can be controlled remotely from a PC equipped with Tek's Virtual Instrument Software (CAT200). The scope's controls can be manipulated at the keyboard or mouse, just as they would be handled manually on the instrument.

The *224* handheld digitizing scope costs $2750.—**Tektronix, Inc.**, Test & Measurement Group, P.O. Box 1520, Pittsfield, MA 01202; Phone: 1-800-426-2200.

DATA-ACQUISITION AND CONTROL SYSTEM FOR PC'S. Claimed to be the lowest-priced general-purpose data-acquisition and control system for personal computers, Prairie Digital's *Model 30* is available for XT's, AT's, 386's, and PS/2 model 30's. The system's printed-circuit board plugs into the PC's expansion bus and occupies a 1/4 slot. The unit includes



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24 lines of programmable digital input/output; an 8-channel, 8-bit A/D converter; and a 12-bit CMOS counter. (An 8-channel, 30-volt, 0.5-amp driver is available for an additional $5.) The system communicates with the PC via four I/O memory locations and is easily interfaced to all popular languages. Sample programs in BASIC, QuikBASIC, and Assembly language are included on a 5¼-inch floppy disk. The data-acquisition and control system can be used to control relays, lights, and motors; to measure temperature, pressure, and light levels; and to input switch positions, thermostats, and liquid levels.

The *Model 30* data-acquisition and control system costs $79.—**Prairie Digital, Inc.**, 846 Seventeenth Street, Prairie du Sac, WI 53578; Phone/Fax: 608-643-8599.

DIGITAL CLAMP-ON METER. The *ACD-11* autoranging, digital clamp-on meter will directly measure AC current, voltage, and resistance. Measurements are shown on a large, easy-to-read, ½-inch display. Overrange is indicated by the

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letters "O.L." appearing on the display. The instrument features circuit protection to 550 volts and a low-battery indicator. It has a maximum jaw opening of 2.14 inches. The *ACD-11* meter comes with a wrist strap, a removable belt clip, a 9V battery, safety test leads, a carrying case, and instructions.

The *ACD-11* clamp-on volt/amp/ohmmeter has a list price of $119.95.—**Amprobe Instruments**, 630 Merrick Road, P.O. Box 329, Lynbrook, NY 11563; Phone: 615-593-5600; Fax: 516-593-5682.

MONOLITHIC OP-AMP. With a unity gain bandwidth of 140 MHz, Analog Devices' *AD811* is the industry's fastest monolithic operational amplifier operating from a ±15V supply. Video specifications such as gain flatness, which ensures broadcast-quality signal transmission, and differential gain and phase, which

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are critical for video cameras, multimedia systems, and special-effects units, are optimized. The *AD811's* output is capable of driving two back-terminated 75-ohm cables, making the device well-suited as a line driver in video routers or distribution amplifiers. The *AD811* current feedback amplifier meets stringent HDTV video specifications, and offers the transient response characteristics needed for high-speed pulsed applications such as infrared imaging and digital oscilloscopes. When used as a buffer for analog-to-digital or digital-to-analog converters, the *AD811* offers low distortion and, as a result of the current feedback design, a wide bandwidth over a large range of gains. The amplifier operates from power supplies ranging from ±4.5V to ±18V, with a minimum output drive current of 100 mA. The video-speed op-amp is available specified over the industrial (−40°C to +85°C) and military (−55°C to +125°C) temperature ranges. Package options include an 8-pin plastic DIP, 16- and 20-pin SOIC, 8-pin Cerdip, or 20-pin LCC.

Specified over the industrial temperature range and packaged in an 8-pin plastic DIP, the *AD811* costs $3.35 in hundreds or $2.85 in thousands.—**Analog Devices**, Literature Center, 70 Shawmut Road, Canton, MA 02021; Fax: 617-821-4273 (for applications assistance, contact Jay Cormier, Analog Devices, Inc., 804 Woburn Street, Wilmington, MA 01887; Phone: 617-937-2507).

SMT PICK-AND-PLACE SYSTEM. Designed for prototyping or low-volume production of surface-mount boards, O.K. Industries' *SMT-880 Series Manual Pick and Place System* provides up to three times greater throughput with substantially improved accuracy over hand placement. The operator chooses a component from the loose-component carousel or the stick or tape feeders, picks

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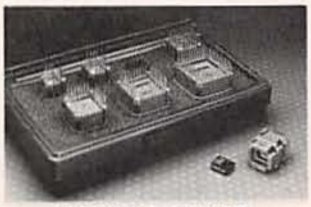
it up with the vacuum head, and then guides it with the free-floating X-Y-Z arm to the appropriate position on the board. A control knob on the vacuum head provides theta rotation to ensure proper component orientation. When the component is lowered, the vacuum head automatically releases it when contact with the board is made.

The *SMT-800* provides a total working area of 8×12 inches, with an adjustable board holder. The system comes complete with an ESD-safe carousel vacuum pump and a movable hand rest that glides over the board holder and provides the user with a stable, fatigue-relieving platform. For easy compatibility with larger automatic machines, optional tape and stick feeders mount on the vise. Other options include a lighted magnifier with four diopter lenses to assist in component alignment. The system is available for 115-volt or 230-volt operation.

Prices for the *SMT-800* pick-and-place system start at $3495.—**O.K. Industries**, 4 Executive Plaza, Yonkers, NY 10701; Phone: 914-969-6800.

PLCC QUAD CLIP KIT. The selection of test adapters included in ITT Pomona's *Model 5515A PLCC Quad Clip Kit* was specifically chosen to test the most popular surface-mounted plastic leaded chip carriers (PCC and PLCC) with "J" leads (JEDEC MO-047 and MO-052). The design of each test adapter incorporates a "snap ring" that allows the quad clip to fit directly onto an IC and provides simultaneous access to all the pins of the surface-mount device for hands-free testing. The wipe action of the snap-ring design, as it is pushed down with normal force into position against the contact, wedges against the IC for a tight fit and assures a good connection.



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The kit contains seven items: one each 20-, 28-, 32- (7×9, EEPROM), 44-, 52, 68-, and 84-pin Pomona Quad Clip test adapters. All the adapters have gold-plated center contacts, silver-plated bodies, and 0.064mm (0.025-inch) square pins staggered on 2.54mm (0.100-inch) centers. The kit is packaged in a durable, reusable plastic case.

The *5515A PLCC Quad Clip Kit* costs $245.—**ITT Pomona Electronics**, 1500 East Ninth Street, P.O. Box 2767, Pomona, CA 91769; Phone: 714-469-2900; Fax: 714-629-3317.

CONTROLLERS/INDICATORS. For start, stop, or limit control of a wide range of process variables, Simpson Electronics has introduced the *Hawk Series* of controllers/indicators that fit in a ⅛ DIN cutout. The series offers high accuracy and ease of installation in electrical, chemical, petrochemical, and other process industries. The controllers accept AC and DC voltage and current, 4–20-mA DC, 1–5V DC resistance, 3-wire potentiometer, frequency, and tachometer (RPM) inputs. RTD inputs may be two-, three-, or four-wire configuration. The Hawk models also accept several thermocouple types, including J, K, R, and S, which input without calibration or internal hardware changes. The compact units are AC or DC powered and are housed in impact-resistant, flame-retardant, plastic cases. Their front-panel keypads are used to program, set, or check the operating parameters of hysteresis, time delay, and set point, as well as alarm levels and relay settings. A user password prevents unauthorized program access. Each instrument also features a highly visible, 0.51-inch, red LED display; plug-in circuit boards for user-selected functions; dual set point with optional

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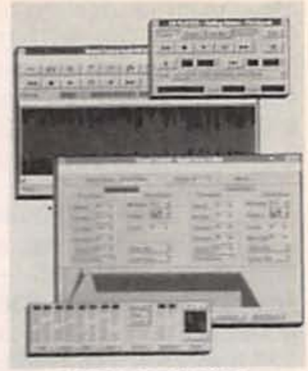
dual relays; a fast, easy, input terminal block that can be unplugged; and an edge-type connector for analog and digital output options.

The *Hawk Series* of controllers/indicators are priced starting at $199.—**Simpson Electric Company**, 833 Dundee Avenue, Elgin, IL 60120-3090; Phone: 708-697-2260; Fax: 708-697-2272.

PC AUDIO CONTROL SOFTWARE. Voyetra's *Sound Central*, a software utility for Windows 3.0, provides a convenient way to control



CIRCLE 23 ON FREE INFORMATION CARD

every aspect of sound generated by PC sound cards or Multimedia PC's (MPC). Its graphical audio editor can be used to audition and edit digital waveforms in the VOC or .WAV format and modify them with such special effects as echo, data compression, bit resolution, and sample-rate conversion. A MIDI songfile editor provides control over major parameters in a MIDI song file so that the music generated by the file can be manipulated—for instance, re-orchestrated, lengthened, or shortened. The full-featured CD "control panel" provides a convenient way to sort, view, and play CD audio tracks. A mixer control panel provides access to all of the MPC's mixer functions including input/output control levels and line/mic monitor settings. Also included are a MIDI file mapper and a "patch editor" for the MPC's FM synthesizer.

Sound Central audio control software has a suggested retail price of $199.95.—**Voyetra Technologies**, 333 Fifth Avenue, Pelham, NY 10803; Phone: 1-800-233-9377 or 914-738-4500; Fax: 914-738-6946.

OSCILLOSCOPE PROBE SWITCH. Providing a simple way to observe and compare waveforms at different points in a circuit, Microvolt

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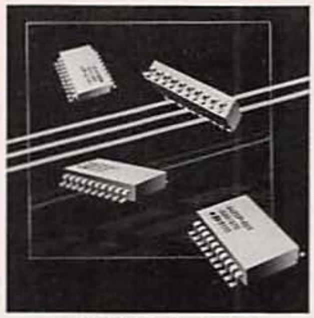
Engineering's *MV103* oscilloscope probe switch accepts two scope probes and attaches to the oscilloscope input. The accessory allows the user to easily select either of the two probes with the flip of a switch. With the *MV103*, a dual-channel scope can accept four separate inputs without performance degradation. High-frequency relay technology provides high isolation and low insertion loss. Compact all-metal design provides excellent shielding and allows the *MV103* to be installed directly on the input BNC connector of the oscilloscope. The switch can also be used as a stand-alone, general-purpose RF switch.

The *MV103* oscilloscope probe switch costs $275.00—**Microvolt Engineering**, P.O. Box 777, Tustin, CA 92680; Phone: 714-544-3441.

EMI/RFI FILTERS. When controlling electromagnetic and radio frequency interference to the environment and complying with FCC regulations on maximum level emissions are concerns, the *601 Series* of surface-mount resistor-capacitor networks from Bourns provide a simple



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solution. Shielding is required between the RS232 connector and the input/output drivers in electronic equipment. The *601 Series* of low-pass filters prevent the transmission of high-frequency noise components and are especially effective on lines to external connectors. Featuring a T-configuration of 16 resistors in series and 8 capacitors bused to a common ground, the surface-mounted RC networks can suppress high-frequency EMI/RFI noise for up to eight separate lines. Smaller than inductive-type filters, the devices are packaged in wide-body SO cases. Typical applications for the filters are in personal computers, data terminals, test equipment, and process controllers for high-frequency suppression into or out of electronic equipment.

Prices for the *601 Series* of surface-mount EMI/RFI filters begin at $2.15 each in quantities of 10,000 pieces.—**Bourns Networks, Inc.**, 1400 North 1000 West, Logan, UT 84321; Phone: 801-750-7200. **R-E**

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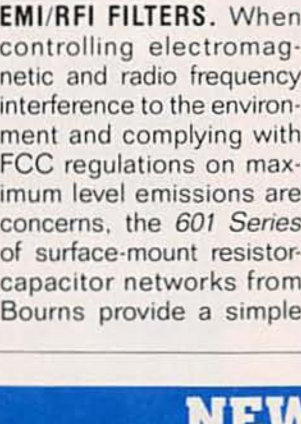
Use The Free Information Card for fast response.

HOW TO GET ANYTHING ON ANYBODY: BOOK II; by Lee Lapin. ISECO, Inc., 2228 South El Camino Real #349; San Mateo, CA 94403; Phone: 415-513-5549; Fax: 415-578-8741; $38.00 postpaid (plus 8% sales tax on California orders).

If the words "espionage" and "spying" bring to mind James Bond (or Maxwell Smart), you're living a couple of decades in the past. These days, just about everyone can snoop (or be snooped upon), thanks to the huge assortment of personal surveillance devices now available. Subtitled "The Encyclopedia of Personal Surveillance," this book provides a guided tour of audio surveillance, including unconventional bugs,



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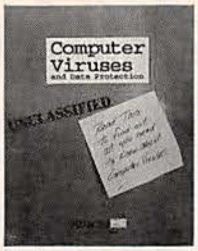
parallel and serial taps, carrier-current bugs, and IR and encrypted transmitters; acoustic analysis and hardwiring, including how to purchase and how to plant super-sensitive subminiature microphones; video surveillance using special cameras and trick lenses hidden in everyday items, inexpensive wireless systems, and using TV's as surveillance devices; and cellular telephone operations and intercepts. The book also explains how to tail someone, how to obtain confidential phone-company records, how to see and hear through walls, how to use infrared devices for night vision, and how to tap into a phone with no equipment. It describes the art of surveillance photography, and shows how to put together a complete dossier on anybody. Also included are legal guidelines and the addresses of more than 200 suppliers of surveillance and counter-surveillance gear.

COMPUTER VIRUSES AND DATA PROTECTION; by Ralf Burger. Abacus, 5370 52nd Street SE, Grand Rapids, MI 74512; Phone: 616-698-0330; Fax: 616-698-0325; $19.95.

Computer viruses—programs with the potential to destroy data and disable computer systems—can be quite costly in terms of lost time, data, and money. The best protection against such viruses is education—learning what steps to take to minimize or avoid losses. Intended as a general guide rather than a reference work, this book aims to teach readers about all kinds of computer viruses to allow them to protect themselves. Beginning with a short history of viruses and a description of



CIRCLE 39 ON FREE INFORMATION CARD

how a virus can gain control over a computer, the book explains how viruses are created and how to remove them from a system. It explores the design and function of viral programs, and includes sample program listings in BASIC, Pascal, and machine language as well as examples of viral software manipulation. The book outlines the protection options available, and provides practical advice about what to do when your PC is infected. Along with examples of protection viruses and strategies, a simple virus-detection program in provided. In addition, the book explains how to design virus-proof operating systems.

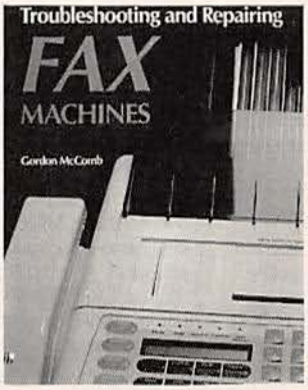
HOME REMOTE-CONTROL & AUTOMATION PROJECTS (SECOND EDITION); by Delton T. Horn. TAB Books, Division of McGraw-Hill Inc., Blue Ridge Summit, PA 17294-0850; Phone: 1-800-822-8138; $18.95.

Besides being practical and educational, the projects described in this book are sure to impress your friends and family. Remote-control and automation projects can also save you both time and money, by letting electronics do the job for you. Although the emphasis is on the practical—in the form of 77 different projects—the book does provide background information on the basics of remote control, mechanical devices, motors, sensors, digitally-controlled potentiometer IC's, and building and safety procedures. The projects themselves fall into 11 categories: lighting, doors and windows, temperature control, liquid control, audio and video, telephone, motor control, electronic switching, timers, wireless control, and computer control. The second edition presents 15 all-new projects and updates and improvements of the original projects. Each project is accompanied by a circuit drawing and a parts list, and most are fairly simple to build. Most of them can also be adapted in various ways to meet other, custom applications.

CIRCLE 38 ON FREE INFORMATION CARD

TROUBLESHOOTING AND REPAIRING FAX MACHINES; by Gordon McComb. TAB Books, Division of McGraw-Hill Inc., Blue Ridge Summit, PA 17294-0850; Tel. 1-800-822-8138; $16.95.

It stands to reason that as soon as an electronic device becomes a necessity in our homes or offices, the need arises for people who know how to maintain and repair that device. This book was written to provide that know-how to the non-technical fax owner. By following its instructions, and using a few inexpensive tools, consumers should be able to keep their fax machines in proper working order—and to recognize a major problem that must be handled by a professional repair person. Aimed at non-technical folks, the book provides plenty of background information about how fax machines work. Most of the book is devoted to the troubleshooting and repair of mechanical problems, which account for about 85% of fax breakdowns. Full coverage of the major electronic subsystems—power supplies, solenoid controls, etc.—is also provided. Because most problems that occur with fax machines involve such things as dirty switch contacts or printing elements, broken wires, aging rubber belts and rollers, and damaged paper, preventative maintenance is emphasized. Simple illustrated instructions show how to clean and lubricate the paper path, light-sensitive reader bar, thermal printing mechanism, paper cutter, fluorescent lamp, and front-panel controls. The book also explains how to diagnose and fix bad phone connections and printing and transmission errors. Emergency first-aid procedures in case of fire or water damage are detailed. An entire chapter is devoted to troubleshooting flowcharts illustrating the proper steps to follow to locate and solve problems.



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MS-DOS 5 QUICK REFERENCE; by Timothy S. Stanley. Que, 11711 North College Avenue, Suite 140, Carmel, IN 46032; Tel: 1-317-573-2500; $9.95.

This slim volume puts the essentials of MS-DOS 5 at your fingertips, providing an instant reference to critical commands and procedures, batch files, the DOS Editor, and error messages. Short on documentation, but full of practical pointers, the book is intended as a supplement to a full-size MS-DOS guide. It explains the proper use of primary DOS functions, as well as advice on how to avoid making serious errors.

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In a compact, easy-to-use format, the book explains the proper DOS commands to use for specific operations. The book is arranged alphabetically by command. Each command name is accompanied by an explanation of its purpose, followed by the syntax needed to invoke the command and the rules for its use. Examples are provided for some of the commands. Separate sections provide in-depth coverage of batch files, the DOS Editor, MS-DOS messages, and error messages. A "DOS Survival Guide" lists specific procedures and the commands needed to invoke them. **R-E**

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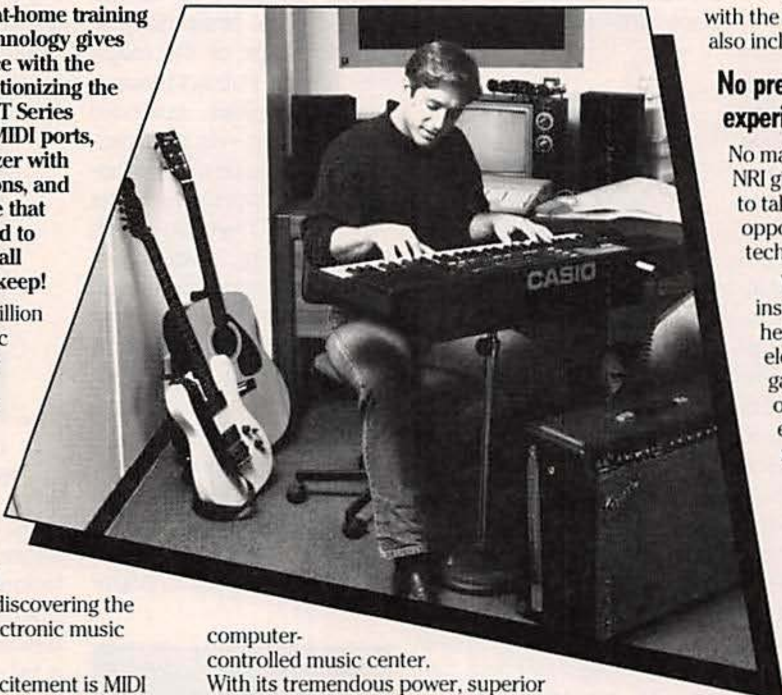

This year, over $1.5 billion worth of digital electronic music instruments, from keyboards to drum machines, will be sold in the U.S. alone. Enthusiasts everywhere—professional musicians and recording technicians, even people who have never touched a musical instrument before—are discovering the excitement of today's electronic music technology.

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3-032

BUILD THIS MIDI INTERFACE FOR YOUR PC

Bring the world of music to your PC with this versatile and inexpensive MIDI interface.

JOHN SIMONTON

AFTER A LONG-TERM FLIRTATION, the marriage of computers and musical instruments has been consummated, thanks to MIDI, the Musical Instrument Digital Interface. The fruits of this union are sequencer programs with the look and feel of a multi-track recording studio. Using those and other PC-based tools, a single musician in a back bedroom can produce recordings that only a few years ago required orchestras and an office staff.

Professional musicians aren't the only ones to benefit—you can too. Instruments with MIDI interfaces are so common that even your local discount store probably has several to choose from. The only thing standing between you and the artistic gratification of writing and performing like the philharmonic is the interface from your PC to the MIDI world, so lets take care of that little detail right now. We'll show you how to build a MIDI interface that is both low-cost for the beginner and upgradable for the serious user. With little further delay we begin, but first...

A little history

The MIDI specification, which was written with low-cost hardware in mind, allows us to use an HD6850P Universal Asynchronous Receiver Transmitter (UART) chip. The 6850 is older than the hills, readily available, inexpensive, and easily produces the 31.25 kilobaud signal that is required for MIDI. The basis of our MIDI interface is that UART assigned to one of the PC's output ports. For more information on MIDI, see **Radio-Electronics**, August 1989.

The most frequent MIDI commands are NOTE ON and NOTE OFF as keys are pressed and released. Those messages happen relatively infrequently; even when a chord is played, there is generally a slight delay between the individual notes. But the protocol also has provisions for continuous controllers such as pitch wheels and foot pedals, and the messages that signal that kind of activity can really spew out data. With nothing more than a UART for an interface, the original IBM PC, with its 4.77-MHz 8088 MPU and 8 bit bus, is just slightly too slow to handle MIDI at the maximum rate possible. It's not so much of a problem for the avocational user, but in a professional environment with lots of equipment, there is the possibility that data can be lost. Losing a little pitch wheel information isn't usually the end of the world, but if a NOTE ON or NOTE OFF command comes in the middle of it, missing that data is a very big deal.

The first widely accepted MIDI interface to overcome that problem was the MPU-401 made by Roland. It has its own dedicated processor and memory, and gets around the lost-data problem by maintaining a first-in-first-out (FIFO) buffer for the MIDI data

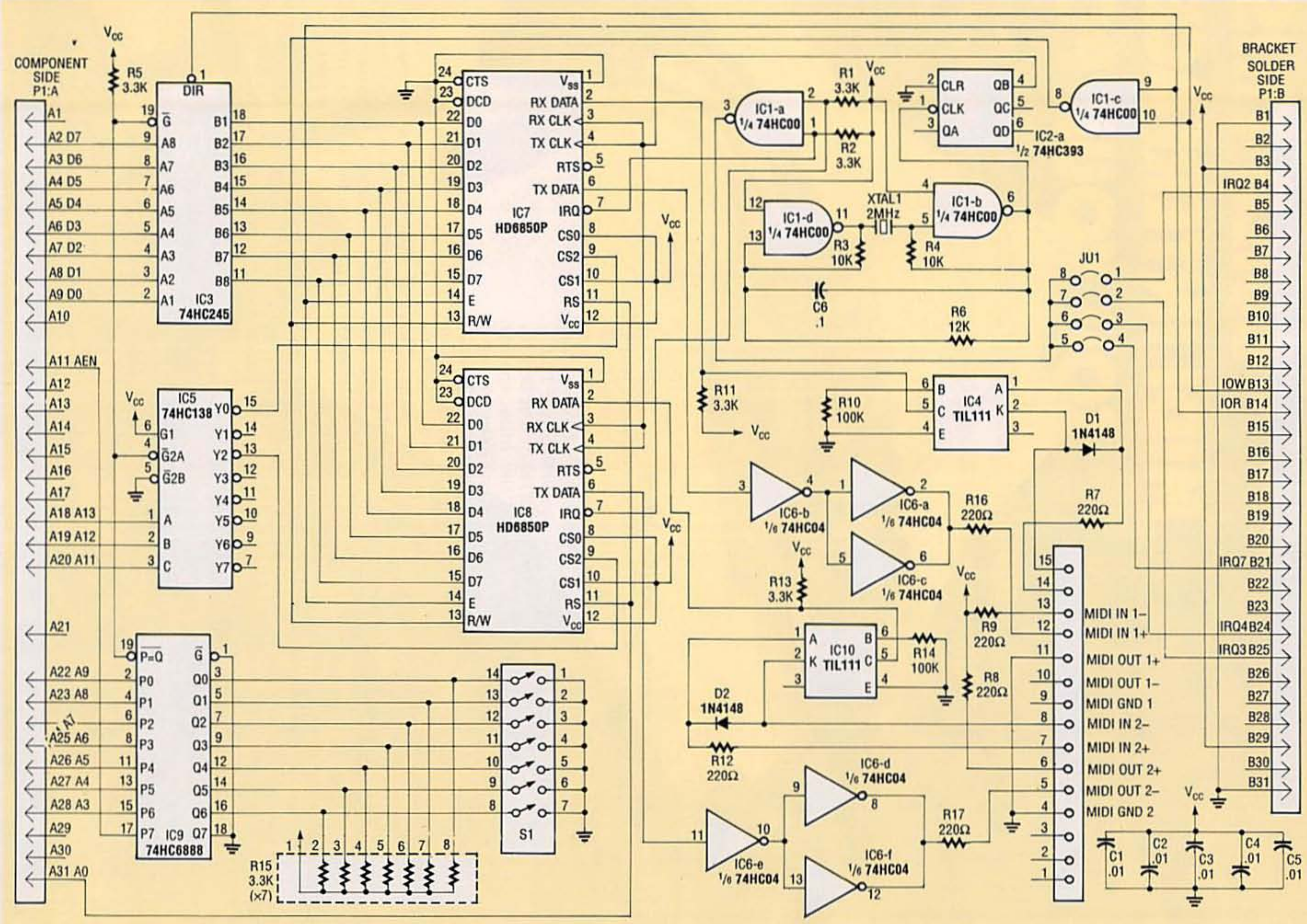


FIG. 1—TWO 6850 UART's are the heart of our MIDI interface. The circuit can be built in either a single-port version for the beginner or dual-port for the more experienced.

received. It also does some tricks such as data filtering and providing a metronome.

All well and good, but the introduction of the first XT-class PC made an intelligent interface unnecessary because the computer alone was fast enough to handle the throughput. As faster and more powerful PC's have become available, the need for an intelligent interface has decreased until finally the MPU-401 has technically become a bottle-neck in the system (though you would never notice that the interface is slowing things down).

What *has* turned out to be a noticeable problem to serious users is the bandwidth limitation of the MIDI channel itself. The solution to that problem has been multiple, separate In and Out jacks, equivalent to multiple interface cards. And here the MPU-401 runs into serious problems. Synchronizing multiple 401's is not trivial—and worse than that, each has to have its own slot and dedicated interrupt. Interrupts and slots, is there anything more precious in the PC world? You can switch MPU-401's into a "dumb" mode so that several of them share an interrupt. But then you have expensive UART's and serious slot depletion.

So, having faster computers and the need for lower-cost multi-port interfaces has started a resurgence of interest in UART's, and all software publishers support them. De-facto standards being what they are, the MPU-401 "standard" continues to hang on. But meanwhile, really hip "power users" are stepping back in time to just the sort of card that we'll come up with here.

PARTS LIST

All resistors are ⅛-watt, 5%, unless otherwise noted.
R1, R2, R5, R11, R13*—3300 ohms
R3, R4—10,000 ohms
R6—12,000 ohms
R7, R8*, R9, R12*, R16, R17*—220 ohms
R10, R14*—100,000 ohms
R15—3300 ohms × 7, 8-pin SIP
Capacitors
C1–C5—0.01 µF, Mylar
C6—0.1 µF, Mylar
Semiconductors
IC1—74HC00 quad NAND gate
IC2—74HC393 dual 4-bit binary counter
IC3—74HC245 octal transceiver
IC4, IC10*—TIL111 opto-coupler
IC5—74HC138 3-to-8 line decoder
IC6—74HC04 hex inverter
IC7, IC8*—6850 UART
IC9—74HC688 8-bit magnitude comparator
D1, D2*—1N4148 silicon diode
Other components
J1, J2, J3*, J4*—inline 5-pin female DIN connector
JU1—8-pin IDC header w/jumper blocks
S1—7-position DIP switch
XTAL1—2 MHz crystal
Note: Components marked with a "*" are optional for a second MIDI in/out.
Miscellaneous: Printed circuit board, hold-down bracket, wire, solder, etc.
Note: The following are available from PAIA Electronics, Inc., 3200 Teakwood Ln., Edmond, OK 73013 (405) 340-6300:
• PCM68pc double-sided, plated thru, PC board and bracket—$24.95
• PCM68k kit of all parts needed to build the single-port interface, including PC board, bracket, wire, MIDI jacks, etc.—$49.95
• PCM68ex expander parts for adding second MIDI port—$14.95
• MIDIpac MIDI starter set consisting of PCM68k interface kit and Voyetra SPJr. 64-track polyphonic sequencer software for PC/clones—$99.00
Add $3.00 P&H per order.

Design analysis

The 6850 UART's, which are the heart of our MIDI interface, are shown as IC7 and, optionally, IC8 in the schematic Fig. 1. The circuit can be built in either a single-port version for the beginner or dual-port version for the more demanding user. Much of the rest of the circuitry is concerned with decoding addresses and managing control lines on the PC's slot.

The lowest-order address line (A0) directly drives the RS (REGISTER SELECT) pins (pin 11) of the UART's to allow selection of either Status/Control or Data registers internal to the chip. We'll look at what those registers do when we test the interface. The next two address lines (A1 and A2) are not used, so each chip occupies 8 bytes of space consisting of four 2-byte chunks which overlay one another.

The next seven address lines (A3–A9) are routed to one set of inputs on IC9, a 74HC688 8-bit magnitude comparator. The other "side" of IC9 connects to DIP switch S1 and seven pull-up resistors in SIP-network R15. When the pattern of bits from the address bus matches the pattern of bits set by S1, pin 19 is pulled low. Notice that the 8th input to IC9 (Q7, pin 18) is grounded on one side and connects to the slot's AEN on the other (P7, pin 17). An address match will be valid only when AEN (ADDRESS ENABLE) is low, indicating that it's not the DMA controller that has the bus.

An address match does two things. It strobes IC3, a 74HC245 transceiver, which routes data either from the slot to the card or from the card to the slot depending on the direction selected by the $\overline{\text{IOR}}$ (I/O READ) line (which connects to the DIR pin (pin 1) of the chip). It also enables IC5, a 74HC138 3-to-8 line decoder which does the final address decoding for UART selection. UART IC7 is selected when A11–A13 match the pattern 0h, and IC8 is selected when the pattern is 2h. $\overline{\text{IOW}}$ (I/O WRITE) ties to the R/W pins of the UART's to select either a read or write to the chips.

The $\overline{\text{IRQ}}$ (INTERRUPT REQUEST) output pins of the two UART's are pulled up by R1 and R2 and combined by NAND gate IC1-c so that an interrupt request by either of them shows up on a line which can be routed to IRQ2, IRQ3, IRQ4, or IRQ7 depending on the placement of jumper JU1. Subsequently, the software will poll the two UART's to determine which of them generated the interrupt.

A 500-kHz transmit and receive clock starts out with the oscillator formed by the two NAND gates IC1-b and IC1-d. The frequency of the oscillator is set to 2 MHz by crystal XTAL1 which is then divided by 4 in one section of the 74HC393 dual 4-bit binary counter IC2.

Two TIL111 opto-couplers (IC4 and IC10) are used on the MIDI inputs to prevent grounds though the path. A continuous ground on the MIDI inputs would likely duplicate a similar ground at the audio inputs and outputs, leading to circulating ground currents and noisy audio. The TIL111's are not the fastest opto's in the world, but are more than fast enough for this application and less expensive than their faster brothers. On the MIDI outputs, two inverter stages from IC6 are paralleled to increase drive current capabilities.

Assembly

Because things run fairly slowly on slot I/O operations of even the fastest PC, there are no extraordinarily high frequencies involved on the PCM68. That means that prototyping boards and wire-wrap can be used to put together a card if you like. Be careful, though: 0.8-inch spacing between slots in a PC doesn't leave a lot of room for wire-wrap pins. And a misplaced conductor can cause a lot of damage in no time at all. It should go without saying that the shortest possible wires should be used to get a signal from the card edge to the IC it connects to.

Of course it's always best to use a PC board for any project, and you can either make your own from the foil patterns we've provided, or purchase a ready-made board from the source mentioned in the parts list.

A parts-placement diagram is shown in Fig. 2. IC sockets can be used, but certainly are not necessary. Note that if you've elected to put together the single MIDI in/out configuration, you can leave out the following parts: IC8, IC10, D2, R8, R12–R14, and R17.

Since PC-slot access holes weren't designed with MIDI in mind, they typically aren't wide enough for DIN connectors to peek through. Current practice

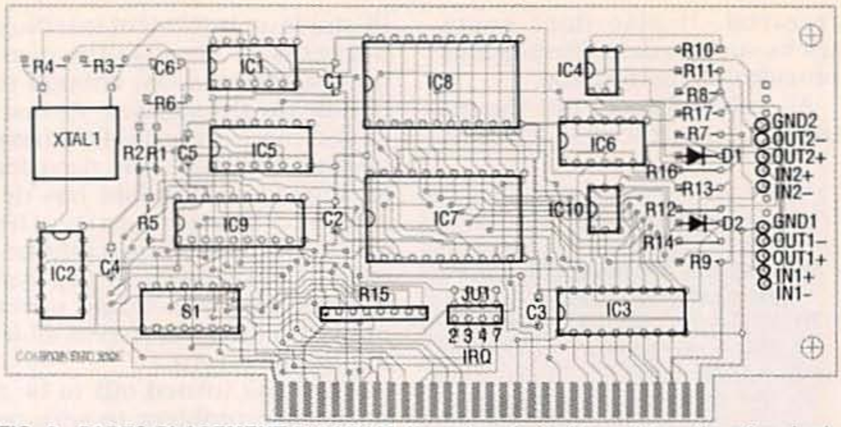


FIG. 2—PARTS-PLACEMENT DIAGRAM. If you've elected to put together the single MIDI in/out configuration, you can leave out IC8, IC10, D2, R8, R12–R14, and R17.

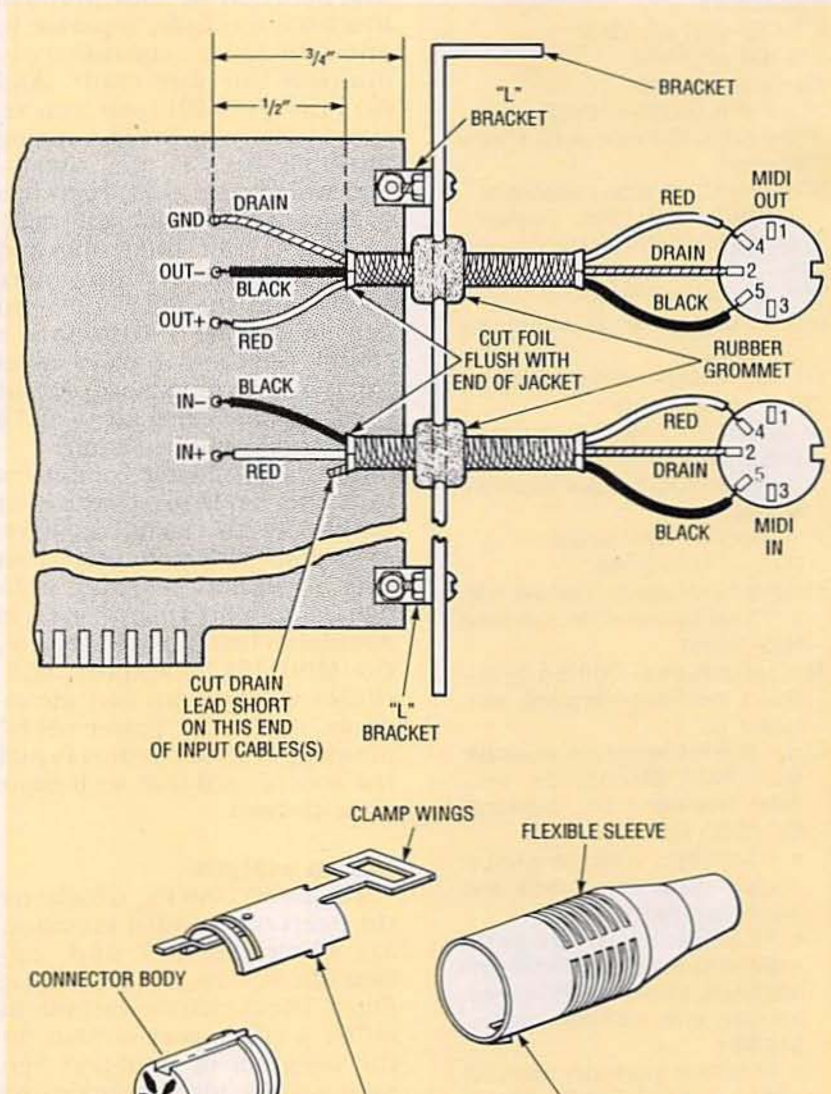


FIG. 3—PC-SLOT ACCESS HOLES aren't wide enough for DIN connectors, so we hang in-line female connectors out on pig-tails. Labeling the connectors will make it easier to tell them apart.

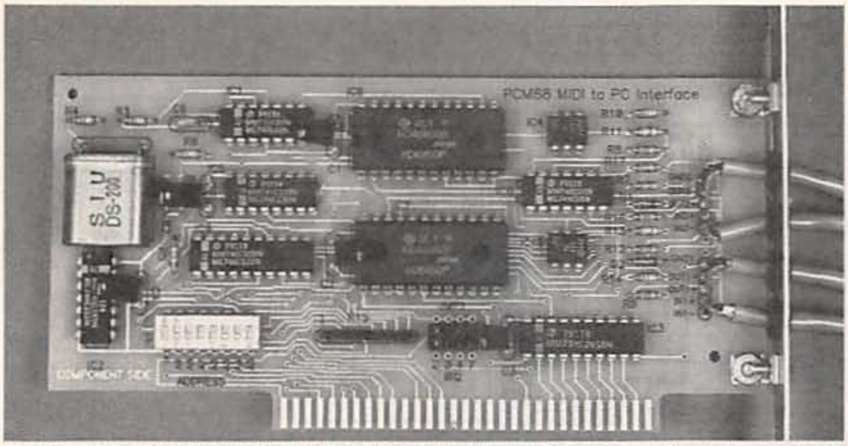


FIG. 4—THE COMPLETED PROTOTYPE CARD. The MIDI jacks are wired directly to the circuit board using shielded twisted pair.

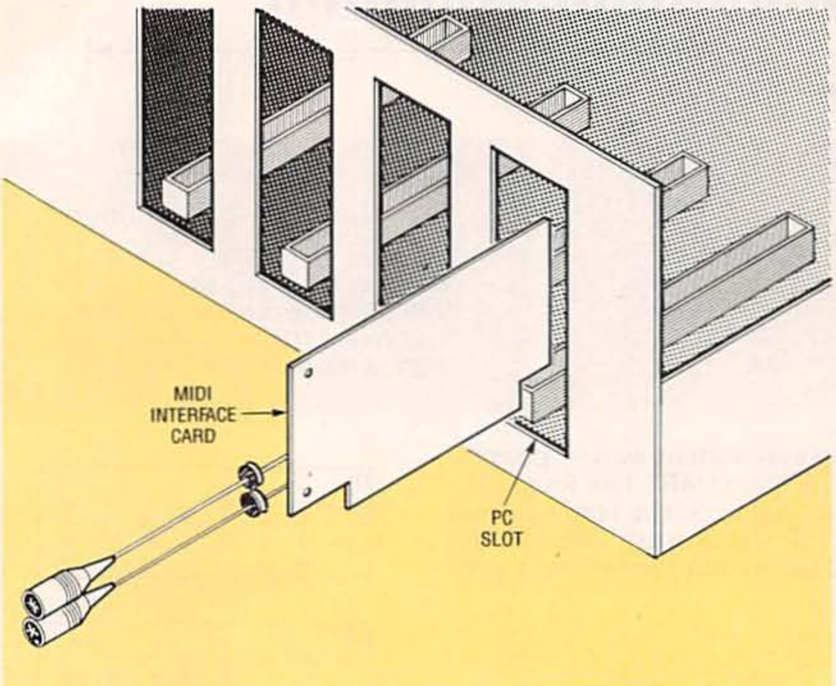


FIG.5—THE CARD FITS through the computer's rear slot.

on many interfaces is simply to hang in-line female connectors out on pig-tails and that's what we'll do here. The circuit board end of those connections can be soldered directly to the circuit board. Use 6-inch lengths of shielded, twisted pair; see Fig. 3. Note that while the shield's drain wire (the wire that connects to the shield itself) is soldered to pin 2 of all the DIN connectors, it connects to the circuit board ground only on the MIDI outputs. Be sure to slide a ¼-inch rubber grommet onto each wire as shown in Fig. 3 before soldering both ends of the wires. It's a good idea to label the connectors, as they are all identical and it will be hard to tell them apart once things are sealed up. Figure 4 shows the completed prototype card.

Installation

When it comes time to install the card in your PC, you'll notice right away that the DIN connectors won't fit through the hole in the back of the case. But by now you've probably also noticed that the interface is somewhat smaller than a usual card, and that's because the card itself is designed to fit through the rear of the PC (see Fig. 5).

A hold-down bracket for the PCM68, shown in Fig. 6, can be fabricated from any material that's handy; ours is bent from 0.040-inch aluminum. After the card is slipped through the access hole in the case, the bracket mounts to the card with two small "L" brackets, and the rubber grommets that you slid on the wires during assembly fit into the notches in the bracket. Finally, push the card down into the selected slot and secure the whole affair with the traditional screw at the top.

Address/interrupt selection

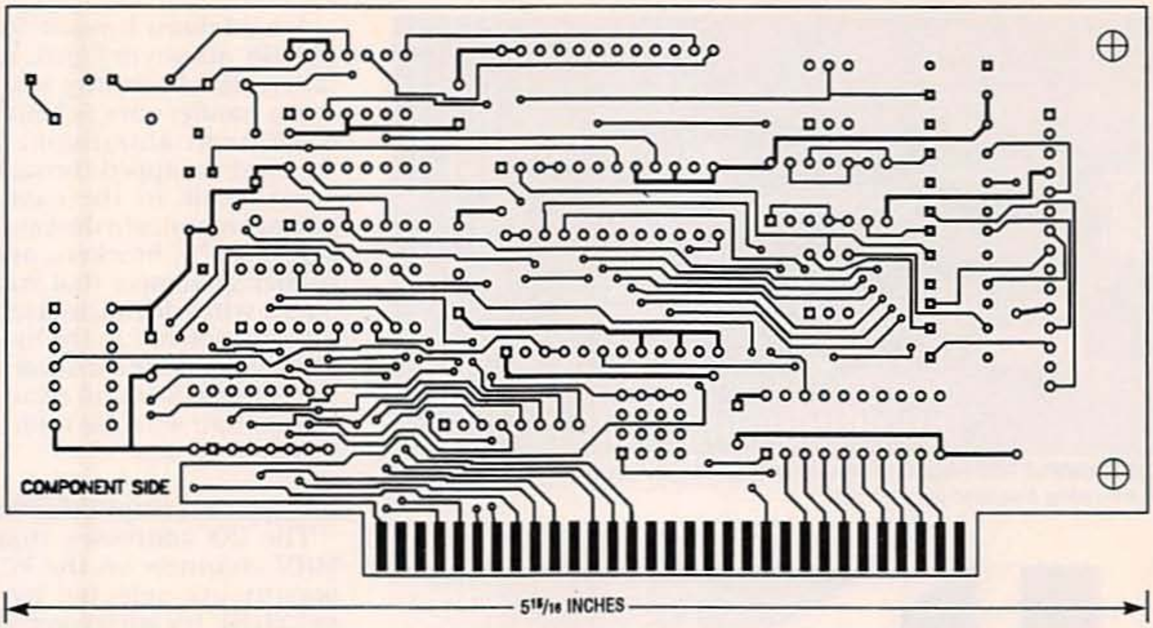
The I/O addresses that the MIDI channels on the PCM68 occupy are selected by DIP-switch S1. It's fairly common for software to default to an address of h330 for the first set of connectors, and Fig. 7 shows the setting of the switches for that situation. If it turns out that there is a conflict, the switches can be set to any address from h0–h3f8. Any software that you select will have some provisions outlined in the owner's manual for changing the port address.

If you've built the interface with two ports, the second pair of inputs and outputs will be at the base address set by S1 plus 1000h. If the first port is at 330h, the second port will be at 1330h.

For interrupts, IRQ2 is normal, and placing a jumper at that location on JU1 will set the card that way (see Fig. 8). If there's a conflict, the jumper can be set to send interrupts to IRQ4 (COM2), IRQ3 (COM1), and IRQ7 (LPT). That's about the order you should try them in if you have to search for one that's unused. Your software will probably default to IRQ2 (or possibly IRQ9 which is re-directed to IRQ2 in AT's) and will definitely have some provisions for changing the default if needed.

Testing

Your software will have a complete test of the interface, but we'll do some simple tests here that will give you a feel for what's going on and confirm that things are working properly. In-



COMPONENT SIDE of the MIDI interface card.

terface tests check to see that data sent from the output side appear at the input side, so the first step is to connect the input to the output with a MIDI jumper cable.

We'll use DOS's handy do-all tool, DEBUG, to directly control the UART and see that it can talk to itself—one of the few cases where that is an indication of sanity. After making sure that DEBUG exists somewhere in the path of your system, invoke it by simply typing "debug" at the DOS prompt. DEBUG responds with its own "-" prompt.

TABLE 1

>debug	
–o 330 03	This resets the UART
–o 330 15	/16, 8 data bits, 1 stop bit
–o 331 aa	Write hAA to the output data register
–i 331	Read the input data register
AA	Alright, a response! Now what?

A 6850 UART has four internal registers; two read-only and two write-only. When the UART's RS (A0) line is low, a write operation puts data into the Control Register which sets the chip's operating parameters and a read brings back the contents of a Status Register which is information on whether the transmit and receive registers

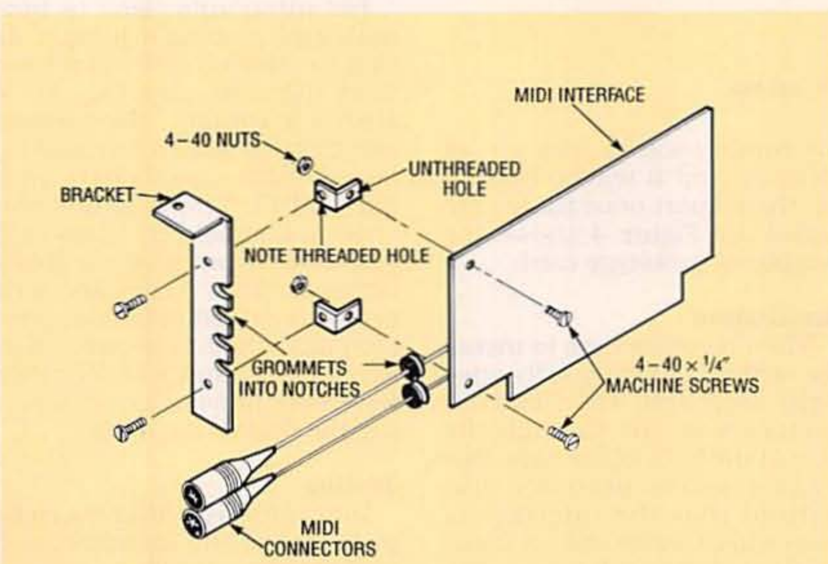


FIG. 6—A HOLD-DOWN BRACKET was fabricated from 0.040-inch aluminum. After the card is slipped through the access hole in the case, the bracket mounts to the card with two small "L" brackets.

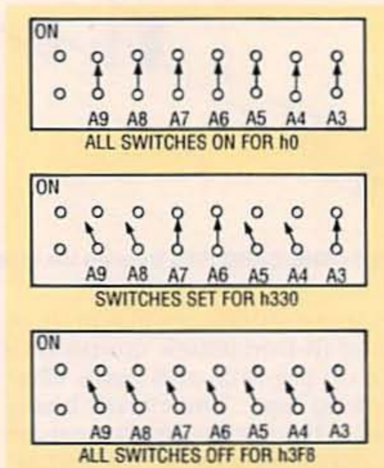
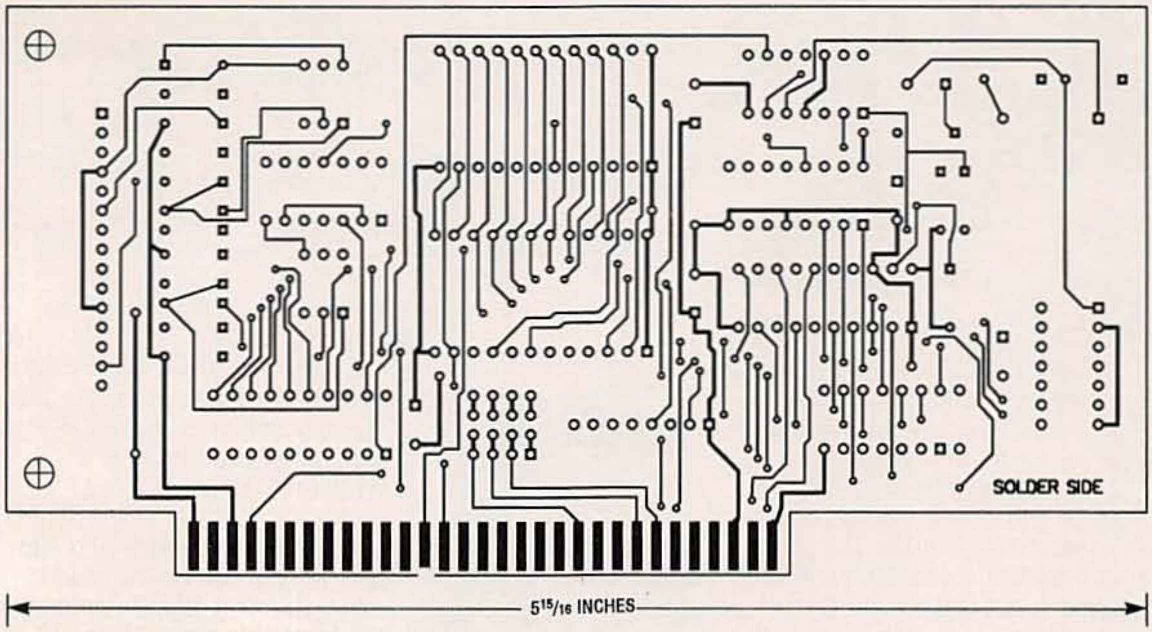


FIG. 7—THE I/O ADDRESSES that the MIDI channels on the PCM68 occupy are selected by DIP-switch S1. Setting the address DIP switches as shown here puts the interface on port h330.



SOLDER SIDE of the MIDI interface card.

are empty or full. One address higher up (RS high) are the Data Registers, and writing to that address sends data out on the serial output, while reading brings back anything which has been received from the serial input.

Unlike some interface chips, a 6850 has no hardware reset line. Instead, a "reset word" is written into the Control Register. The first part of our test will be to do that by entering "o 330 03" from the keyboard. To DEBUG that means to write (output) the datum 03h to the port at address 330h. "03" is the reset word and if you have set up the base address to be other than 330h you will want to change that part of your entry.

The next instruction will be "o 330 15," and that writes a byte to the Control Register, which sets the UART to a mode of 8 data bits and one stop bit and sets the internal frequency divider on the transmit and receive clocks to divide by 16.

Now we output a byte by typing "o 331 aa" which writes the datum hAA to the Data Register of the UART, which in turn sends the data out serially. To see that the data was received, the entry "i 331" reads (inputs) from port h331 and should cause the screen to display "AA." The test process is summarized in Table 1.

The pattern in Table 1 shows how you can write whatever data you like with "o 331 xx" and check to see that the data was received with "i 331." The second port, if you have one, can be checked by writing the reset and setup words to h1330 and writing and reading data to h1331.

Using the interface

After installing your software following its publisher's instructions and fully testing the interface using their tests,

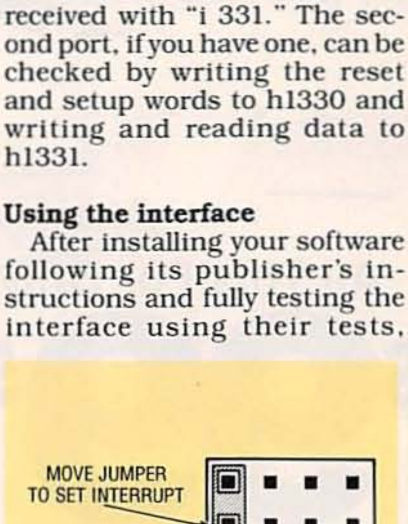


FIG.8—JU1 SETS THE INTERRUPT (see text).

you're ready to plug things together and start composing and recording. As you become more involved with MIDI, you'll realize that there are a lot of different ways to hook things up, depending on what you're going to be doing. But the simplest configuration for the beginner is simply to use MIDI patch cords to connect the MIDI output of your keyboard to the MIDI input of the PCM68 and vice versa.

The keyboard that you choose may have its own means of enabling MIDI, such as a slide switch which has a "MIDI" position or something similar. Of course that switch should be set appropriately. More professional instruments might have more exotic capabilities such as re-mapping the keyboard or other controllers onto different MIDI channels, but you'll learn about those things as you go along.

MIDI can be dealt with at a fairly low level for the beginner, yet it offers the capability of becoming as complex as you like. A good place to start learning is "All About MIDI" in the August 1989 issue of **Radio-Electronics**. And for a really well done treatment of MIDI (not only the technical details but also the user side of it), try reading *MIDI for Musicians* by Craig Anderton, published by Amsco Publications. **R-E**

SCANNER CONVERTER

We'll be converting those 800–1000 MHz signals down to 400–500 MHz in no time at all.

WILLIAM SHEETS and RUDOLF F. GRAF

WE ARE IN THE MIDDLE OF BUILDING our scanner converter—it's a device that allows the reception of signals from 800–1000 MHz on any scanner that covers frequencies in the 400–500 MHz range. Last month we discussed the scanner converter's circuitry. This month we are going to build the unit and get it working properly.

Construction

If you are going to make your own PC board from the foil patterns we've provided, you must use G-10 type PC material, 1/16-inch thick, with a dielectric constant of 4.8. There's nothing inherently special about the common material except that the printed inductors and filters were designed around it. If other PC-board material is used, the printed inductors and filters will not have the proper electrical characteristics. Because of the high frequencies involved, don't substitute components or change the layout. Also, when drilling the holes in the board, use the solder-side foil pattern as a drilling guide, and drill through any hole you see even if you don't see one on the component side. The parts layout is shown in Fig. 1. Note that a piece of wire must be inserted and soldered on both sides anywhere you see an "X" in Fig. 1.

The resistors should be installed while installing all jumpers, which are made from component-lead clippings. To ensure solid grounding, all components that have grounded leads, especially the trimmer capacitors, must be soldered top and bottom.

Coils L7, L8, and L9 are made from #22 enameled wire wound tightly on an 8-32 screw. See the parts list for coil-winding details. Coil L16, as shown in Fig. 2, is only a loop of wire and not at all critical, and L6 and L15 are simply ferrite beads placed over a length of wire, also shown in Fig. 2. Coil L14 is similar, although this time a ferrite bead is placed over one lead of R20, again as shown in Fig. 2. Coil

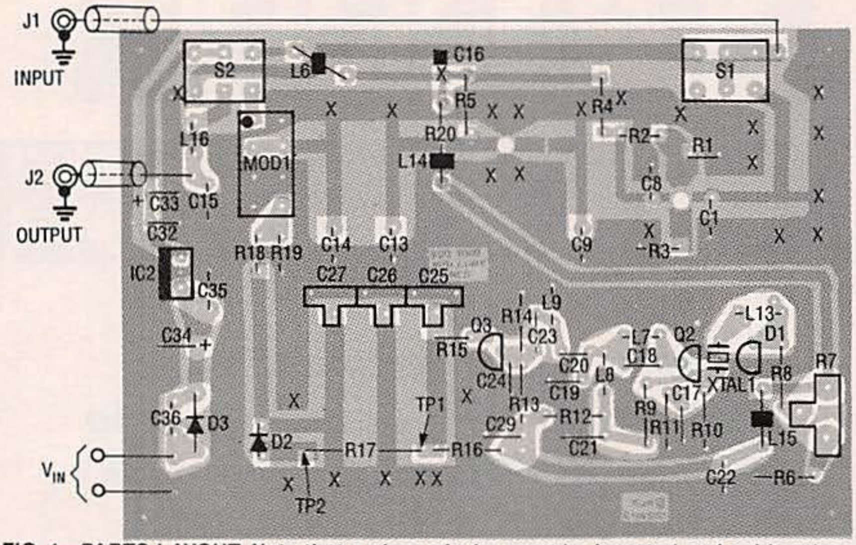


FIG. 1—PARTS LAYOUT. Note that a piece of wire must be inserted and soldered on both sides of the board anywhere you see an "X." The chip components mount on the solder side as shown in Fig. 3.

L13 is an RF choke and should have a ferrite core for a high "Q" value.

Slide switches S1 and S2 should be mounted very close to the PC board, with leads ⅛-inch or less, measured from the top surface of the PC board. Mixer MOD1 is a prepackaged diode bridge balanced mixer; the blue dot on MOD1 indicates pin 1. Note that IC1, Q1, and all chip capacitors are installed on the solder side of the PC board as shown in Fig. 3. However, do not yet install IC1 or Q1–Q3. You can install the chip capacitors after all regular capacitors are installed on top of the board.

Install IC2 and D1–D3. Now connect power (12 VAC or 15–25 VDC), place S2 in the "on" position, and connect a voltmeter to TP3. You should see around +12 volts ±0.5 volt. If not, find the problem before proceeding. Check your work for shorts, solder bridges, missing solder connections, etc., and then install the remaining semiconductor devices, observing the polarity on all of them. Watch the lead configurations of IC1 and Q1: once soldered in, they are difficult to remove without damaging them.

Keep all coaxial leads going to the PC board very short. Solder them to the board as shown in Fig. 4 for best operation. The two slide switches (S1 and S2) must be ganged together. You can use the method shown in Fig. 5 or devise your own.

The converter board can be

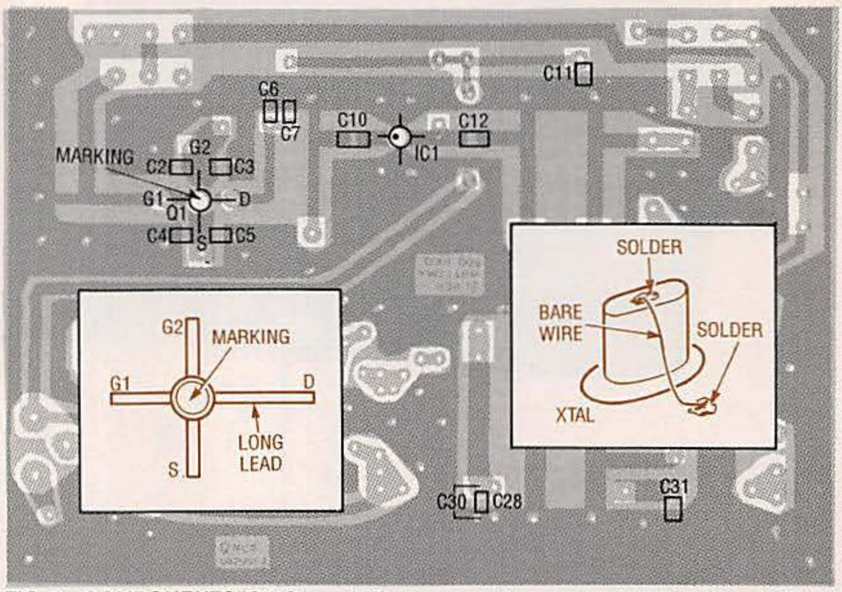


FIG. 3—COMPONENTS IC1, Q1, and all chip capacitors are installed on the solder side of the PC board. Note how to position Q1 and how to ground XTAL1.

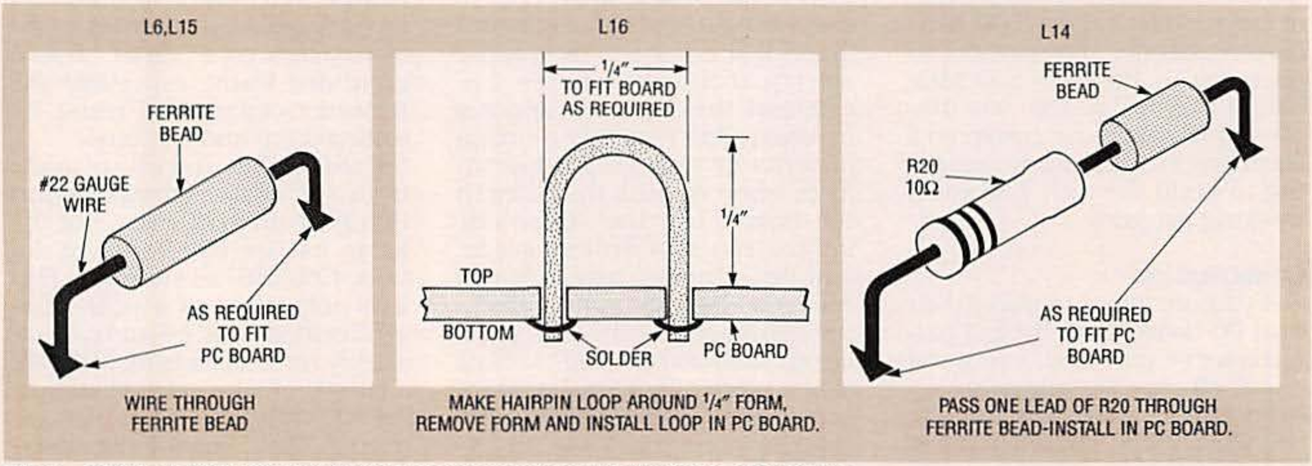


FIG. 2—COILS L6 AND L15 are ferrite beads placed over a length of wire, L16 is just a loop of wire, and L14 is a ferrite bead placed over one lead of R20.

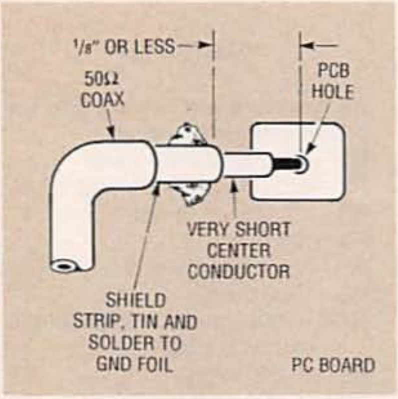


FIG. 4—ALL COAXIAL LEADS going to the PC board must be kept as short as possible. Solder them to the board as shown here.

mounted in a case with enough room for a 12-volt transformer. You can also mount the board inside an existing scanner, if +15 volts at 100 mA is available. If you have a regulated +12-volt supply, you can use it for power by connecting the +12 volts to the junction of C32, C33, and S2-b—in this case you can omit IC2, C34–C36, and D3 from the circuit. Figure 6 shows the inside of the completed prototype.

Tune and align

To align the scanner converter you'll need a VOM, a 100-MHz or higher frequency counter, and a non metallic screwdriver. Preset all trimmer capacitors as shown in Fig. 7, and set the slugs halfway in L7, L8, and L9.

First check all wiring for shorts, opens, and correct component orientation. Then connect either +14-volts DC or 12-volts AC to the power input and check for the following voltages:

- Junction of C16, L6, and R20 for +12 volts ±0.5 volt
- Source of Q1 (the junction of C4, C5, and R3) for +1 to +2 volts
- Drain of Q1 (the hot side C8) for +10 to +11 volts
- Gate 2 of Q1 (the junction of R1 and R2) for +1.5 to +2.5 volts
- Output of IC1 (the junction of R5 and C12) for +5 volts ±1 volt
- Wiper of R7 for +10 to +15 volts (vary the setting of R1)
- Junction of R8 and D1 for +10 to +15 volts
- Emitter of Q2 for +1.5 to +3 volts
- Collector of Q2 for +10 to +11.5 volts
- Collector of Q3 for +8 to +12 volts
- TP2 for −1 to +1 volt

Do not proceed any further until those voltages are obtained. Slight variations outside the stated ranges might be acceptable, but any major ones should be investigated. Table 1 gives some troubleshooting hints.

Couple a frequency counter to L7 using a 2-turn wire loop as shown in Fig. 8. Set R7 in the center of its range and adjust L7 for a 50-MHz reading. Vary R7 and see if you can obtain about ±1-kHz variation. Use the nonmetallic screwdriver.

Couple a frequency counter to L9 using a 2-turn loop, and connect a VOM between TP1 (negative lead) and TP2 (positive lead). Adjust L8 and L9 for maximum voltage reading, which should be between 2 and 3 volts. Check to see that your counter reading is about 100 MHz.

Make sure that you have set trimmer capacitors C25, C26, and C27 according to Fig. 7 for coverage of either 800–900 or 900–1000 MHz. Connect a voltmeter to TP2 and adjust C25,

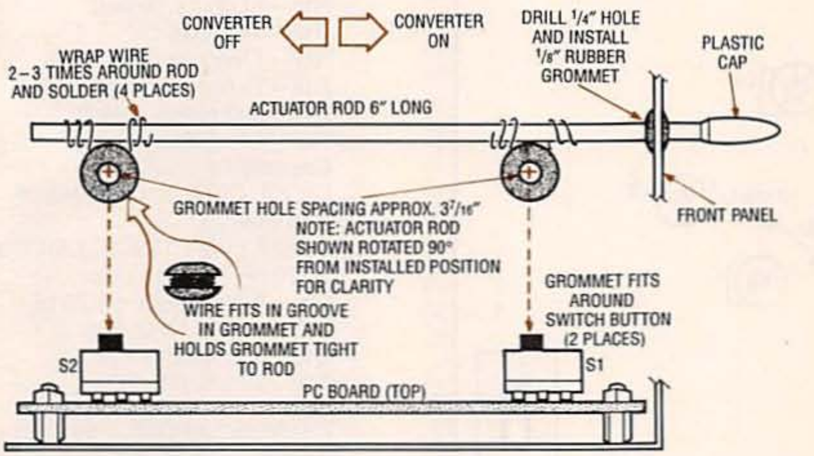


FIG. 5—ACTUATOR ROD S1/S2 CONSTRUCTION. The two slide switches (S1 and S2) must be ganged together. This method uses a brass rod or coat-hanger wire and rubber grommets. You can also devise your own method of ganging them together.

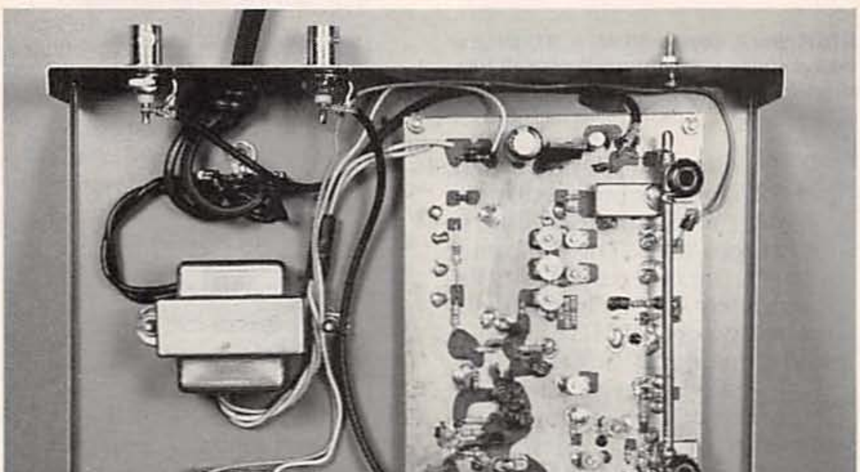


FIG. 6—THE INSIDE OF THE PROTOTYPE UNIT. The converter board can be mounted in a case along with a 12-volt transformer.

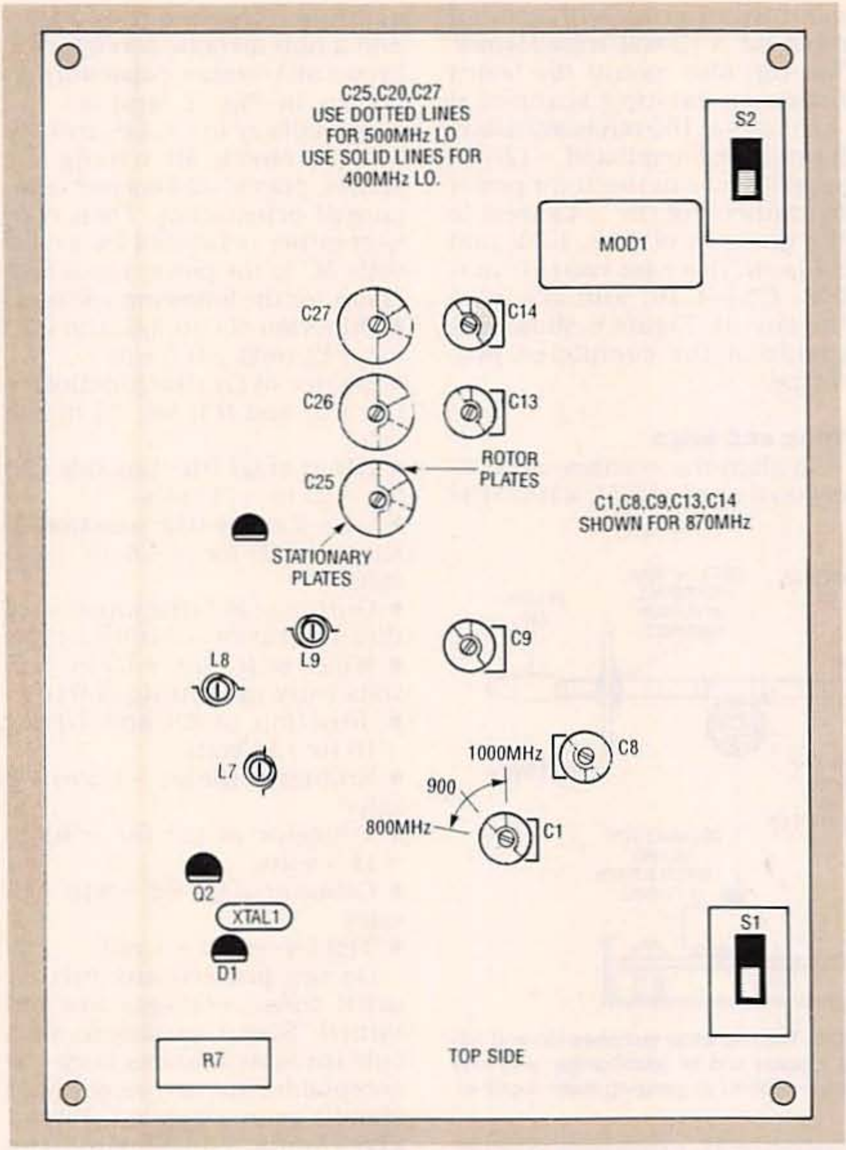


FIG. 7—TO ALIGN THE SCANNER CONVERTER you'll need a VOM, a 100-MHz or higher frequency counter, and an insulated non-metallic screwdriver. Preset all trimmer capacitors as shown here, and set the slugs halfway in L7, L8, and L9.

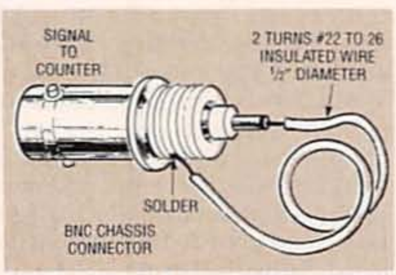


FIG. 8—COUPLE A FREQUENCY COUNTER to L7 using a 2-turn wire loop as shown here.

C26, and C27 for the greatest reading. Short the base of Q2 to ground; the reading at TP2 should be about +0.2 volt. With the short removed, the reading should drop and ideally even go negative, to about −0.1 to −0.15 volts. Adjust C25, C26, and C27 to go as far negative as possible. You should be able to obtain zero volts. The difference between the two readings is approximately the local oscillator injection level at R18, which should be about 0.3 volt RMS.

Use the counter to check the frequency of the signal at the junction of R18 and R19. It should be within a few kilohertz of either 400 or 500 MHz. Potentiometer R7 should vary the frequency ±5 kHz or more. Adjust L7 so that R7 can do that, and also so that R7 is in the middle of its range when either 400 or 500 MHz is produced.

Connect an antenna to J1.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.

R1—100,000 ohms, ⅛-watt
R2—470,000 ohms, ⅛-watt
R3—180 ohms, ⅛-watt
R4—180 ohms
R5—390 ohms, ⅛-watt
R6—1000 ohms
R7—10,000 ohms, trimmer potentiometer with shaft
R8—10,000 ohms
R9—15,000 ohms
R10—3900 ohms
R11—330 ohms
R12—100 ohms
R13—15,000 ohms
R14—2200 ohms
R15—10 ohms, ⅛-watt
R16—47 ohms
R17—1 megohm
R18—15 ohms, ⅛-watt
R19—390 ohms, ⅛-watt
R20—10 ohms

Capacitors

C1, C8, C9, C13, C14—1–5 pF trimmer
C2–C7, C10–C12, C16, C28, C31—100 pF, 50 volts, chip
C15—5.6 pF NPO ±0.25 pF
C17—100 pF NPO, 5%
C18—39 pF NPO, 5%
C19—22 pF NPO, 5%
C20—2.2 pF NPO, ±0.25 pF
C21, C29—470 pF ±20%, disc
C22, C30, C32, C35, C36—0.01 µF, 50 volts, GMV disc
C23—33 pF NPO ±5%
C24—56 pF NPO ±5%
C25–C27—2–10 pF trimmer
C33—10 µF/16 volts, electrolytic
C34—470 µF/25 volts, electrolytic

Semiconductors

IC1—MAR-1 UHF amplifier
IC2—7812 +12-volt regulator
D1—MV2107 varactor diode
D2—HP5082-2800 hot carrier diode
D3—1N4007 rectifier diode
Q1—NE25137 dual-gate GaAsFET
Q2—2N3563 VHF NPN transistor
Q3—MPS3866 VHF NPN transistor

Preset C1, C8, C9, C13 and C14 as shown in Fig. 7, and connect output J2 to a scanner tuned in the vicinity of 500 MHz (470 to 530 MHz will do). Now, set the scanner in a "search" mode so as to gradually tune from the low end to the high end of the range. Find a suitable signal to align the RF stages. If you have access to a signal generator in

LED1—green light-emitting diode (optional)
LED2—red light-emitting diode (optional)

Inductors

L1–L5, L10–L12—part of PC-board etching
L6, L15—ferrite bead on wire jumper (see Fig. 2)
L7—0.2–0.32 µH (9½ turns #22 enameled wire wound on 8-32 screw with ferrite slug, Cambion part # 515-3225-06-21-00)
L8, L9—0.05–0.1 µH (3½ turns #22 enameled wire wound on 8-32 screw with ferrite slug, Cambion part # 515-3225-06-21-00)
L13—1.0 µH RF choke
L14—ferrite bead over lead of R20 (see Fig. 2)
L16—½-turn #22 enameled wire on ¼-inch form (see Fig. 2)

Other components

J1, J2—female BNC connector
MOD1—MCL SBL-IX mixer module
S1, S2—DPDT PC-mount slide switch
XTAL1—50-MHz 3rd overtone crystal

Miscellaneous: PC board, small-diameter 50-ohm coaxial cable, project case, 14.5–24-volt DC or 12-volt AC, 350-mA transformer (see text), hardware as required, brass rod or wire, two ¼-inch rubber grommets, line cord if required, solder, etc.

Note: The following items are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804:

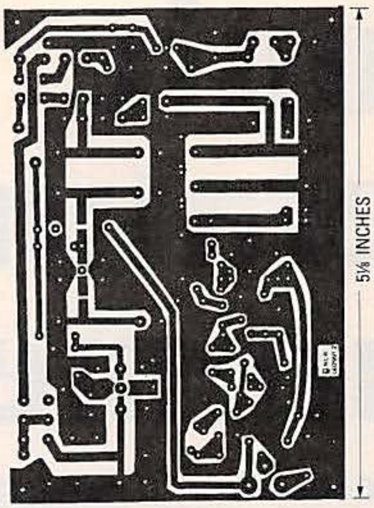
- **Converter kit including all parts except case and transformer—$67.50 + $3.50 S&H**
- **PC board only—$13.50 + $3.50 S&H**
- **Transformer—$9.50 + $3.50 S&H**

New York State residents must add appropriate sales tax.

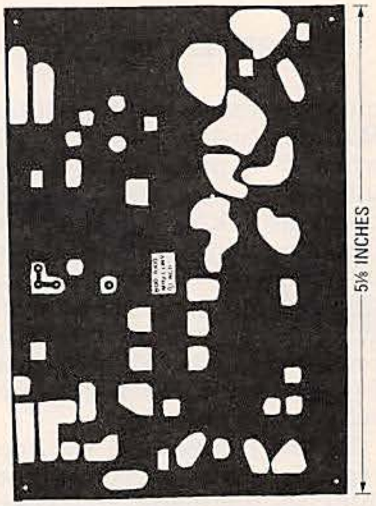
the 900-MHz range, use it (connected to J1) as a signal source.

On a weak signal, peak C1, C8, C9, C13, and C14 for best signal-to-noise ratio. If you use an off-the-air signal, the signal may disappear before you are through.

Do not mistake a stray 470–530 MHz signal that may leak into your scanner for 900



COMPONENT SIDE of the scanner converter board. Board shown half size.



SOLDER SIDE of the scanner converter board. Board shown half size.

MHz. To check this, turn off the converter using the built-in switch. If the signal is false, it will get stronger. If it is a real 900-MHz signal, it will disappear when the converter is turned off. You can re-peak the converter at any time on any part of the frequency range. Typical RF bandwidth is 40 MHz at the 3 dB points. Signals will be heard 10 to 20 MHz beyond those limits, so if you use the converter for, say 800–825 MHz and 851–868 MHz (most common), you can peak the converter in the middle (825 MHz) and still get satisfactory performance. It is possible to "stagger tune" the circuits to increase bandwidth, although you will lose some gain. **R-E**

Electronic Temperature Measurement

What is temperature and how can it be measured electronically?

HARRY L. TRIETLEY

TEMPERATURE IS PERHAPS THE most common of all physical measurements. From weather forecasts to industrial processes to patient monitoring, its measurement pervades our lives. Yet, unless our jobs directly involve temperature measurement, most of us don't give much thought to what temperature is or how it's measured. In this article we will look briefly at how temperature is defined and survey the field of electronic temperature measurement. We'll then begin an in-depth study of temperature sensors and application circuits, closing with a look at noncontact infrared thermometry.

What is temperature?

Any grade school science student knows that heat is molecular motion. The hotter something is, the faster its molecules move; absolute zero is defined as the point where all molecular motion ceases. All well and good but, since we can't see molecules move, how do we measure temperature?

The bedrock standard used by the NIST (National Institute of Standards and Technology, formerly the National Bureau of Standards) is based on the perfect gas law. The law states that as temperature rises, either the pressure or volume of the gas must increase in proportion. Mathematically, $P \times V = kT$, where P = pressure, V = volume, T = absolute temperature, and k is a constant. Doubling the molecular velocity in a constant volume results in twice as many molecular collisions per second, or twice the pressure. At absolute zero a perfect gas would collapse to zero volume and pressure.

Figure 1 illustrates the concept of a constant-volume helium gas thermometer. (Perfect gases do not exist, but helium comes close.) A mercury manometer—a device used for measuring the pressure of gasses and vapors—with an adjustable reservoir measures the gas pressure of a helium-filled bulb. As temperature changes, a plunger in the reservoir is adjusted to maintain the left leg of the manometer at a constant height, thus maintaining the helium at a constant volume. When a vacuum is pulled above the right leg, the mercury height indicates the gas pressure, and thus the temperature of the helium.

The concept sounds simple, but precision measurements are difficult. Temperature affects the volume of the bulb and the interconnecting tube is not at the same temperature as the bulb. Also, the relatively small change in mercury level, plus the meniscus of the mercury's surface, limits measurement accuracy. On top of all that, corrections must be made for helium's deviations from the perfect gas law. Therefore, gas-law thermometry is used primarily by national standards laboratories such as the NIST.

Temperature scales

Companies and laboratories which manufacture or calibrate thermometers need a more practical standard. For that reason, the International Temperature Scale (ITS) was established. Previously known as the International Practical Temperature Scale to distinguish it from the fundamental gas-law scale, it is regularly reviewed and revised by international conferences involving a number of national standards laboratories. The latest revision, published in 1990, is known as ITS-90.

The scale begins with a series of agreed-upon fundamental temperatures, or fixed points. The freezing (or melting) point—or, in some cases, a variation known as the triple point—of certain high-purity materials have been assigned precise temperature values by agreement among the participating labs. Figure 2 shows a typical fixed-point cell. A graphite crucible containing a high-purity metal is sealed in a quartz envelope filled with argon or some other inert gas.

Table 1 lists several fixed points. The freezing point of silver, for example, has been assigned the value of 1234.93 Kelvin (absolute) or 660.323 degrees Celsius. Water's triple point, which can be controlled more precisely than the freezing point, is defined to be 273.16K or 0.01°C.

(The triple point is like the freezing point, except that the material is sealed in an evacuated glass container. Instead of being at atmospheric pressure, the water sees only its own vapor pressure. Since the freezing point is affected by both air pressure and contamination, the triple point is more repeatable. The term, "triple point," refers to the fact that the material is in three-phase equilibrium—vapor, liquid, and solid.)

To make the scale practical it is necessary to have sensors that can interpolate between the defined fixed points. ITS-90 defines several such sensors, covering various portions of the scale.

The "center" of the scale, between the hydrogen triple point and the silver freezing point, is interpolated using high-grade resistance thermometers known as SPRT's (Standard Platinum Resistance Thermometers). SPRT's are carefully constructed of high-purity platinum wire, wound and assembled with a minimum of support so as to be strain-free. The thermometers are calibrated at three or more fixed points, then used between those temperatures. Their R versus T equations are very complex and must be handled by computers. Figure 3 shows a SPRT enclosed in a Pyrex sheath.

The very low end of the scale, down to 0.65K, is defined by Helium gas-law thermometry. Several overlapping ranges are defined, each with its own set of complex equations and tables. At the high end, temperatures above the silver freezing point are defined using radiation thermometry. We'll look at radiation thermometry next month, but basically it makes use of the fact that infrared or optical radiation increases with temperature. (The older IPTS also used thermocouples made of platinum alloys to define part of the temperature scale, but this was dropped in the 1990 revision.)

Commercial sensors

For the balance of this article we'll examine and compare commercial temperature sensors: thermocouples, resistance thermometers, thermistors, and silicon (IC) sensors. Let's begin with a quick survey: Table 2 compares their characteristics, while Fig. 4 shows operating ranges and accuracies.

Incidentally, for a first-rate mail-order source of temperature sensors, instruments, and information contact Omega Engineering, One Omega Drive, Box 4047, Stamford, CT 06907, 1-800-826-6342 (CT and international, 203-359-1660).

Thermocouples are nothing more than two dissimilar metals joined together. When connected, an EMF is produced which increases (approximately linearly) with temperature. The thermocouple's sensitivity, linearity, and temperature range depend on the metals used.

Over the years several types of thermocouples have emerged as standards. In the US the NIST publishes millivolt-versus-temperature tables for eight types, identified by letter codes. Five (types J, K, T, E, and N), made from base-metal alloys, cover varying temperature ranges and applications. Sensitivities are typically tens of microvolts per degree C. The other three (types R, S, and B) are formed of platinum and platinum alloys. Obviously expensive, they are the most stable and repeatable of thermocouples, and most often used for high-temperature work, but their sensitivities are lower.

Thermocouple wire and probes made to these standards are available from a number of manufacturers and distributors. In addition, some manufacturers produce special thermocouples for high temperature, cryogenic, and other specialized applications. Most common of these are tungsten alloy thermocouples which allow measurements as high as 2315°C (4200°F).

A resistance thermometer (commonly called an RTD, or Resistance Temperature Device) consists of a coil of fine-gauge wire or metal film. Most metals change resistance with temperature, but platinum or nickel are most often used to make RTD's. RTD's generally are more stable, accurate, and sensitive than thermocouples, but are limited to lower temperatures. Platinum RTD's are the most stable and accurate and cover the highest temperature range.

Nickel's lower cost has made it attractive for moderate-temperature industrial applications; however, recent advances in the art of manufacturing platinum-film elements (similar in principle to metal-film resistors) has eliminated the cost advantage of nickel. Other metals, primarily copper and an alloy named Balco, are sometimes used as well.

Thermistors are probably somewhat familiar to most readers. Unlike thermocouples and RTD's, they are highly sensitive, highly nonlinear, and cover limited temperature ranges. Positive temperature coefficient (PTC) thermistors exist, but those best suited to temperature measurement are negative temperature coefficient (NTC) devices which decrease in resistance by about 3 to 5% per °C. Thermistors offer the widest variety of sizes, shapes, accuracies, and prices of any commercial temperature sensors.

Integrated circuit (IC) temperature sensors are newest and easiest for most experimenters to apply. They are sensitive and linear, and interface easily to op-amps and A/D converters. On the flip side, IC's have not become as standardized as other sensors. Precisely-calibrated (selected) grades tend to get expensive. Their temperature range is about the same as epother end of the scale, thermistor washers and discs are offered with diameters up to 1 inch. Thermocouple wire is available to 14 AWG and even larger, with insulations ranging from PVC to ceramic fibers or beads. Surface temperatures may be measured by ribbon-style thermocouples, or thermocouple wires may be welded directly to metal surfaces.

Now that our survey is complete, let's look at each in detail.

IC sensors

Forward-biased silicon diodes and base-emitter junctions have often been used to measure temperature. At room temperature, a forward-biased

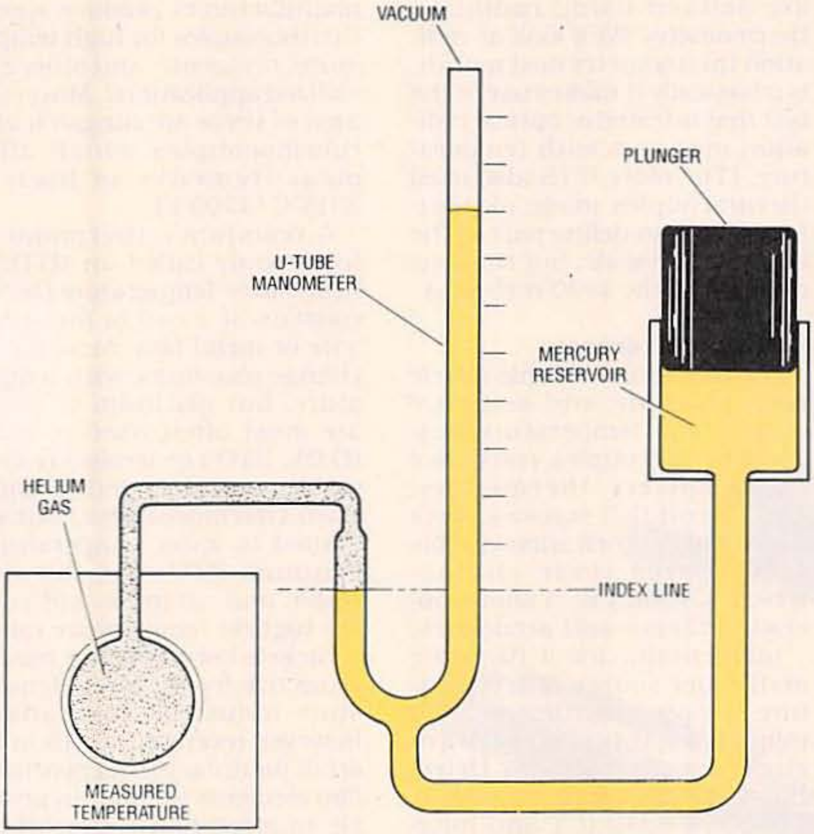


FIG. 1—CONSTANT-VOLUME GAS THERMOMETER. The plunger is adjusted to maintain the left leg of the manometer at the index line as the gas pressure changes.

TABLE 1

Fixed Point	Temp (K)	Temp (°C)
Hydrogen Triple Point	13.8033	−259.3467
Neon Triple Point	24.5561	−248.5939
Oxygen Triple Point	54.3584	−218.7916
Argon Triple Point	83.8058	−189.3442
Mercury Triple Point	234.3156	−38.8344
Water Triple Point	273.16	0.01
Gallium Melt Point	302.9146	29.7646
Indium Freeze Point	429.7485	156.5985
Tin Freeze Point	505.078	231.928
Zinc Freeze Point	692.677	419.527
Aluminum Freeze Point	933.473	660.323
Silver Freeze Point	1234.93	961.78
Gold Freeze Point	1337.33	1064.18
Copper Freeze Point	1357.77	1084.62

oxy-coated thermistors.

Which sensor is best?

It depends upon temperature, application and accuracy. At high temperatures thermocouples may be the only choice. Best accuracy generally is given by platinum RTD's, although precision thermistors may excel near room temperature. Thermistors, because of their high sensitivity, are superb in narrow-range applications such as medical thermometers. Thermistors and IC's both serve well for moderate accuracy measurements and temperature compensation applications.

IC's and, to a lesser extent, RTD's offer limited package selections. For small size and fast response, glass-bead thermistors are available in diameters from 0.014 down to 0.005 inch while uninsulated thermocouple wire is available down to 0.0005-inch diameter. At the

FIG. 2—FIXED POINT CELL. The graphite crucible, visible through the quartz enclosure, contains a high-purity metal. (Courtesy of YSI Inc.)

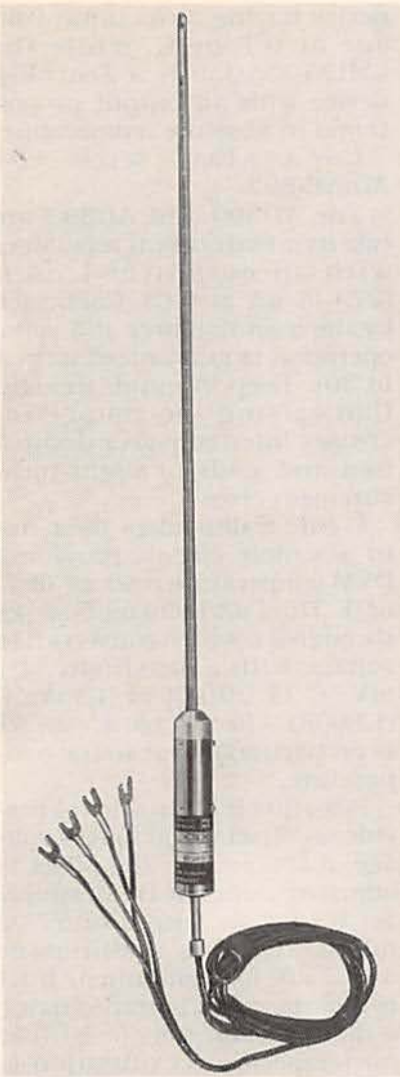


FIG. 3—STANDARDS-QUALITY SPRT, assembled into a quartz sheath. (Courtesy of YSI Inc.)

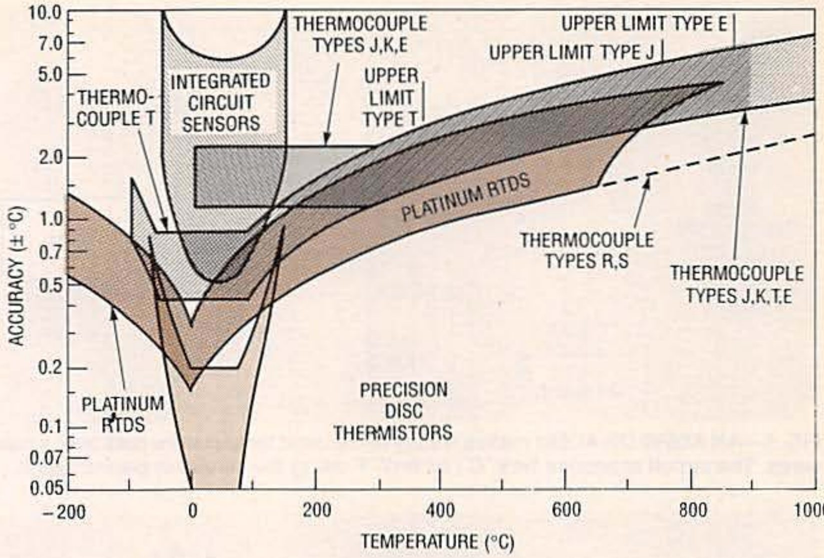


FIG. 4—THE "BEST" TEMPERATURE SENSOR depends on the temperature range and accuracy required.

TABLE 2—SENSOR COMPARISON CHART

Sensor Type	Typical Sensitivity	Temperature Range	Midrange Accuracy	Non-Linearity
Base Metal Thermocouples Types J, K, T, E, N	40 to 70 µV/°C	−270 to 1372°C	1.1 to 2.2°C	1 to 5%
Platinum Alloy Thermocouples Types R, S, B	7 to 12 µV/°C	−50 to 1820°C	0.6 to 1.5°C	1 to 5%
Tungsten Alloy Thermocouples	10 to 21 µV/°C	−17 to 2315°C	4.5°C	2 to 7%
Platinum Resistance Thermometers (100Ω)	0.4Ω/°C	−200 to 650°C	0.1 to 0.25°C	1 to 3%
Nickel Resistance Thermometers (100Ω)	0.7Ω/°C	−60 to 180°C	0.4°C	1 to 5%
Precision Disc Thermistors	−3 to −5 %/°C	−80 to 150°C	0.1 to 0.2°C	Inherently Nonlinear
Glass Bead Thermistors	−3 to −5 %/°C	−60 to 300°C	Noninterchangeable	Inherently Nonlinear
Integrated Circuit Sensors	1µA/°C or 1 to 10mV/°C	−50 to 150°C	0.5 to 5°C	0.3 to 3°C

junction drops about 0.7 volts, with a negative temperature coefficient of approximately −2mV/°C. The exact voltage and temperature coefficient depends upon the junction's geometry, current density, and other factors.

Precise calibration requires individual measurement of each diode or transistor at known temperatures. The basic equation for a P-N junction is:

$$I = I_o\left(e^{\frac{qV}{kT}} - 1\right)$$

where q is the charge of an electron, k is a physical constant known as the Boltzmann constant, and T is the absolute temperature (Kelvins). I_O is a constant, basically equal to the reverse-biased leakage current. At room temperature, the quantity kT/q is about 26 mV. Under normal forward-biased conditions the −1 term is insignificant and can be ignored, so:

$$I \cong I_o e^{\frac{qV}{kT}}$$

so

$$\ln\left(\frac{I}{I_o}\right) = V$$

An IC temperature sensor's operation is based on the difference between two base-emitter voltage drops where the junction currents are maintained at a constant ratio, I2/I1. Applying a little algebra to that equation shows that the voltage difference is given by:

$$V_2 - V_1 = \frac{kT}{q}\ln\left(\frac{I2}{I1}\right)$$

Circuits within the IC use that difference to create an output voltage or current which is proportional to temperature.

Table 3 lists four IC's. The AD590 and AD592 behave iden-

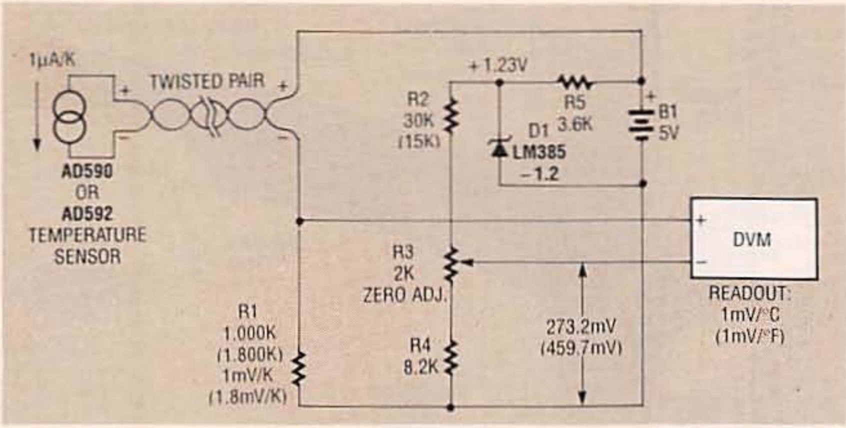


FIG. 5—AN AD590 OR AD592 makes it easy to transmit temperature data over a pair of wires. The circuit produces 1mV/°C (or 1mV/°F using the values in parentheses).

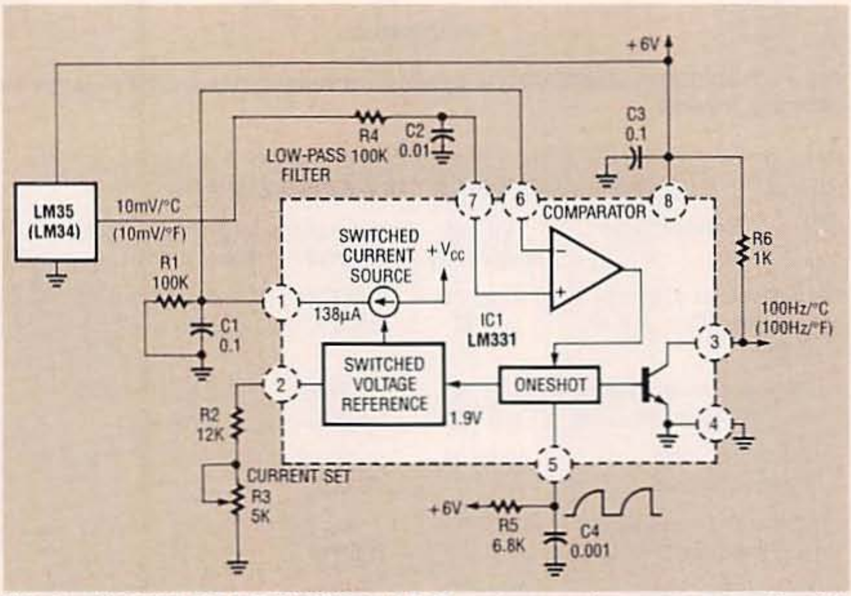


FIG. 6—AN LM35 OR LM34 PLUS A V/F IC produces a frequency proportional to temperature.

TABLE 3—TEMPERATURE SENSORS

Type & Mfr	Description	Available Ranges	Available Accuracies
AD590: Analog Devices, Harris	Two terminal current source 1µA/K	−55 to 150°C	1.7 to 10°C (0.5 to 5°C @ 25°C)
AD592: Analog Devices	Two terminal current source 1µA/K	−25 to 105°C	1 to 3.5°C (0.5 to 2.5°C @ 0 to 70°C)
LM34, LM35: National	Three terminal current source 10mV/°F (LM34) 10mV/°C (LM35)	−55 to 150°C	1.5 to 2°C (0.5 to 1°C @ 25°C)
LM135/235/335: National	Two terminal voltage regulator 10mV/K, calibratable	−40 to 100°C −40 to 125°C −55 to 150°C	2.7 to 9°C (1 to 6°C @ 25°C) without user calibration

tically, but the newer AD592 is less expensive (plastic TO-92 case), covers a narrower range, and, over that range, offers tighter accuracy. National's LM34/LM35 is a three-terminal device having zero output voltage at 0°F or C, while the LM135/235/335 is a Zener-like device with an output proportional to absolute temperature.

Let's start with the AD590/592.

The AD590 and AD592 are two-terminal current regulators with an output of 1 µA/K (273.15 µA at 0°C). Calibrated by the manufacturer at 5 volts, operation is guaranteed from 4 to 30V. Keep in mind, though, that raising the voltage increases internal power dissipation and leads to slight measurement errors.

Figure 5 illustrates their use in a simple circuit providing DVM temperature readout in °C or °F. The 1 µA/K current passes through R1, which converts it to voltage with a sensitivity of 1 mV/°C (1.000K) or 1 mV/°F (1.800K). The voltage across R1 is proportional to absolute temperature.

Resistors R2, R3, and R4 provide an offset equal to R1's voltage at 0°C or 0°F. The offset is adjusted using the DVM: simply set R3 for an output of 273.2 mV for Celsius readings or 459.7 mV for Fahrenheit. If R1 is purchased (or trimmed using a digital ohmmeter) to ±0.1%, no temperature calibration is required to achieve the IC's rated accuracy.

If you want to achieve superior accuracy using a lower grade (looser tolerance) IC, you can make R1 adjustable. Place the IC at a known temperature, connect the DVM across R1, and adjust it for the correct reading based on 1 mV/degree. (Suggestion: place the IC in a closed-end sheath and let it come to equilibrium in a stirred ice-and-water bath. Trim R1 until the voltage across it is 273.2 at 0°C

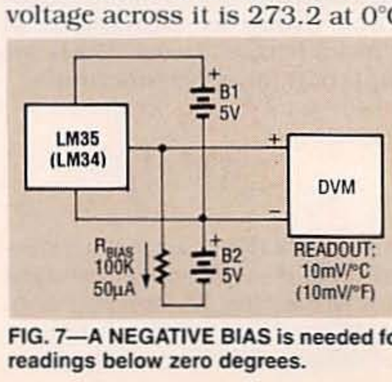


FIG. 7—A NEGATIVE BIAS is needed for readings below zero degrees.

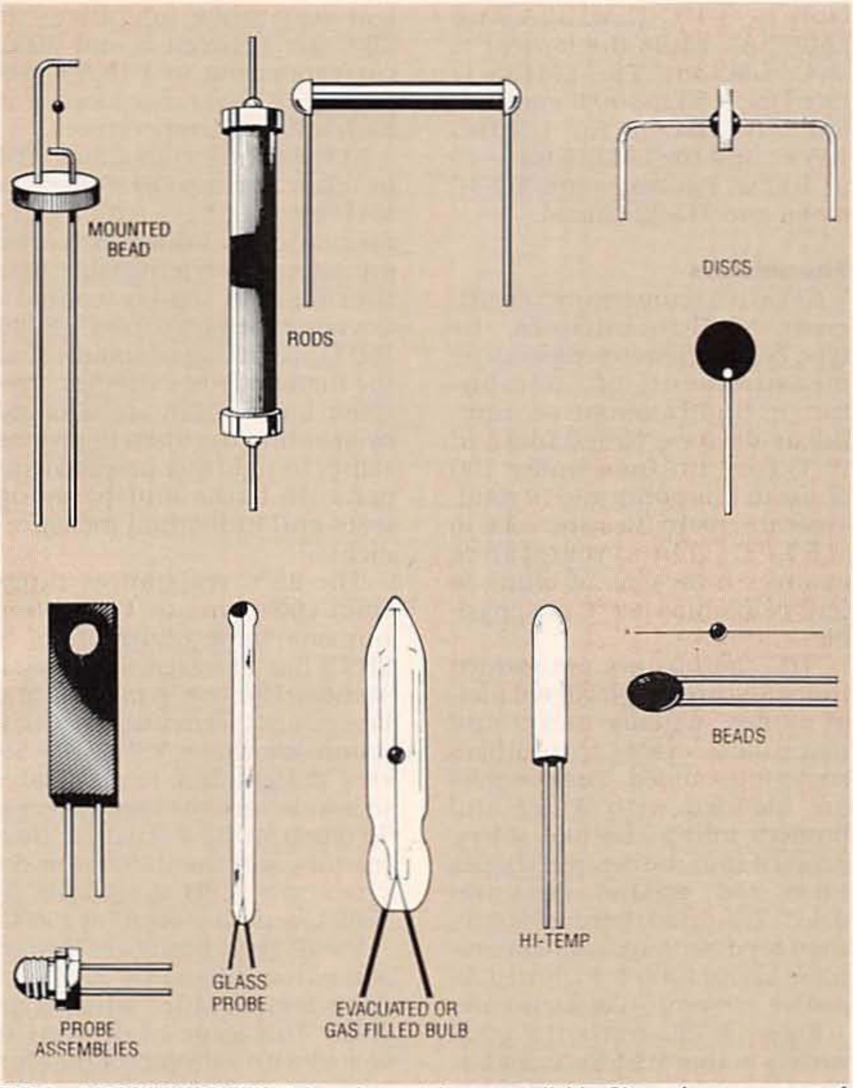


FIG. 8—A BROAD VARIETY of thermistor styles are available. Shown here are some of the more common ones.

TABLE 4—THERMISTOR CHARACTERISTICS

Thermistor Type	Available Resistances	Mid-Range Accuracy	Typical Temperature Range
Low Cost	100 ohms to 200K	5 to 20% (1 to 5°C)	−50 to 150°C
Precision Interchangeable Disc	100 ohms to 1 megohm	0.1 to 0.2°C (0.5 to 1%)	−80 to 150°C
Glass Bead	200 ohms to 1 megohm	20% (5°C)	−60 to 300°C
Glass Coated Interchangeable Disc	2.2K to 30K	0.05 to 0.2°C (0.2 to 1%)	−80 to 250°C

or 491.7 mV at 32°F.) Adjust R3 as described earlier.

The AD590 is available in several grades from ±5°C (AD590J) to ±0.5°C at 25°C (AD590M). The AD592's guaranteed 25°C accuracies range from ±2.5°C (AD592AN) to ±0.5°C (AD592CD). The AD590 is available in TO-52 transistor can or flat-pack enclosures, while the AD592 is sold in a TO-92 plastic transistor package. Both are sold as unpackaged, trimmed chips.

National's LM34/35 series is even easier to use. A three-terminal IC, it outputs 10 mV/°F (LM34) or 10 mV/°C (LM35) and is zero-based (zero millivolts at zero degrees). All that is needed to read temperature is a DVM and a battery or voltage source (anywhere from 4 to 30 volts).

Figure 6 combines an LM34 or LM35 with an LM331 voltage-to-frequency converter to provide a frequency proportional to temperature. The component values shown produce an output of 100 Hz/degree (10 kHz at 100°F or C). For more information on the LM331 and other V/F converters see "V/F Converters," **Radio-Electronics**, June 1991.

As with the AD590/592, no temperature calibration is necessary. To calibrate it, you temporarily disconnect the sensor, provide a precise 1.000 volt input, and adjust R3 for 10.00-kHz output. No zero adjustment is necessary. For improved accuracy using loose-tolerance IC's, you can place the IC at an accurately-known temperature near the high end of its range and adjust R3 for the proper output.

The LM34/35 needs a negative bias to track temperatures below zero. Figure 7 shows the basics: the IC is powered by a positive supply, but a negative bias current of approximately 50 μA is added to the output.

The LM35 is available with temperature ranges of −55 to 150°C, −40 to 110°C (suffix C), and 0 to 100°C (suffix D), and with 25°C guaranteed accuracies of ±1°C and ±0.5°C (suffix A). Similar grades are available for the LM34 Fahrenheit version. Packages are TO-46 metal and TO-92 plastic. The last IC in the table is National's LM135/235/335 series.

The LM135 operates as a Zener-like two-terminal voltage regulator IC, similar to an LM185 reference. A third terminal allows a potentiometer to be added for user calibration. The bias or "Zener" current may be anywhere from 400 μA to 5 mA. Its output is proportional to absolute temperature, 10 mV/K (2.73 volts at 0°C).

The tightest 25°C guaranteed accuracy without user calibration is ±1°C (LM135A and LM235A), while the loosest is ±°C (LM335). The LM135 is rated for −55 to 150°C continuous, the LM235 for −40 to 125°C, and the LM335 for −40 to 100°C. Packages are TO-46 metal and TO-92 plastic.

Thermistors

Negative temperature coefficient (NTC) thermistors, the type best suited to temperature measurement, are narrow-range, highly sensitive, nonlinear devices. Resistances at 25°C can run from under 100 ohms to 1 megohm and beyond. Typical sensitivities are −3% to −5%/°C. Thus resistance changes from tens of ohms to tens of kilohms per °C are possible.

NTC thermistors are formed from mixtures of powdered metal oxides, usually nickel and manganese oxides with others sometimes added. The powders are blended with water and binders into a clay-like slurry, pressed into the desired shapes (disc, rod, washer, etc.) and dried. The dried thermistors are then fired (sintered) at temperatures above 1000°C to form a resistive, ceramic-like structure.

Figure 8 illustrates the great variety of thermistors available. Most common for temperature measurement applications are epoxy-coated discs, generally under 0.1-inch in diameter. Similarly-sized glass-coated discs perform at higher temperatures. Bead thermistors, both glass-coated and bare, offer small size and fast response. Sizes vary from around 0.05 inch down to 0.005 inch. At the other end of the spectrum, thermistor rods are available as well as disc and washer shapes up to 1-inch diameter. In addition, several manufacturers offer thermistor sensor assemblies ranging from straight-stick probes to bolt-on and surface-mount assemblies to transistor cans.

Specifications vary greatly, but Table 4 summarizes several types. Thermistors have a reputation of being not too accurate or stable—and that is true of most inexpensive devices. Typical resistance tolerances at 25°C are between 5 and 20%, corresponding to 1 to 5°C accuracy. The tolerance loosens at high and low temperatures.

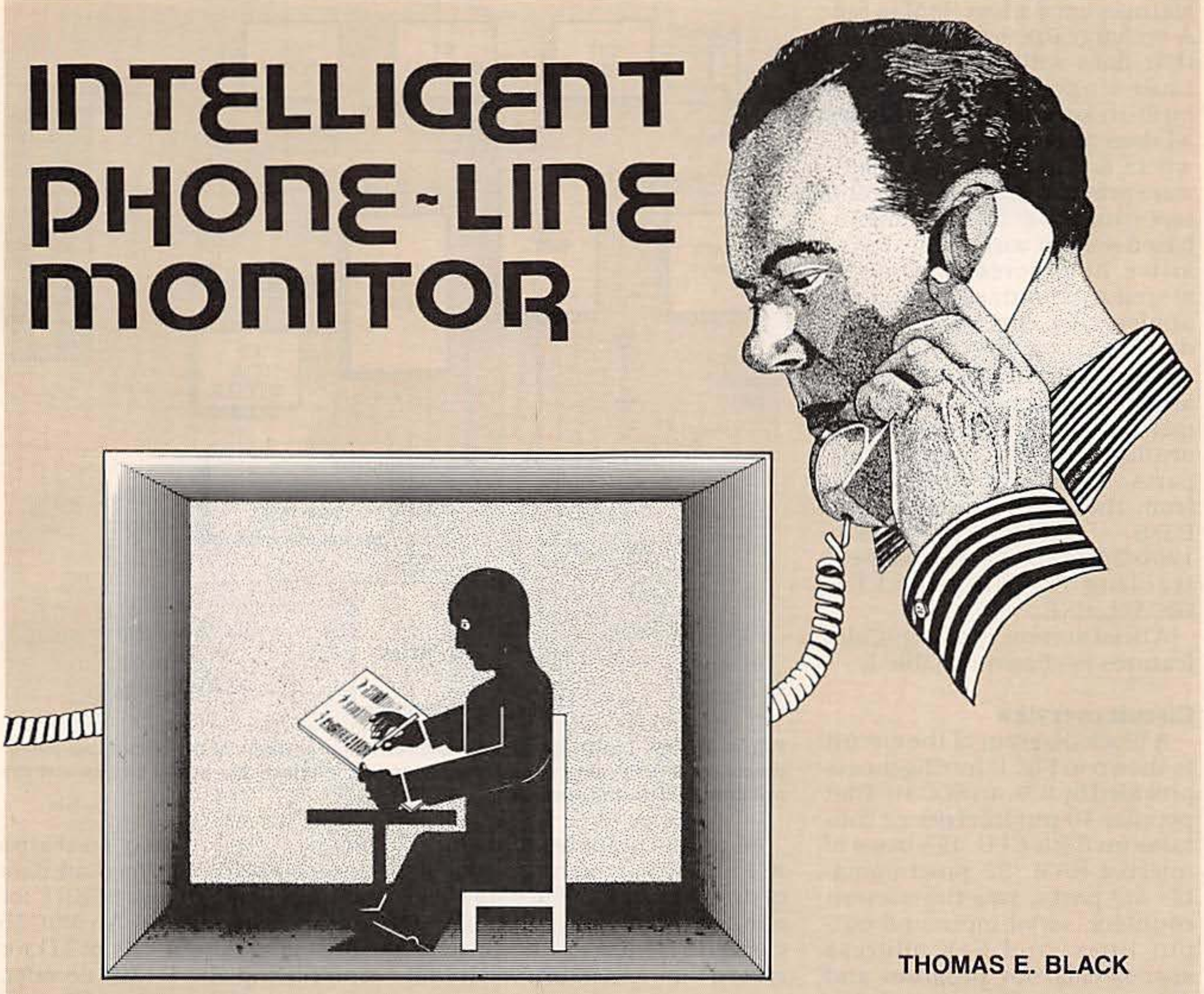
At least three companies (YSI in Yellow Springs OH, Fenwal in Milford MA, and Thermometrics in Edison NJ) offer precision interchangeable disc thermistors (epoxy coated). Covering the range from −80 to 150°C, loosening to about 1°C at the high and low extremes. Precision and stability are achieved by grinding the discs to precise values in tightly-controlled temperature baths and by aging tests and individual measurements.

The 25°C resistances range from 100 ohms to 1 megohm, but one value (2252 ohms at 25°C) has emerged as a quasi-standard for use in medical and laboratory thermometers. Commonly known by YSI's "400 Series" designation, it is available in a wide variety of probe styles. To illustrate how sensitive thermistors are, the 2252-ohm devices are 1.66 megohms at −80°C and 41.9 ohms at 150°C.

Small glass beads are formed somewhat differently. A pair of high-temperature wires (typically fine-gage platinum) is coated with a droplet of the slurry, fired, and then dipped into molten glass. The result is a high-temperature device which typically is more stable than epoxy-coated discs but which cannot be ground or trimmed. For precision applications thermistors may be supplied by the manufacturer with individual test measurements. For interchangeability, the manufacturer may select and preassemble two thermistors in parallel to match a specific calibration curve. Glass beads generally are specified to about 300°C.

Next month we'll look at some thermistor application circuits, then move on to resistance thermometers and thermocouples. We will conclude with a look at noncontact radiation thermometry. If you want to study thermistors in detail, look at **Radio-Electronics**' three-part series, "All About Thermistors," January—March 1985. **R-E**

INTELLIGENT PHONE-LINE MONITOR



THOMAS E. BLACK

Log telephone/modem/fax usage automatically and inexpensively with our intelligent phone-line monitor.

RESOLVING MONTHLY TELEPHONE bills can be a struggle, especially in a shared household. It seems that there are always some long-distance calls that we would like to dispute (did someone really call Oshkosh, Wisconsin?) One solution is to maintain a telephone log on paper, but doing so requires personal discipline that may be hard to keep up. Managing telephone usage is a problem that extends into the office, too. Knowing how long you spoke to each caller is a necessity if you bill for your time. If only one could log all phone calls automatically!

As a matter of fact, there is: Digi-Call (Digital Call Auto-Logger). This unobtrusive device can solve your telephone-management troubles. Digi-Call is a microprocessor-based system that connects to any standard telephone outlet and passively waits for incoming or outgoing calls. When you make an outgoing call, Digi-Call silently logs the time, telephone number, call length, and other vital information. When you receive an incoming call, Digi-Call records the time, call length, number of rings before answering, and more. A four-digit account-coding system optionally allows you to associate each call with a particular client, user, or housemate simply by pressing the appropriate code any time during the conversation. Digi-Call can work with both rotary and *Touch-Tone* phones, but the account-management feature is available only on tone phones.

Digi-Call's intelligence is provided by an 8-bit microprocessor, 32K of RAM, and 8K of EPROM-based realtime software. Digi-Call's internal RAM allows it to record more than 1550 calls without user intervention; audible and visual alarms signal when RAM is full. A rechargeable battery ensures that data will not be lost because of a power interruption. A built-in serial interface allows all data to be uploaded to a PC where sophisticated host software provides data analysis and reporting in a friendly, menu-based system with context-sensitive help screens. Data is stored in standard format for analysis by spreadsheet and database programs.

A complete kit of parts is available for about $170; a commercial-quality PC board is also available, as are hard to find parts. All software is available from the author and the R-E BBS (516-293-2883, 1200/2400, 8N1) as a self-extracting ZIP file called DIGICALL.EXE.

A brief summary of Digi-Call's features is shown in Table 1.

Circuit overview

A block diagram of the circuit is shown in Fig. 1. Intelligence is provided by IC9, an 80C31. That popular 40-pin Intel device contains an 8-bit CPU, 128 bytes of internal RAM, 32 programmable I/O ports, two timer/event counters, serial input and output lines, and 64K address spaces each for program and data memory. Telephone interface circuitry cleans up the audio and feeds it to DTMF (Dual-Tone, Multi-Frequcncy) decoder IC2, which drives a parallel input/output (PIO) expander, IC8. The line interface also provides a digital interrupt signal so that the microprocessor will know when something is happening on the line. A MAX232 buffers serial inputs and outputs from the microprocessor and provides RS-232 signal levels from a 5-volt supply; several lines from the PIO drive serial-control lines DTR (Data Terminal Ready) and CTS (Clear to Send).

Miscellaneous functions performed by the 8031 include driving several LED's for status indication, and monitoring the PWRON line from the power supply. When there is a power outage, the microprocessor senses and signals that fact both audibly and visually.

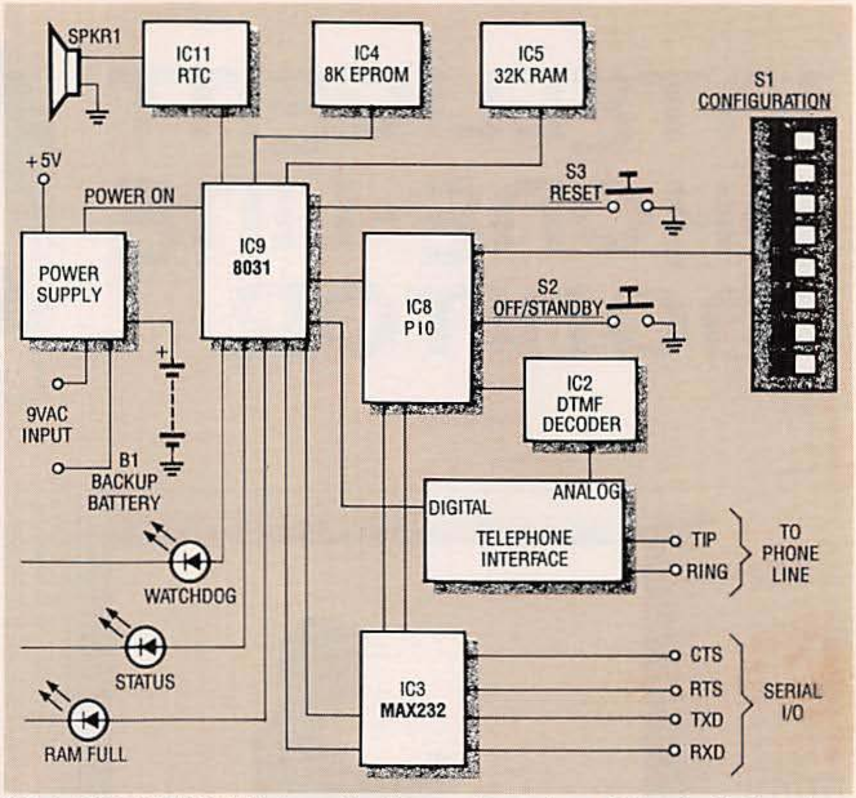


FIG. 1—BLOCK DIAGRAM shows the three major sections of the circuit: the microprocessor and memory circuit, the phone-line interface, the power supply, and the switches, LED's, and speaker.

Support components include IC4 and IC5, which provide 8K of program and 32K of data storage, respectively. A realtime clock (IC11) allows the unit to record time and data of each call accurately; it also contains some RAM for intermediate data storage, and drives SPKR1 for audible signalling. An 82C55 (IC8) provides 24 bits of I/O for interfacing the DTMF decoder, configuration switch S1, and the serial I/O control lines (DTR and CTS).

TABLE 1—DIGICALL FEATURES

- Stand-alone operation while recording calls
- PC interface uses standard serial COM port
- Turn-on chime reminder
- Real time clock
- 32K buffer stores more than 1550 calls
- Built-in hardware diagnostic utilities
- Battery backup with alarm
- RAM full visual/audible alarm
- Data sorting, formatting and printing features
- Hardcopy and disk file report output
- Export feature compatible with many spradhsheet programs
- Supports popular PC/XT/AT video formats, including 50-line VGA color
- Account Group Recording (9999 accounts)
- Total Cost less than $200

Circuit details

Due to its size, the schematic cannot be presented in one piece. Instead we present it in several sections: microprocessor, memory, and decoding (Fig. 2); telephone interface (Fig. 3); miscellaneous (Fig. 4); and power supply (Fig. 5). We'll start with the microprocessor section.

The 8031 requires an 8-bit latch (a 74HCT373) to demultiplex the low-order memory address. The latch holds the address presented by the microprocessor on the falling edge of ALE (IC9, pin 30). Whenever ALE is low, those same 8 bits function as the data bus.

The 8031 has separate 64K program and data spaces. The data space consists of 32K of

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted
R1, R2—100,000 ohms
R3, R10, R13—470,000 ohms
R4–R6—22,000 ohms
R7, R14—470 ohms
R8—56,000 ohms
R9, R11, R12, R28—47,000 ohms
R15—1 megohm
R21, R23, R25—220 ohms
R17—10,000 ohms
R18, R29—1000 ohms
R19—100 ohms
R20, R22, R24—10,000 ohms
R30—10 megohms
R31—470 ohms, ½ watt

Capacitors
C1, C2—0.001 µF, 100 volts, polyester, radial lead
C3, C14—0.01 µF, 100 volts, polyester, radial lead
C4, C7, C15–C21, C28, C31, C32—0.1 µF, 50 volts, monolithic, radial lead
C5, C6, C8–C13, C22, C25, C33—10 µF, 16 volts, electrolytic, radial lead
C23, C24, C27—27 pF, 100 volts, ceramic
C26—5–35 pF, variable, top adjust, 5 mm, PCB mount
C29—1000 µF, 16 volts, electrolytic, axial lead

Semiconductors
BR1—DB103, 200 volts, 1 amp, bridge rectifier, DIP package
BR2—W005M, 50 volts, 1 amp, bridge rectifier
LED1, LED2—Not used
LED3, LED5—LED, red, T-1¾
LED4—LED, green, T-1¾
D1–D7—1N4148 or 1N914 switching diode
D8—1N4732A, 4.7 volts, 1 watt, Zener diode
D9, D10—1N4001, 50 volts, 1 amp, rectifier
Q1–Q4—2N2222, general-purpose transistor
IC1—LM324, low-power op-amp
IC2—75T204 (SSI204) or 75T202 (SSI202) DTMF decoder (see text)
IC3—MAX232 or ICL232, 5-volt RS-232 driver
IC4—27C64-2, 8K CMOS EPROM
IC5—M5M5256A or HM62256LP-15, 32K × 8 static RAM
IC6—74HCT373, CMOS 8-bit latch
IC7—74HCT138, CMOS 3-to-8 line decoder
IC8—82C55A, CMOS peripheral interface
IC9—80C31 or 80C32, CMOS microprocessor
IC10—74HCT14, CMOS hex inverter
IC11—MC146818A, realtime clock with RAM (see text)
IC12—LM2940T, 5 volts, 1 amp, low-power regulator

Other Components
B1—6 Ni-Cd AA Cells, 400–600 mAH
P1—6-pin, 0.1" header connector
SPKR1—8-ohms, 1½"
S1—8-position DIP switch
S2—SPST, normally open, momentary, PC board mount
S3—SPST, normally open, momentary, panel mount
XTAL1—3.58 MHz, HC-18
XTAL2—11.0592 MHz, HC-18
XTAL3—4.194 MHz, HC-18
MOV1—ERZ-C07DK201U, 130 volts, 400 amps, ZNR surge suppressor
Miscellaneous: 6-cell AA battery holder, TO-220 heatsink, wall transformer (8–9 VAC, 300–1000 mA), PC board, IC sockets, enclosure (8.25 × 6.25 × 2), modular telephone line cord, assembly hardware, software.

Note: The following parts are available from Digital Products Company, Attn: Thomas E. Black, 134 Windstar Circle, Folsom, CA 95630: Complete kit of PC-board and parts without enclosure, $169.95; printed circuit board #DC001, $42.50; 75T204 DTMF decoder $14.50, programmed EPROM, $16.50, software on disk (5.25" only), $7.50. All orders add $3.75 S&H. CA residents add CA tax. U.S. funds only, no foreign shipments. Personal and business checks allow 3–4 weeks. No COD's or bank cards accepted. Prices subject to change.

static RAM (IC5), which occupies the lower 32K of memory. The realtime clock (IC11), and the peripheral interface (IC8) share the upper 16K of the address space, as decoded by IC7, beginning at C000h. Outputs of IC7 are enabled at 100h intervals, i.e., the realtime clock is addressed at C000h, the PIO at C100h, and the remaining outputs are unused.

Current time and date are maintained by realtime clock IC11, an MC146818A, which also has a simple square-wave tone generator and 50 bytes of RAM. The RAM serves as a buffer for incoming RS-232 data; Digi-Call uses the square-wave generator portion for audible signalling.

The EPROM (IC4) contains all system code; it is accessed beginning at 0000h whenever $\overline{PSEN}$ is low.

Telephone interface

The key to Digi-Call's operation is its telephone interface, shown in Fig. 3. Note that this circuit uses two separate grounds: analog and digital. Electrically, they meet at a common point near the power-supply ground. To avoid noise problems, the two ground circuits must remain separate except where they meet at the power supply. (Our PC board ensures that that is so.)

Digi-Call determines the status of the phone line by watching the voltages present on it. A standard phone line sits at −48-volts DC when not in use (when it is on-hook). When the phone is in use (when it is off-hook) the nominal voltage is about −7-volts DC. When the phone rings, a 90-volt, 20-Hz AC signal appears across the line.

When you dial a number using a rotary-dial phone (or the pulse-dial option on a modern phone, modem, or fax machine), what happens is that the device interrupts phone-line current, thereby causing line voltage to swing between the off- and the on-hook voltages. For instance, dialing the digit "9" causes nine oscillations between the two voltages, usually at a rate of about ten pulses per second. Rather than interrupt the flow of current, pushbutton phones usually send DTMF tones, which we will describe momentarily.

The telephone interface connects to the phone line at the tip

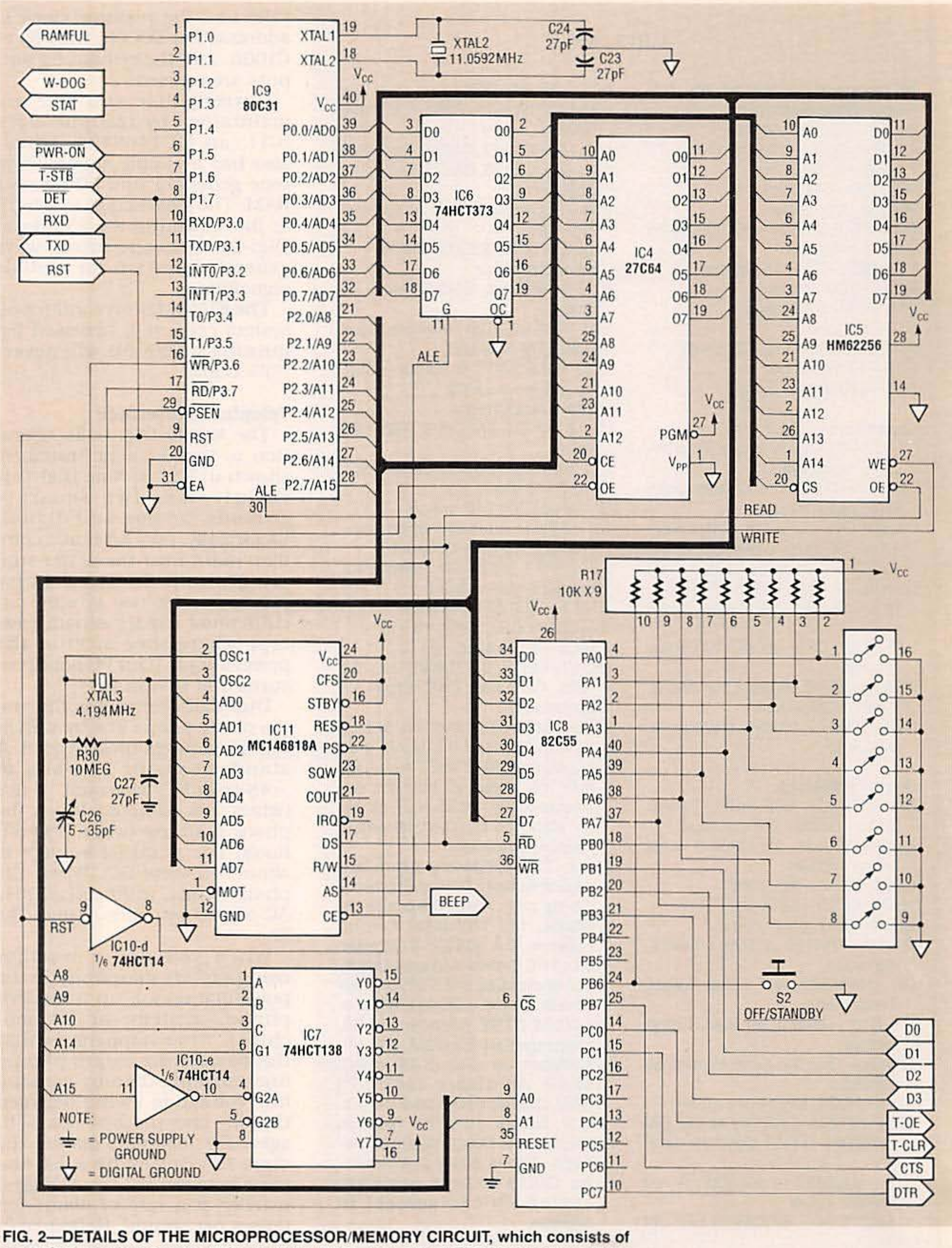


FIG. 2—DETAILS OF THE MICROPROCESSOR/MEMORY CIRCUIT, which consists of an 80C31 microprocessor, 32K of static RAM, and 8K of EPROM-based realtime software.

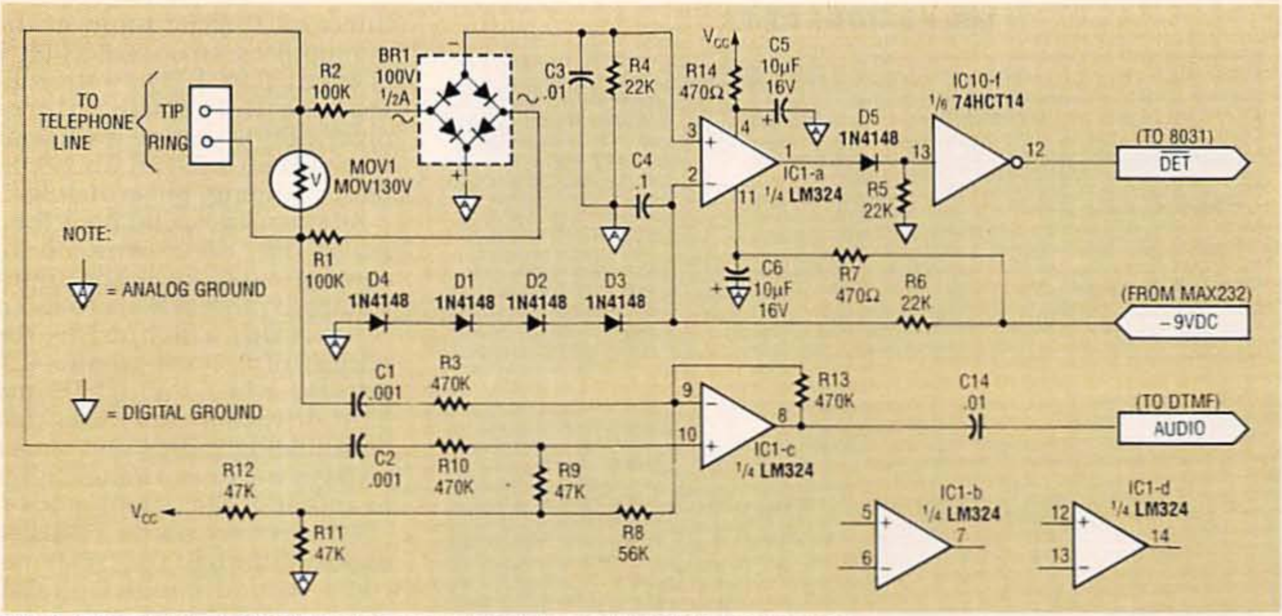


FIG. 3—TELEPHONE-LINE INTERFACE presents a high-impedance interface to avoid line loading. Note the use of separate analog and digital grounds.

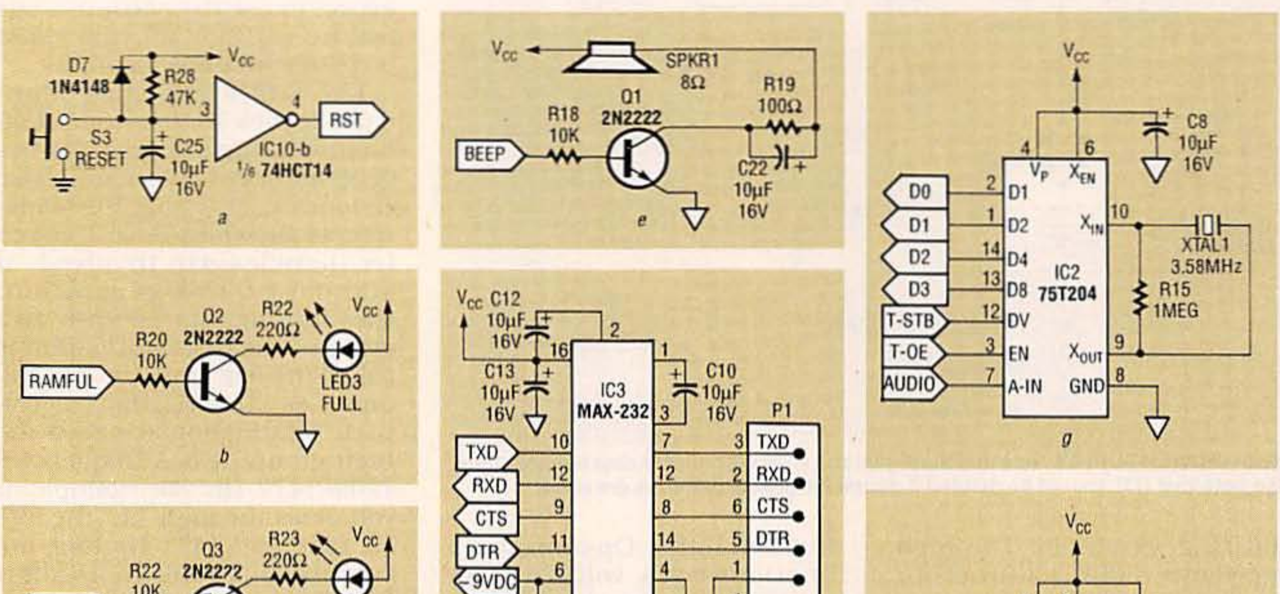


FIG. 4—MISCELLANEOUS CIRCUITS: (a) shows the reset circuit; (b), (c), and (D) show the status LED drivers; (e) shows the speaker driver; (f) shows the RS-232 interface; (g) and (h) show the DTMF interfaces. Use only one of (g) or (h), depending on the availability of DTMF decoder IC's.

TABLE 2—DTMF TONES

	High Group		
	Column 0	Column 1	Column 2
Low Group	1209 Hz	1336 Hz	1477 Hz
Row 0, 697 Hz	1	2	3
Row 1, 770 Hz	4	5	6
Row 2, 852 Hz	7	8	9
Row 3, 941 Hz	*	0	#

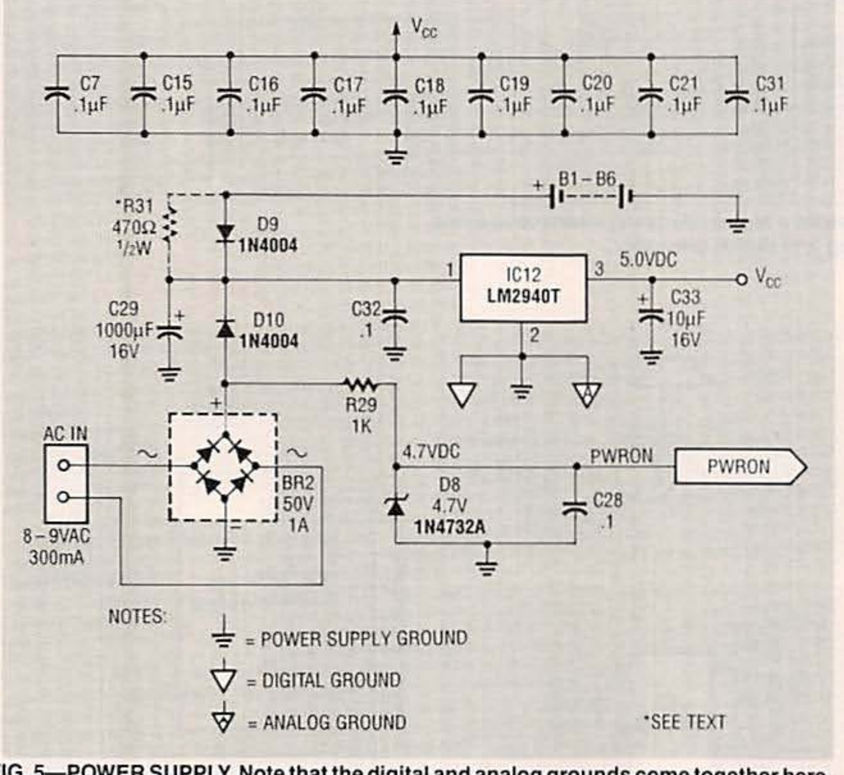


FIG. 5—POWER SUPPLY. Note that the digital and analog grounds come together here. Also note that R31 should be deleted if nonrechargeable batteries are used.

and ring terminals. The high impedance (200K) nature of our design ensures that Digi-Call does not load the phone line. *Note: The high-impedance nature of the circuit requires that Digi-Call be isolated from grounded equipment during normal operation. Only connect the PC's serial port cable during data downloads; remove the cable immediately when done. Further data recording will not occur with the PC connected! Battery-powered portables are exempt from this limitation.*

Surge absorber MOV1 provides protection against lightning strikes. Bridge rectifier BR1 provides polarity protection; BR1 also rectifies the AC ringer voltage. Op-amp IC1-a functions as a voltage comparator with a threshold of −2-volts DC, which is provided by the series connection of diodes D1–D4. The input voltage at IC1-a is the rectified phone line voltage divided down through R1/R2 and R4, which together divide the input by a factor of 10. With the phone line on-hook, the input voltage at pin 3 of IC1-a is −4.8-volts DC, which when compared to the −2-volt reference at pin 2 of IC1-a, drives the pin-1 output to about −9-volts DC. Diode D5 blocks this negative voltage, which would harm IC1-f; that input is normally pulled low by R5. The output of IC1-f, $\overline{\text{DET}}$, drives the interrupt 0 ($\overline{\text{INT0}}$) input of the microprocessor, as well as bit 7 of input port 1. The interrupt feature helps the microprocessor determine the following states: off- or on-hook, phone-ringing, pulse dialing.

All states except on-hook (i.e., not in use, not dialing, no incoming ring) force the input voltage at pin 3 of IC1-a to about −1-volt DC, which drives the output of IC1-a to about +5-volts DC, which through D5 and IC1-f drives $\overline{\text{DET}}$ low. Note that both dialing pulses and ringer voltages will cause digital pulses to appear at the output of IC1-f.

The primary source of dialed digits is through the DTMF decoder, IC2. Although Digi-Call can recognize pulse-dialed digits, tone dialing is faster, and is now the standard dialing practice in most areas. Also, if you expect to use the Account Code feature of Digi-Call, you must have tone-dialing capability.

The DTMF encoding standard defines 16 dual-tone combinations, but standard phones generate only 12 of them. Those 12 tones arise from a 3-by-4 matrix, as shown in Table 2. Seven frequencies are involved in standard DTMF generation; they are separated into two groups. The row information is called the low group; it has frequencies 697–941 Hz. The column information is called the high group; it has frequencies 1209–1477 Hz. For example, if you press the digit "3," the 697 Hz tone and 1477 Hz tone are combined. (Note: In 16-digit DTMF, there is an eighth tone, 1633 Hz, in a third column.)

Op-amp IC1-c functions as a unity-gain differential amplifier to buffer telephone audio. Capacitors C1 and C2 AC-couple the audio from the phone line; the pin-8 output of IC1-c (AUDIO) drives the DTMF decoder (IC2, shown in Figure 4) directly. (The circuit allows for two different DTMF decoders, a 75T204, shown in Fig. 4-g, and a 75T202, shown in Fig. 4-h. The PC board allows use of either.) The DTMF decoder incorporates switched-capacitor filtering to separate the low- and

continued on page 88

RICHARD D. TENNEY

SINGLE-CHIP MESSAGING SYSTEM

Our one-chip voice messaging system makes it easy to add audio-storage capability to your next project!

TALKING DEVICES SEEM TO BE ALL around us today. Virtually everywhere we go we're being spoken to by vending machines, arcade games, toys, cars, and even computer-spoken junk phone calls! There seems to be no limit to applications for devices that mimic the human voice, but the quality of the voice emanating from most talking devices has several serious flaws. It's usually monotone, lacking the natural inflection of real speech, and has less than adequate enunciation. In other words, most machine speech sounds "robotic." Worse yet is the necessity of programming a ROM (Read Only Memory) in order to change the message. It's obvious that the standard solutions are less than ideal.

The ISD 1016 Single-Chip Voice Messaging System (Information Storage Devices, Inc., Austin, TX) eliminates all those drawbacks while at the same time introducing several features and functions which greatly enhance its versatility and simplify system design.

Features

As the industry's first non-volatile analog storage chip, the ISD 1016 can record and play back up to 16 seconds of analog, or "audio" information. All analog signal conditioning circuits, amplification, and digital control circuits are contained in the single 28-pin package. Therefore, a complete voice record/playback system can be implemented by simply connecting an external microphone and speaker, and a few capacitors, resistors, and switches to the analog storage chip.

Several configuration options are available including multiple message, continuous repeat, and fast forward. These options are in addition to, but mutually exclusive of, the message addressing mode, which allows the user to directly address any segment of the analog storage array. By offering capabilities such as direct analog input, analog storage, and analog output, the ISD 1016 provides a high-grade voice record and playback system.

Novel approach

Key to the ISD 1016 is the unique method of storing the analog signal. Conventional circuits first sample the incoming analog signal and send it to an A/D converter that provides a digital output, typically eight bits wide, which is proportional to the amplitude of the incoming signal. Therefore, this method requires at least eight bits of storage per sample. Playback of the data requires that the eight bits of digital data be sent to a D/A converter to reproduce the original analog signal.

The ISD 1016 eliminates the A/D and D/A conversions by using CMOS EEPROM (Electrically Eraseable Programmable Read Only Memory) technology and storing the sampled data as an analog level in the EEPROM storage array. This method requires only one cell per sample and has the added advantage of being nonvolatile. The signal can be stored for ten or more years without power.

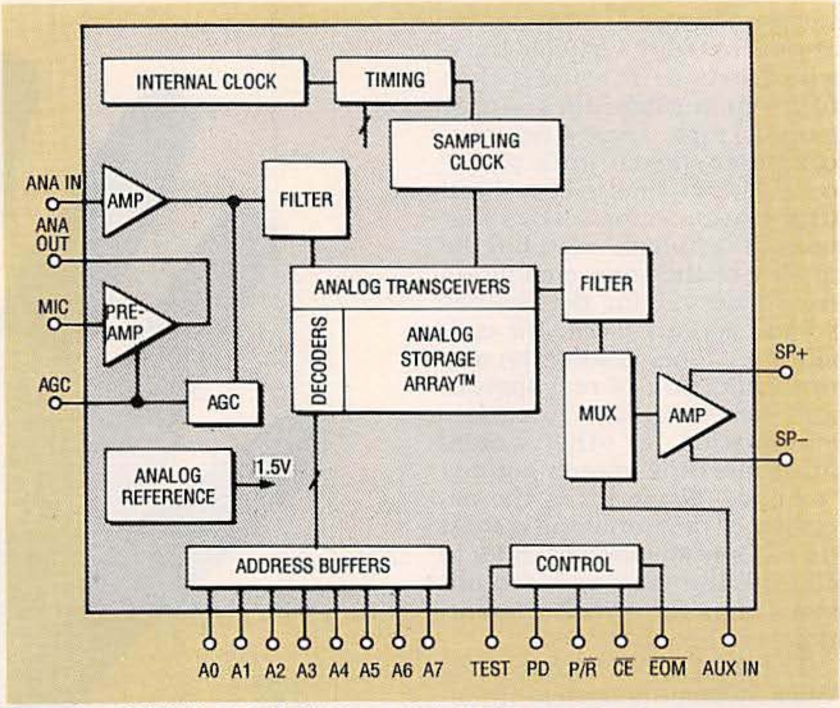


FIG. 1—FUNCTIONAL BLOCK DIAGRAM OF THE ISD 1016. The microphone signal is capacitively coupled to the input preamp, and the gain of the preamp is dynamically adjusted by the AGC circuit.

How it works

Figure 1 shows the functional block diagram of the ISD 1016. The microphone signal is capacitively coupled to the input preamp. The gain of the preamp is dynamically adjusted by the AGC (Automatic Gain Control) circuit, which reduces the gain of the preamp for large input signal levels, and increases it for lower-level signals, thereby expanding the range of input signal levels that can be accommodated without distortion.

The output of the preamp is then coupled to an additional amplifier stage through an external capacitor. This stage has two main functions. One is to provide an input to the AGC circuitry so it can adjust the gain of the preamp according to the strength of the incoming signal. The second role of this stage is to drive the filter network which will remove noise and other unwanted signals outside of its passband.

The gain-adjusted and filtered signal is then fed to the analog transceivers. In the record mode, these transceivers take their input from the input filter and send the signal to the analog storage array. In playback mode they take their input from the analog storage array and send it to the output filter network.

Timing circuitry internal to the ISD 1016 synchronizes the operation of the analog storage array and the analog transceivers, and also generates a sampling clock. The analog audio input signal is sampled by that clock at an 8-kHz rate, which is adequate for an audio passband of 3.4 kHz (about the same as a telephone), and is stored in the analog storage array as a voltage level. During playback, the storage array is sampled and sent to the output filter via the analog transceivers. This filtered signal is then sent to one input of an analog multiplexer, which will select one of its two inputs to drive the power amp. In playback mode, the stored message will be selected, amplified, and sent to the speaker. When not in record mode, and not playing

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise noted.
R1—2000 ohms
R2—10,000 ohms
R3—470,000 ohms
R4—1000 ohms × 9, 10-pin SIP resistor

Capacitors
C1, C4—22 µF, 16 volts, tantalum
C2, C6—0.1 µF, ceramic
C3—4.7 µF, 16 volts tantalum
C5—0.22 µF, polystyrene
C7—1 µF, 16 volts, tantalum

Semiconductors
IC1—ISD 1016 Voice Messaging System

Other components
S1–S3—SPDT miniature slide switch
S4—8 position DIP switch
MIC1—miniature electret microphone

Miscellaneous: 28-pin IC socket, 16-ohm speaker, power source of at least 5 volts, wire, solder, etc.

Note: The following items are available from R. Tenney, 33 Eastmeadow Way, Manchester, N.H. 03109:
- **ISD 1016 IC—$35.00**
- **Etched and drilled PC board—$9.75**
- **A kit of all parts except speaker—$55.00.**

Please add $2.50 postage and handling.

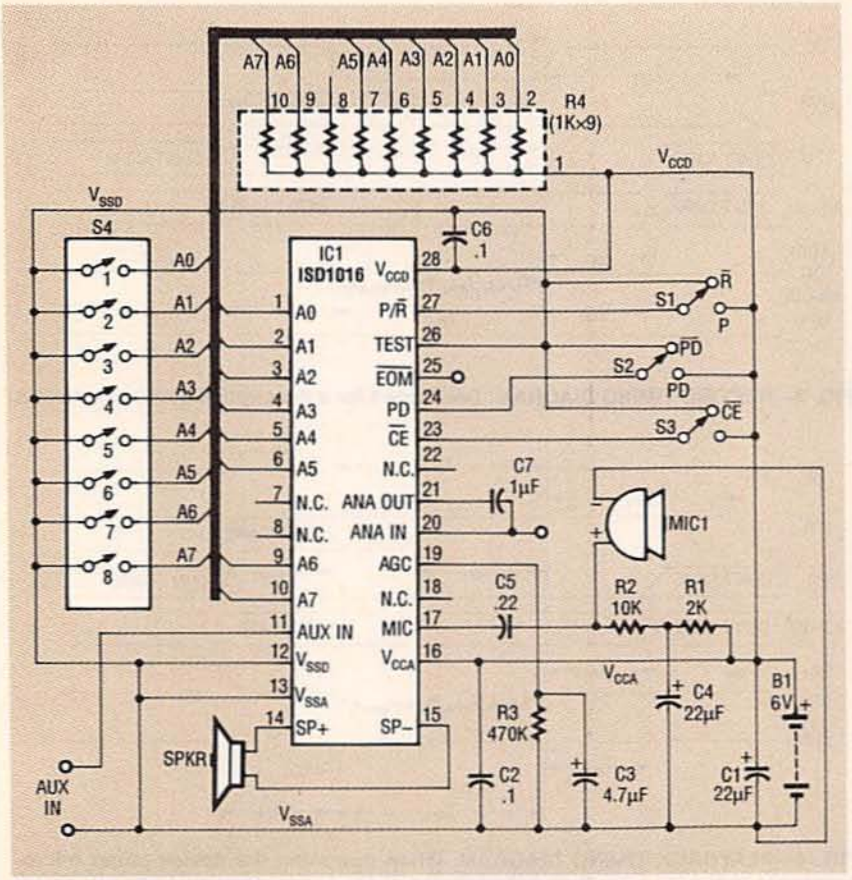


FIG. 2—SCHEMATIC DIAGRAM of the complete voice recording and playback system capable of storing up to 16 seconds of telephone-grade audio.

back a message, the multiplexer will select the auxiliary input as its source, thus allowing us to take advantage of the output amplifier when the ISD 1016 is otherwise idle.

Circuit details

Figure 2 shows the schematic diagram of a complete voice recording and playback system that is capable of storing up to 16 seconds of telephone-grade audio. Before we go over the schematic, let's go over the pin functions of the ISD 1016 to make it easier to understand the overall operation of the circuit.

• Microphone Input (MIC), pin 17—An external microphone is coupled to this input through a series capacitor. The value of the capacitor and the 10K internal resistance of the input determines the low-frequency cutoff for the ISD 1016. A good-quality omni-directional electret microphone is recommended. Its impedance should be about 1K, sensitivity 64 dB, frequency response 50 Hz to 8 kHz, and S/N ratio greater than 40 dB. Refer to the parts list for sources.

• Analog Out (ANA OUT), pin 21—The amplified analog input signal appears on the analog output pin. The gain of the preamp is determined by the voltage level at the AGC pin. Maximum gain is about 24 dB for low-level signals.

• Analog Input (ANA IN), pin 20—This pin has two roles. The analog output (pin 21) of the preamp can be coupled via an external capacitor to this analog input pin. The value of the capacitor and the 2.7K input resistance of this input pin can provide additional cutoff at the low-frequency end of the passband. Alternatively, this pin can be used to input analog signals other than the microphone signal.

• Automatic Gain Control (AGC), pin 19—As described in the section on the block diagram, the AGC circuit will dynamically adjust the gain of the preamp. Peak output voltages of the preamp will be detected and charge an external capacitor. The time it takes for the capacitor to charge to a level that will start to reduce the gain of the preamp (about 1.8V) is known as the "attack time," and is determined by the value of the capacitor and the 5K internal resistance of the AGC input. The "release time" of the AGC is determined by this capacitor in parallel with an external resistor.

• Speaker Outputs (SP+), pin 14 and (SP–), pin 15—The ISD 1016 can directly drive speakers with impedances as low as 16 ohms. The maximum output power of 50 mW is achieved when the speaker is connected between these two pins. In that configuration no coupling capacitor is required. The device can be used in a single-ended configuration; however, an AC coupling capacitor must be used and the output power will be reduced to about 12 mW. While recording, the speaker outputs are disabled. An 8-ohm speaker can be used, but the volume will be louder and some audio distortion can result.

• Power Down (PD), pin 24—This pin serves two purposes in the operation of the chip. First, it provides a low-power mode when the ISD 1016 is at idle (not recording or playing back) and the pin is high. The second function of this pin is to provide a means to reset the address counter. Whenever the ISD 1016 reaches overflow (after 16 seconds total record or playback time) the address counter is at its maximum recording count (9Fh) and an EOM (end of message) pulse will be generated. Activating CE (chip enable) will not restart the device until PD was cycled high and low. NOTE: When recording multiple messages, the user should terminate each message by disabling CE while keeping PD low. That will prevent the address counters from getting reset to zero at the start of the subsequent message, thereby causing the previous message to be overwritten.

• Chip Enable ($\overline{\text{CE}}$), pin 23—When taken low, this pin enables all playback and record operations. The address and play/record inputs that meet the set-up time (300 ns) are latched on this falling edge. When this pin is taken high, the ISD 1016 is deselected and the auxiliary input is selected as the input to the output power amp.

• Play/Record (P/$\overline{\text{R}}$), pin 27—The state of this input is latched into the ISD 1016 on the falling edge of $\overline{\text{CE}}$ (along with the address inputs (A0–A7). A logic high selects playback mode and a logic low selects a record operation. The message to be played will start at the address latched when $\overline{\text{CE}}$ went low. The message will continue until an $\overline{\text{EOM}}$ (end of message) is encountered on pin 25. The $\overline{\text{EOM}}$ bit is automatically inserted during a record operation when the storage area is full or when the record operation is terminated by PD going low or $\overline{\text{CE}}$ going high. If multiple messages have been recorded, $\overline{\text{CE}}$ should be pulsed low for the device to play back a single message. If $\overline{\text{CE}}$ is held low (active), all the stored messages will be played back in sequence.

• Address Inputs (A0–A7), pins 1–6, 9, 10—Two functions are performed by the address inputs: mode and option selection, and message address. The ISD 1016 has two modes of operation, Address Mode and Configuration Mode. Address bits 6 and 7 determine which mode will be selected. If either bit 6 or bit 7 is low, Address Mode will be selected. In that mode the address pins specify the starting address of the operation to be performed. If both address 6 and 7 are high, the configuration mode is selected. Table 3 lists the configuration mode options. Of the options listed, continuous repeat and multiple message recording can be of the most use to the experimenter. Further details of their use can be found in the section on "Modes of Operation."

• End Of Message ($\overline{\text{EOM}}$), pin 25—At the end of each recorded message, an $\overline{\text{EOM}}$ marker is automatically inserted in a non-volatile register. The $\overline{\text{EOM}}$ output will go low at the end of each message and at message overflow. The width of the negative pulse is 12.5 ms minimum. Another function of $\overline{\text{EOM}}$ is as a low-power indicator. If power to the chip should drop below 3.5V, $\overline{\text{EOM}}$ will be forced low and the ISD 1016 placed in playback mode. This feature helps prevent recording while in an unreliable power condition.

• Auxiliary Input (AUX IN), pin 11—As explained earlier, AUX IN is selected as the input to the output power amplifier when either $\overline{\text{EOM}}$ is true or $\overline{\text{CE}}$ is not true, thus allowing us to take advantage of the amplifier for other uses when the ISD 1016 is otherwise inactive.

• 5-volt Analog and Digital Power Inputs (V_{CCA}), pin 16 and (V_{CCD}), pin 28—The ISD 1016 voice messaging system chip incorporates both digital and analog circuitry. The digital circuitry generates considerable noise from rapid switching of gates within the device, as does any other digital device. The noise is easily detected by the analog circuitry and can, therefore, be recorded as noise in the analog signal. For that reason, separate power and ground buses are provided for the analog and digital portions of the device. In that manner, currents flowing in the digital portions of the device cannot cause significant voltage fluctuations in the analog power buses. The two power pins should be connected together as close as possible to the power source. That is the *only* location where the two power busses should be connected together. If another direct connection between V_{CCA} and V_{CCD} were to be made at any other point, a "loop" would be formed and slight voltage differences between the two points would cause unwanted currents to flow in this loop, providing another source of noise.

• Analog and Digital Ground Connections (V_{SSA}), pin 13 and (V_{SSD}), pin 12—NOTE: The ground connections for the ISD 1016 do not conform to a stan-

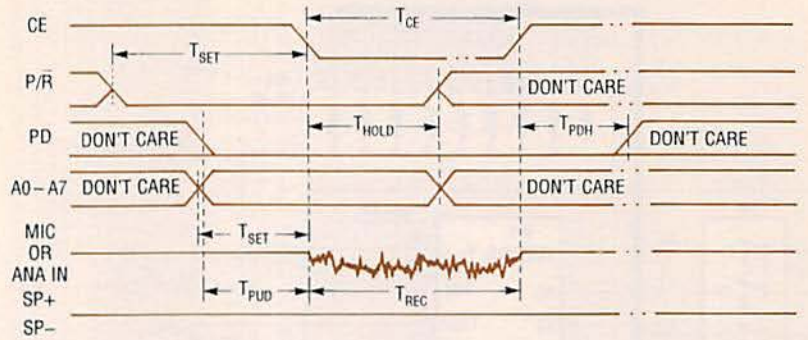


FIG. 3—RECORD TIMING DIAGRAM. See Table 1 for a description of the parameters.

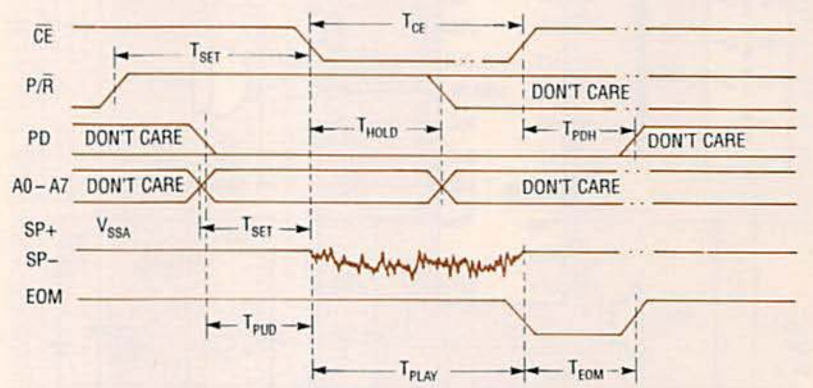
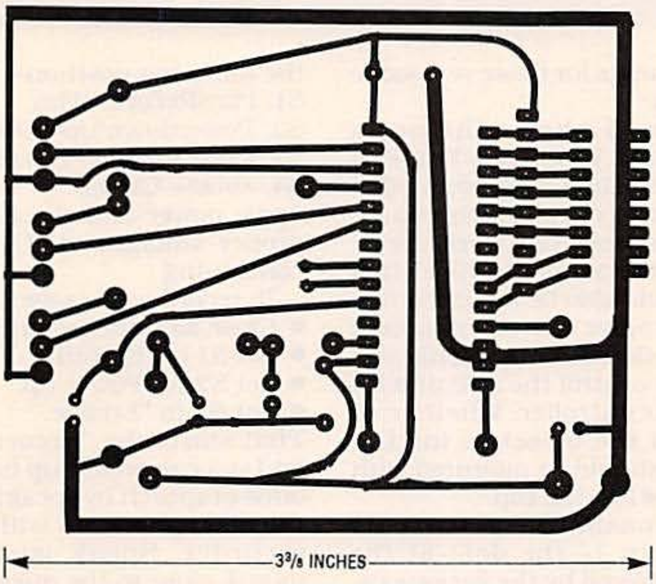


FIG. 4—PLAYBACK TIMING DIAGRAM. When operating the device under microprocessor control or other high-speed device, these parameters must be considered.

TABLE 1—TIMING & VOLTAGE PARAMETERS

Symbol	Parameter	Value
FS	Sampling Freq.	8 kHz
BW	Bandwidth	3400 Hz typ.
P_{OUT}	Speaker Output Power	50 mW max.
V_{IN1}	Mic Input Voltage	20 mV max. p-p
V_{IN2}	Ana Input Voltage	80 mV max. p-p
V_{IN3}	Aux Input Voltage	1.25 V max. p-p
T_{SET}	Control/Address Set-up	300 ns min.
T_{HOLD}	Control/Address Hold	0 ns max.
T_{CE}	$\overline{CE}$ Record Time	100 ns min.
T_{PUD}	Power Up Delay	25 ms min.
T_{PDH}	Power Down Hold	0 ns min.
T_{REC}	Record Time	16 s max.
T_{PLAY}	Playback Time	16 s max.
T_{EOM}	$\overline{EOM}$ Pulse Width	12.5 ms typ.



FOIL PATTERN for the voice messaging system.

dard 28-pin DIP. V_{SSA} and V_{SSD} are the return paths for the analog and digital sections of the device, respectively. Follow precautions similar to those described for the power inputs. Pins 12 and 13 should be tied together at the package, and power should be decoupled using 0.1µF capacitors between V_{CC} and V_{SS}, as close as possible to the package, for both analog and digital power.

• Test Input, pin 26 (TEST)—This pin is used during the manufacturing operation prior to product shipment. For proper device operation this pin *must* be tied low.

Now that we have a better understanding of how the ISD 1016 works, let's go over the schematic (Fig. 2). Resistors R1 and R2 supply the microphone bias for the electret microphone (MIC1) recommended in the parts list. Capacitor C4 provides microphone decoupling and C5 provides input coupling and DC blocking for the microphone while also acting as a single-pole, low-frequency cutoff filter. Capacitor C7 provides AC coupling between the preamp output and the input amplifier, and also provides additional low-frequency cutoff.

Resistor R3 and capacitor C3 provide the AGC attack/release time constants. For strong input signals, the AGC circuit internal to the ISD 1016 starts charging C3. If the signal remains strong long enough for C3 to reach the AGC threshold level (about 1.8V), the gain of the preamp is reduced to prevent it from being overdriven. If the input signal level decreases, C3 starts to discharge through R3, thus increasing the gain of the preamp for low-level signals.

Capacitor C1 provides V_{CC} decoupling, C2 is the V_{CCA} high-frequency decoupling capacitor, and C6 provides the same function for V_{CCD}. C1 should be located as close to the supply as possible, and C2 should be as close to IC1 as possible. Switches S1, S2, and S3 provide the control functions for PLAYBACK/RECORD, POWERDOWN, and CHIP ENABLE inputs respectively.

Resistor R4 is a SIP (Single-Inline-Package) containing nine resistors, one of which is not used. Those pull-up resistors are used so we can implement the address switches with an inexpensive eight-position DIP switch (S4) instead of eight individual switches.

The output amplifier of the ISD 1016 is designed to drive a 16-ohm speaker; a standard 8-ohm speaker can be used, but you'll end up with slightly louder volume, slightly greater power dissipation, and some distortion. In general, the better the quality of the speaker, the better the sound quality.

Timing diagrams

Figures 3 and 4 show the timing diagrams for the record and playback modes respectively. The parameters referenced are shown in Table 1. When operating the device manually, parameters such as setup and hold times are met by simply following the recommended procedures outlined later in this article. When operating the device under microprocessor control or other high-speed device, these parameters must be considered when controlling the chip. For example, to set up for a record operation the address lines should be set by one instruction and the $\overline{CE}$ line set by a subsequent instruction to ensure the 300-ns control/address setup time (T_{SET}) is met.

Construction

A complete kit of parts, including an etched and drilled

PC board, is available from the source in the parts list. A foil pattern is provided here if you would like to make your own board. None of the component values are critical, but be sure to leave pins 7, 8, 18, and 22 unconnected, no matter what you do.

If you're making your own layout, some simple guidelines should be followed for best results. Note that V_{CCA} and V_{CCD} should be connected at one point only, right where power enters the board. Likewise, V_{SSA} and V_{SSD} should be connected together right at pins 12 and 13 of IC1. That isolates the analog signal and ground paths from the digital paths, thus reducing noise. Also, the analog components should be physically separated from the digital components for those very same reasons.

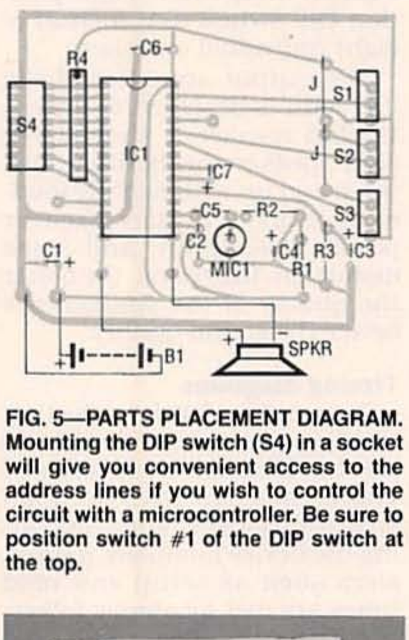


FIG. 5—PARTS PLACEMENT DIAGRAM. Mounting the DIP switch (S4) in a socket will give you convenient access to the address lines if you wish to control the circuit with a microcontroller. Be sure to position switch #1 of the DIP switch at the top.

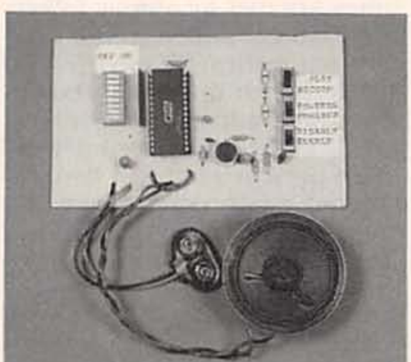


FIG. 6—THE COMPLETED PROTOTYPE. The 9-volt battery clip attaches to a 4-AA cell holder that has a matching connector; the prototype voice messaging system, therefore, is powered from a total of 6 volts.

TABLE 2—OPTIONS

Function	Address Bit	Use
Playback chip enable level activated	5	Provide switch debounce
Message start pointer reset only play/record changed	4	Recording multiple messages
Continuous repeat of message	3	Continuous repeat at $\overline{EOM}$ encounter
During playback $\overline{EOM}$ pulses low at overflow only	2	Concatenate chips for longer messages
$\overline{EOM}$ markers deleted by next message	1	Assures that $\overline{EOM}$ markers are cleaned up when recording over message
Fast forward (speaker output is disabled)	0	Selecting messages when address is unknown

Figure 5 shows the parts placement diagram. The ISD 1016 (IC1) should be mounted in a 28-pin socket, which can be installed now, but leave the IC out for the moment. DIP switch S4 should also be mounted in a socket to give convenient access to the address lines should you wish to control the circuit with a microcontroller. Whether or not you use a socket, the DIP switch should be mounted with switch #1 at the top.

Next mount SIP resistor R4 (with pin 1—the dot—at the top), followed by the various capacitors, discrete resistors, and the microphone. Be certain to observe polarity when installing C1, C3, C4, C7, and the microphone. Next mount switches S1–S3 and the leads for the speaker and the power source. (The prototype uses a standard 9-volt battery clip and a 4-AA cell holder that snaps onto the 9-volt clip.) Figure 6 shows the completed prototype.

After all components have been mounted, check for any shorts or solder bridges, and verify proper orientation of all components. After these checks have been made, install IC1 in its socket verifying proper orientation, and connect a speaker to the speaker terminals.

Operation

Before connecting power to the circuit, set all switches to the following positions:
S1, Play/Record—Play
S2, Powerdown/Up—Down
S3, Chip Enable—Disable
S4, A0–A7—Closed
Apply power and check for the proper voltages at IC1 before continuing.

To record a message:
- Close all switches on S4.
- Set S1 to "Record."
- Set S2 to "Power up."
- Set S3 to "Enable."

That starts the "Record" time and you can record up to 16 seconds of speech by speaking into the microphone, as with a tape recorder. Speak with your mouth close to the microphone in a normal voice. When you are finished recording your message you should:
- Set S3 to "disable."
- Set S2 to "Powerdown."
- Set S1 to "Play."

To play back a message:
- Set S1 to "Play."
- Set S2 to "Power up."
- Toggle S3 to the "Enable" position and back to the "Disable" position.

Your pre-recorded message will now play back and stop at the end. When the message is complete, set S2 to the "Power down" position.

Addressing mode

The ISD 1016 has two mutually exclusive modes of operation: the "Addressing Mode" and the "Configuration Mode." The addressing mode is selected

continued on page 92

WORKING WITH LED DISPLAY DRIVERS

Let's take an in-depth look at LED display drivers.

RAY MARSTON

IT'S EASIER THAN YOU THINK TO DEsign LED display drivers with National Semiconductor's LM391X and LM2917 series IC's. In this article, we'll show you how to use those IC's to build moving-dot and bar-graph voltmeters as well as frequency-to-voltage converters. We'll also give you an introduction to binary coded decimal (BCD) to 7-segment decoder/driver circuits that are commonly used in electronics design.

LM391X-series basics

National Semiconductor's LM391X dot/bar display drivers are versatile 18-pin DIP IC's that can be used to drive up to 10 LED's in either dot or bar mode. The three members of the LM391X display driver series are the LM3914, LM3915, and LM3916. All three versions use the same basic internal circuitry, as shown in Fig. 1, but have different output scaling modes, as shown in Table 1.

The LM3914 is a linearly-scaled device that's intended for use in LED voltmeters, with the number of lit LED's being directly proportional to the input voltage (pin 5). The LM3915 is a logarithmically-scaled device that's intended for use in power meters, and spans a range of 0–30 dB in ten 3-dB steps. Finally, the LM3916 is a semi-logarithmically-scaled device that's intended for use in volume-unit (VU) meters.

Figure 1 shows an LM3914 used in a simple 10-LED voltmeter, which ranges from 0 to 1.25 volts DC. The LM3914 has 10 internal comparators, each with its non-inverting terminal connected to a specific tap on a floating, precision, 10-stage, internal resistive voltage-divider. The inverting terminals on all ten of the comparators are fed by a unity-gain buffer on pin 5. Each comparator is externally accessible, and can sink up to 30 milliamps. The sink currents are internally limited, and are externally pre-set via R1.

The LM3914 also has a floating 1.25-volt DC reference between pins 7 and 8, externally connected to the 10-stage internal voltage divider on pins 4 and

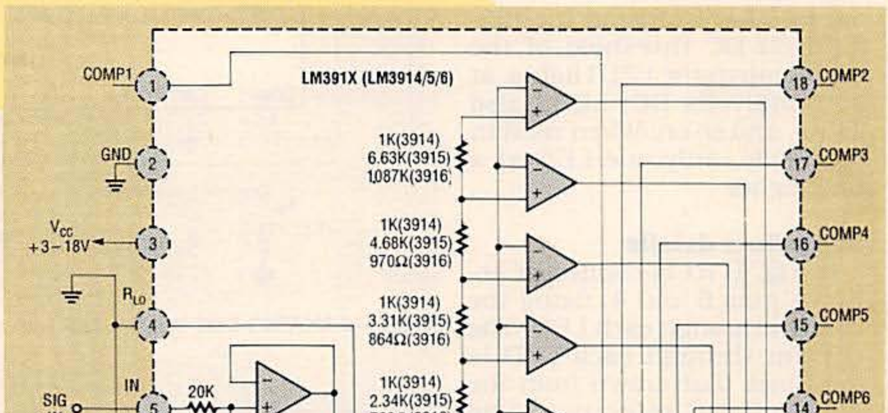


FIG. 1—INTERNAL CIRCUIT OF THE LM3914, with connections for making a 10-LED, 0 to 1.25 volts DC, linear meter using either dot or bar mode.

6. Pins 4 and 8 are grounded, so that the bottom of the 10-stage internal voltage divider is at ground, and the top is at 1.25 volts DC. The LM3914 also has an internal logic network that can be used to select either moving-dot or bar-graph mode.

If the LM3914 is set for bar mode, the 1.25-volt DC reference is connected across the 10-stage internal voltage divider. Because of the linear scaling of that divider, each succeeding inverting comparator input has an additional 0.125 volts DC applied to it.

When there is no signal on the input, pin 5 is at ground, all 10 internal comparators are disabled, and LED's 1–10 are off. With a slowly rising signal on the input, the voltage increases to 1.25 volts DC, and an LED lights for each 125-millivolt increment, until LED's 1–10 are on. In other words, at the 125-millivolt DC threshold of the first comparator, LED1 lights, at 250 millivolts DC, LED2 also lights, and so on. When used in dot mode, only one LED at a time lights.

Some finer details

In Fig. 1, R1 is connected between pins 6 and 4, fixing the current through each LED. The current through each LED is ten times that drawn from the 1.25-volt DC reference. The 1.25-volt DC reference can source up to 3 milliamps, so the maximum current through each LED is 30 milliamps, set by R1, but the LED current doesn't normally get that high.

The nominal value of 1.25 volts DC can also be varied between 1.20 and 1.32 volts DC, or its value can be externally programmed to produce up to 12 volts DC. If R1 equals 1.2K, then R1 in parallel with the full 10K value of the internal voltage divider is equivalent to 1.07K. The current drawn from the 1.25-volt DC source is

$$1.25\ V/1.07K = 1.2\ mA,$$

so that each LED nominally draws 12 milliamps when it's lit.

Since the maximum individual current through each LED is 30 milliamps, then the LM3914 draws up to 300 milliamps total in bar mode with LED's 1–10 on. The maximum power rating of an LM3914 is only 660 milliwatts, which can easily be exceeded in bar mode if you're not careful. The LM391X series runs on a supply of 3–25 volts DC, and the LED's can use the same voltage supply, or they can use an independent supply for minimal IC heat dissipation.

The internal voltage divider is floating, with both ends externally available for maximum

TABLE 1—COMPARISON OF TYPICAL INPUT THRESHOLDS FOR THE LM391X IC FAMILY

LED	LM3914	LM3915		LM3916		
	V	V	dB	V	dB	VU
1	1.000	0.447	−27	0.708	−23	−20
2	2.000	0.631	−24	2.239	−13	−10
3	3.000	0.891	−21	3.162	−10	− 7
4	4.000	1.259	−18	3.981	− 8	− 5
5	5.000	1.778	−15	5.012	− 6	− 3
6	6.000	2.512	−12	6.310	− 4	− 1
7	7.000	3.548	− 9	7.079	− 3	0
8	8.000	5.012	− 6	7.943	− 2	+ 1
9	9.000	7.079	− 3	8.913	− 1	+ 2
10	10.000	10.00	0	10.000	0	+ 3

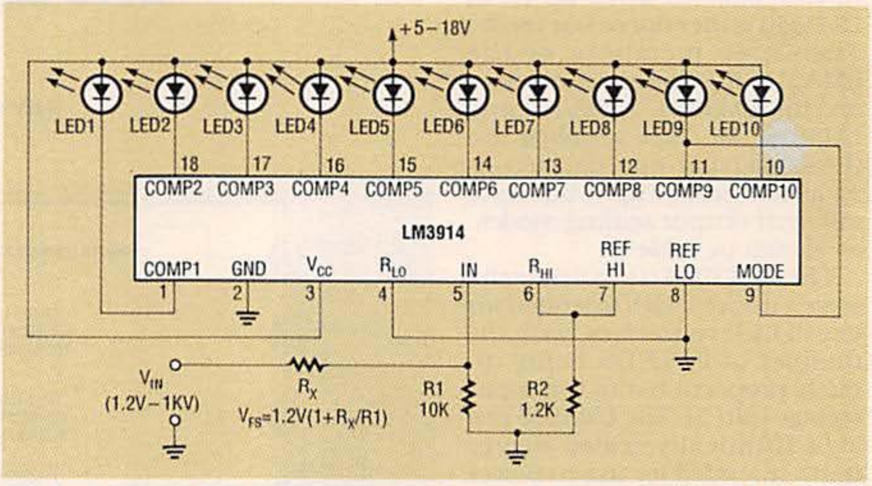


FIG. 2—A MOVING-DOT VOLTMETER with a range of 1.25 volts to 1 kilovolt DC.

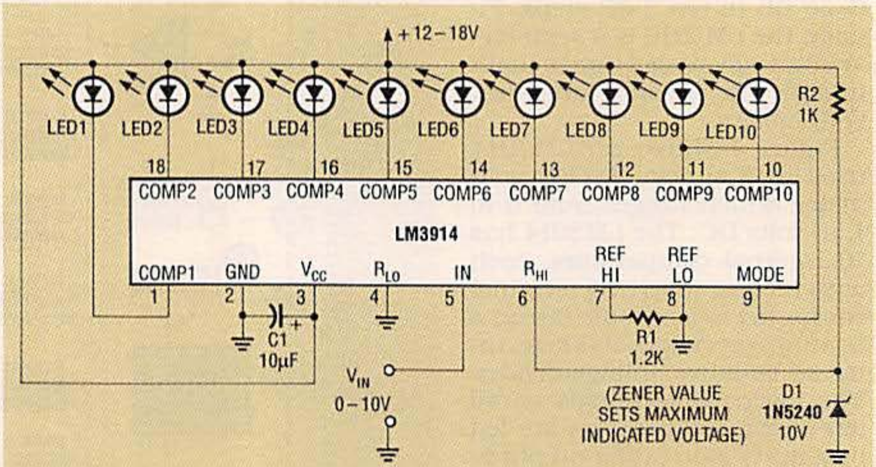


FIG. 3—A VOLTMETER RANGING from 0 to 10 volts DC using an external reference.

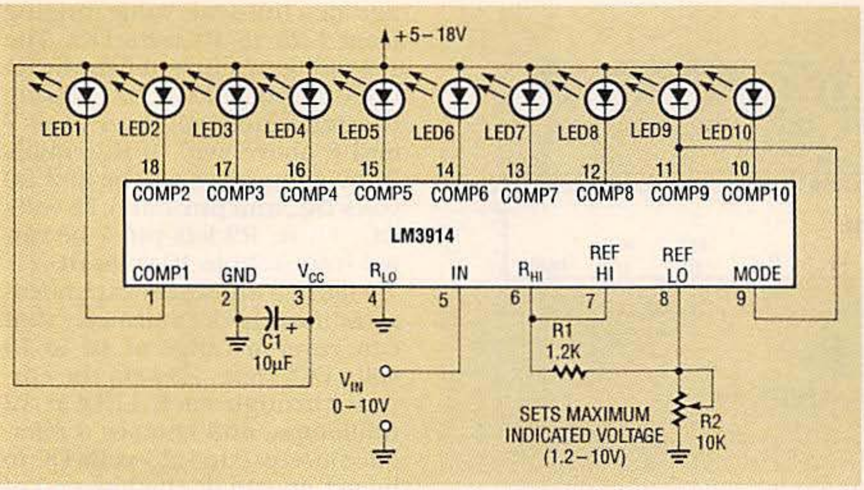


FIG. 4—AN ALTERNATE VARIABLE-RANGE voltmeter that can allow a variation in the maximum value of its range from +1.25 to 10 volts DC.

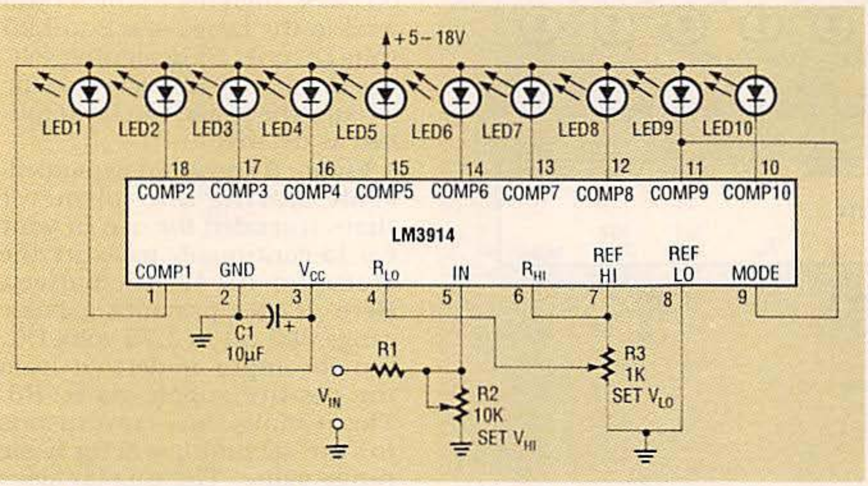


FIG. 5—AN EXPANDED-SCALE MOVING-DOT voltmeter that ranges from 10 to 15 volts DC.

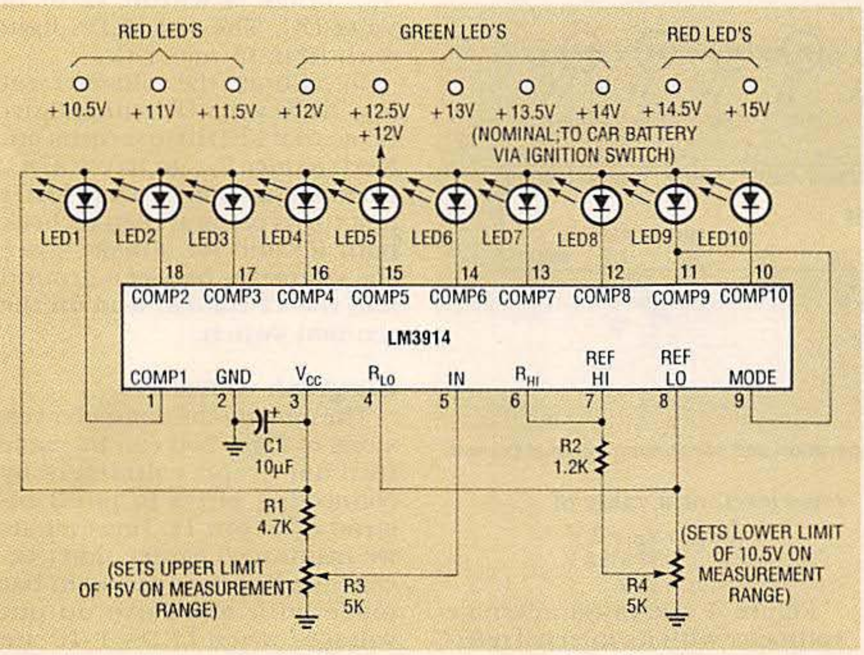


FIG. 6—AN EXPANDED-SCALE DOT-GRAPH voltmeter for use with a car battery.

versatility, and it can be powered by either the internal reference or an external source. If pin 6 is connected to 10 volts DC, then the LM3914 becomes a voltmeter ranging from 0 to +10-volts DC if pin 4 is grounded, or a restricted-range DC voltmeter ranging from 5 to 10 volts DC if pin 4 is connected to 5 volts DC.

The only constraint is that pin 4 cannot go more than 2 volts below V_{CC}. The input is fully protected against overloads up to ±35 volts DC.

As we mentioned earlier, the major difference between the three members of the LM391X family is in the weighting of the ten-stage internal voltage dividers. In the LM3914, the values are equal, producing a ten-step linear display. In the LM3915, the values are logarithmically-weighted, producing a log display spanning 30 dB in ten 3-dB steps. The values are semi-logarithmically weighted in the LM3916, producing a volume unit (VU) meter display. Let's now examine some LM391X applications, focusing on the LM3914.

Moving-dot voltmeters

Figures 2–6 show the LM3914 used in various 10-LED moving-dot voltmeters. In all of them, pin 9 is connected to pin 11, and a 10 μF capacitor is connected between pins 2 and 3 for stability.

Figure 2 shows a variable-range moving-dot voltmeter that can cover a range of 1.25 volts to 1 kilovolt DC. The low ends of the internal reference and the 10-stage internal voltage divider are grounded, while the top ends are joined. The voltmeter has a basic full-scale sensitivity of 1.25 volts DC, with variable ranging provided by voltage divider Rx-R1. When Rx equals 0 ohms, the full-scale value is 1.25 volts DC, and when Rx equals 90K, the full-scale value is 12.5 volts DC. Also, R2 is connected across the internal reference and sets the current through each LED at 10 milliamps, as before.

Figure 3 shows a fixed-range moving-dot voltmeter that can

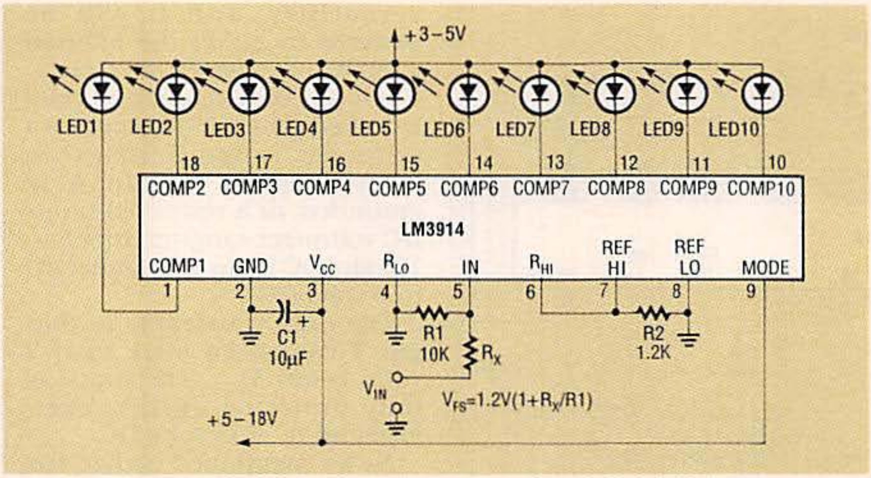


FIG. 7—A BAR-GRAPH VOLTMETER USING a separate supply for LED's 1–10.

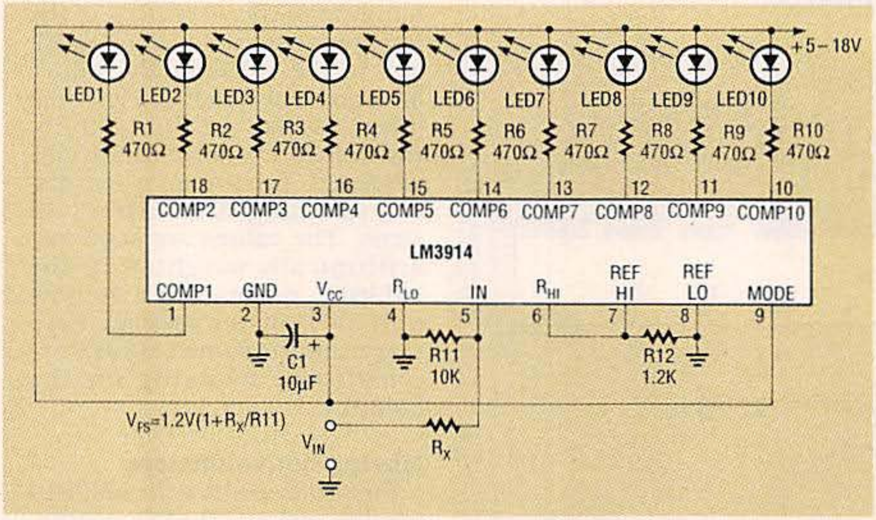


FIG. 8—A BAR-GRAPH VOLTMETER USING a common supply for both IC1 and LED's 1–10.

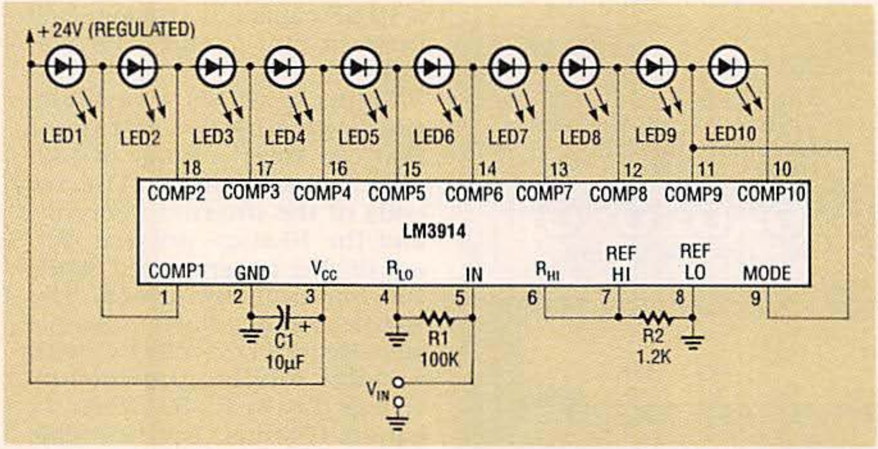


FIG. 9—A BAR-GRAPH USING dot-mode operation and consuming minimal current.

cover a range of 0 to 10 volts DC. It uses an external Zener diode reference D1 going to the top of the 10-stage internal voltage divider for a 10-volt DC reference. Also, the supply must be at least 2 volts DC above the Zener reference level, or a value of

$$V_{CC} = V_{D1} + 2\ V$$
$$= 10\ V + 2\ V,$$
$$= 12\ V.$$

Figure 4 shows an alternate voltmeter with its internal reference providing a variable voltage for a full-scale value ranging from 1.25 to 10 volts DC. The 1.2-milliamp current fixed by R1 goes to ground via R2, raising the reference value on pins 7 and 8 above zero. If R2 equals 2.4K, then pin 8 will be at 2.50 volts DC, and pin 7 at 3.75 volts DC. Thus, R2 lets pin 7 be varied from 1.25 to 10 volts DC.

Figure 5 shows an expanded-scale moving-dot voltmeter that can cover a range of 10 to 15 volts DC. Here, R3 sets the current through each LED at 12 milliamps, and enables a reference level of 0 to 1.25-volts DC to be set on pin 4, the low end of the 10-stage internal voltage divider. If R3 is set for 0.8 volts DC on pin 4, then the voltmeter will read in the range of 0.8 to 1.25 volts DC only. By designing voltage divider R1-R2 for a specific circuit, the range can be amplified as desired.

Figure 6 shows an expanded-scale moving-dot voltmeter that's intended for use in your car to continually measure the status of its 12-volt battery. Here, R2-R4 provides a basic range of 2.50 to 3.75 volts DC, but the input is derived from the positive supply via R1-R3. The reading thus corresponds to a pre-set multiple of the basic range value. The display uses red and green LED's, with the green LED's lighting when the V_{CC} range is within 12 to 14 volts DC. The red LED's light with 10 to 15 volts DC.

To calibrate the voltmeter, set V_{CC} to 15 volts DC, and adjust R3 so that LED10 just turns on. Next, reduce V_{CC} to 10 volts DC, then adjust R4 so that LED1 just turns on, and then recheck both R3 and R4. Finally, place the voltmeter between ground and the 12-volt-DC lead on the ignition switch.

Bar-graph voltmeters

The moving-dot voltmeter versions of Figs. 2–6 can be made into bar-graph voltmeters by connecting pin 9 to pin 3 instead of to pin 11. However, as we mentioned earlier, don't exceed the IC power rating in bar mode with excessive output voltages when LED's 1–10 are on. Figure 7 is a bar-graph voltmeter that uses a separate supply for its ten LED's.

Most LED's drop about 2 volts when on, so one way around that problem is to use a separate 3 to 5-volt DC source for them, as shown in Fig. 7. Figure 8 is another variation of the bar-graph voltmeter using the same supply for the LM3914 and the ten LED's. If you use the same supply to operate both the IC and the LED's, then be sure to use a current-limiting resistor in series with each LED as shown in Fig. 8, so the IC output terminals saturate when they are lit.

Figure 9 shows another bar-graph display, one that doesn't exhibit excessive power loss. Here, LED's 1–10 are all in series, but each one is connected to an individual IC output, and the IC is in dot mode. Thus, if LED5 was on, its current would be drawn through LED's 1–4, so LED's 1–5 would also be on, creating a bar-graph display. In that case, the total current through all of the LED's is that of a single LED, so the total power dissipation is very low.

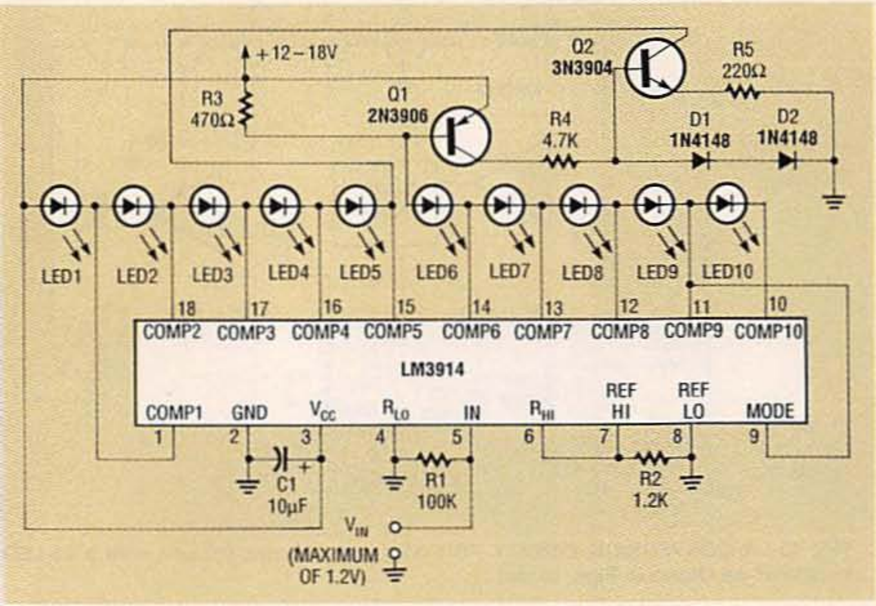


FIG. 10—A MODIFICATION OF THE VERSION in Fig. 9, using an unregulated 12 to 18-volt DC supply.

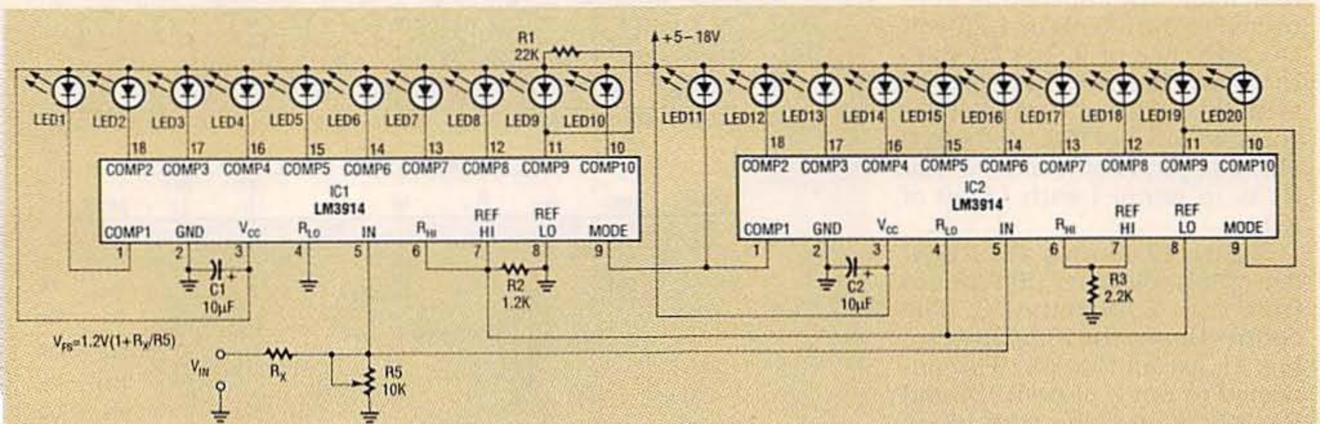


FIG. 11—A MOVING-DOT 20-LED VOLTMETER that ranges from 0 to 2.56 volts DC when Rx equals 0 ohms.

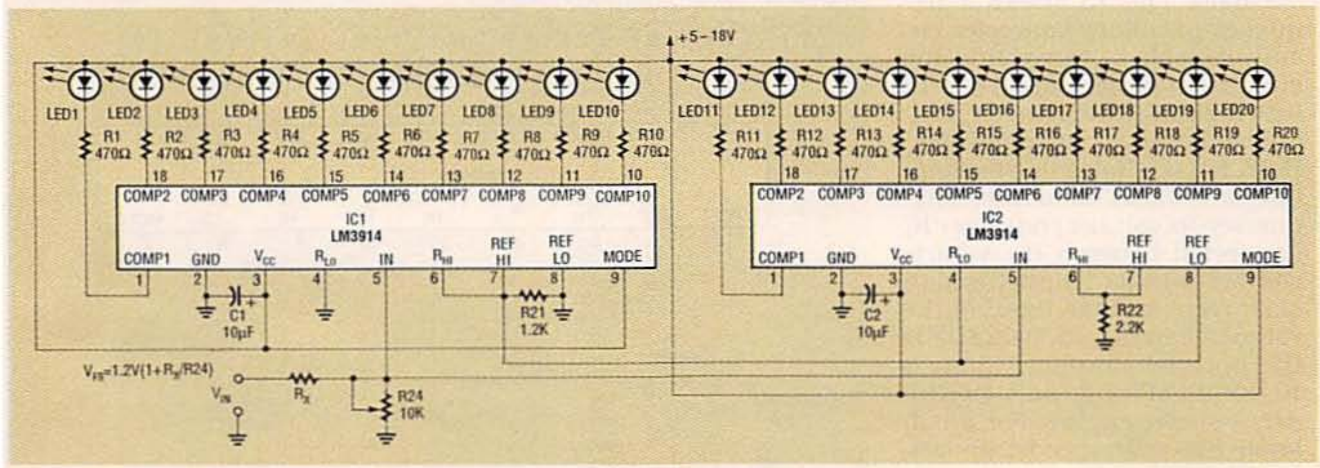


FIG. 12—A BAR-GRAPH 20-LED VOLTMETER that ranges from 0 to 2.56 volts DC when Rx equals 0 ohms.

The supply for the LED's has to be greater than the sum of the total drop with LED's 1–10 on, but within the voltage limits of the IC. Here the V_{CC} is a regulated value of 24 volts.

Figure 10 shows a modification of Fig. 9, using an unregulated V_{CC} ranging between 12 and 18 volts. In that case, LED's 1–10 are split into two chains, with Q1 and Q2 switching LED's 1–5 on when any of LED's 6–10 are active: the maximum total current through the LED's is twice that of a single LED.

The 20-LED voltmeter

The circuit in Fig. 11 uses two LM3914's in a 20-LED moving-dot voltmeter. The inputs of IC1 and IC2 go in parallel, but IC1 reads 0 to 1.25 volts DC, while IC2 reads 1.25 to 2.50 volts DC.

For the latter range, the low end of the 10-stage internal voltage divider in IC2 is connected to the 1.25-volt DC reference of IC1, while the top end is connected to the top of the 1.25-volt DC reference of IC2, 1.25 volts DC above that of IC1. The circuit is in dot mode, with pin 9 of IC1 going to pin 1 of IC2, and pin 9 of IC2 to pin 11 of IC2; note that R1 is in parallel with LED9 of IC1.

Figure 12 shows a 20-LED bar-graph voltmeter that ranges from 0 to 2.56 volts DC. The connections are like those of Fig. 11, except that pin 9 is connected to pin 3 of each IC, and R1–R20 go in series with LED's 1–20 to reduce power dissipation.

Finally, Fig. 13 shows a frequency-to-voltage converter circuit, capable of converting the circuits in either Figs. 11 or 12 into a 20-LED tachometer suitable for use in automobiles. Here, IC1 is a National Semiconductor LM2917 monolithic frequency-to-voltage converter IC connected between the vehicle contact-breaker points (used in older cars) and the input of the voltmeter. In Fig. 13, 0.022 µF is the optimal value of C2 for a 10,000-RPM range on a 4-cylinder, 4-stroke engine. For much lower full-scale speeds, the value of C2 might need to be changed for vehicles that have

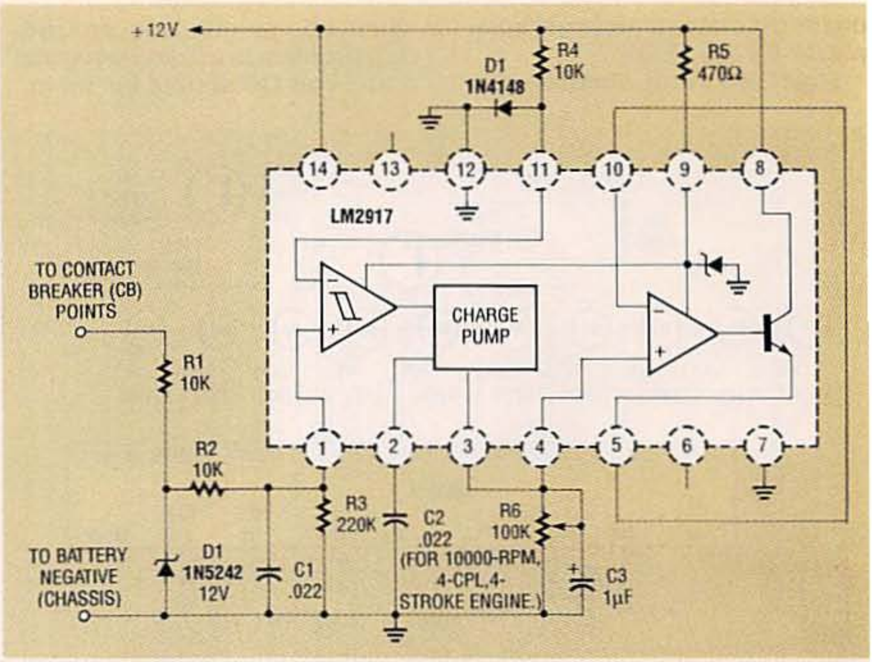


FIG. 13—A CONVERSION CIRCUIT FOR A car tachometer, for use with a 20-LED voltmeter, as shown in Figs. 11 and 12.

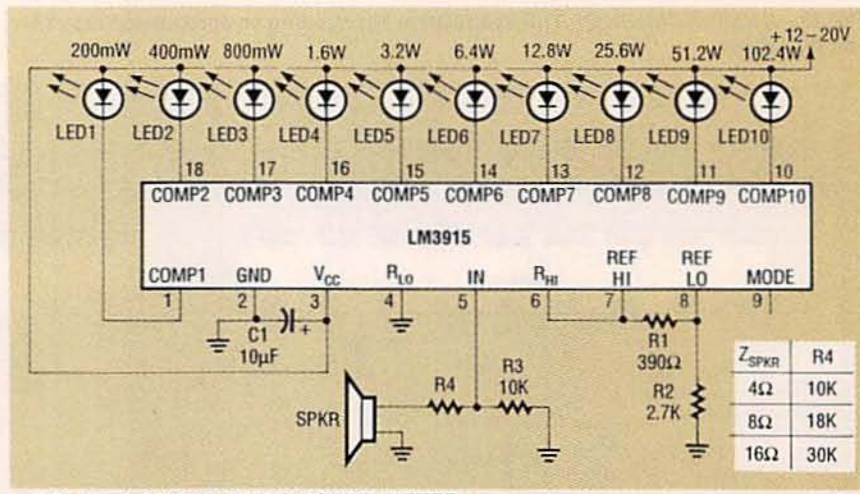


FIG. 14—A SIMPLE AUDIO POWER METER.

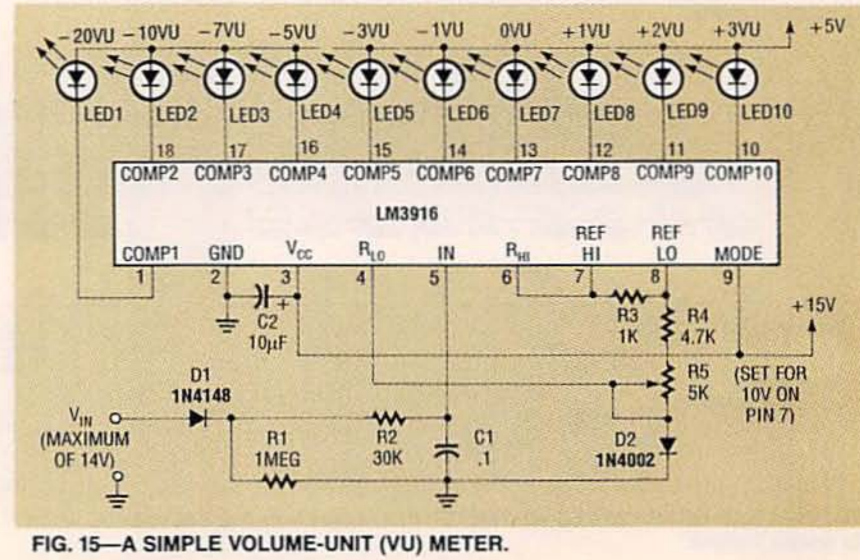


FIG. 15—A SIMPLE VOLUME-UNIT (VU) METER.

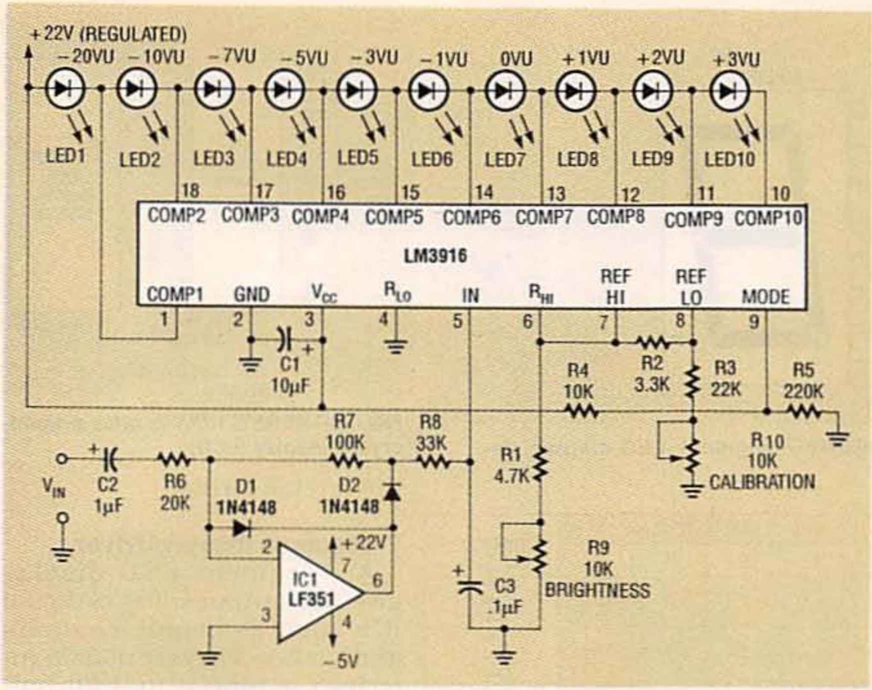


FIG. 16—**A PRECISION VU METER with low current drain.**

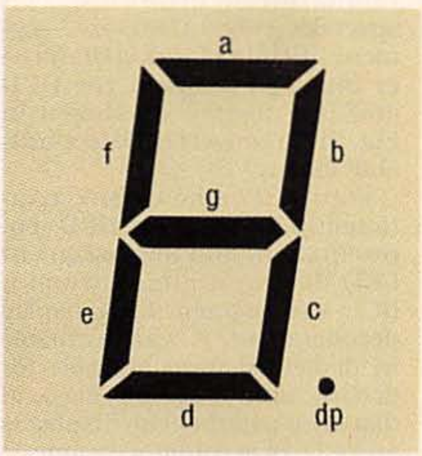


FIG. 17—**THE STANDARD CONFIGURATION for a 7-segment LED display.**

six or more cylinders.

LM3915 and LM3916 circuits

The LM3915 logarithmic and LM3916 semi-logarithmic versions basically work the same way as the LM3914, and can be directly substituted in most of the circuits shown in Figs. 2–12. The LM3915 and LM3916 will give an LED meter reading for an AC signal going to the input, and respond only to positive halves of the signal, with the number of LED's lit being proportional to the instantaneous peak value. The IC should be in dot mode, and set for 30 milliamps of LED drive.

Figure 14 shows an LM3915-based audio power meter. Pin 9 is left open for dot mode, and R1 equals 390 ohms, for an LED current of 30 milliamps. The range of the audio power meter is 200 milliwatts–100 watts. A better approach is to half-wave rectify the signal on the input and feed in the resulting DC, as shown in the VU-meter circuits of Figs. 15 and 16.

Figure 15, a simple volume-unit (VU) meter, uses an LM3915 in bar mode; the signal at the input is rectified by D1 and filtered by R1-R2-C1, with D2 compensating for the forward drop of D1. Figure 16, a precision VU meter offering low current drain, uses an LM3916, with the combination of IC1-D1-D2 acting as a precision half-wave rectifier.

Also, LED's 1–10 are in series, and IC2 is in dot mode, giving a low-power bar-graph display. To calibrate the audio power meter, adjust R10 for 10 volts DC on pin 7; R9 controls the level of display brightness.

The 7-segment LED display

Alphanumeric displays are used in electronics, in digital watches, pocket calculators, and in test equipment such as multimeters and frequency counters. The most common

SEGMENTS							DISPLAY	SEGMENTS							DISPLAY
a	b	c	d	e	f	g		a	b	c	d	e	f	g	
1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	8
0	1	1	0	0	0	0	1	1	1	1	0	0	1	1	9
1	1	0	1	1	0	1	2	1	1	1	0	1	1	1	A
1	1	1	1	0	0	1	3	0	0	1	1	1	1	1	b
0	1	1	0	0	1	1	4	1	0	0	1	1	1	0	C
1	0	1	1	0	1	1	5	0	1	1	1	1	0	1	d
1	0	1	1	1	1	1	6	1	0	0	1	1	1	1	E
1	1	1	0	0	0	0	7	1	0	0	0	1	1	1	F

FIG. 18—**THE TRUTH TABLE for a 7-segment LED display.**

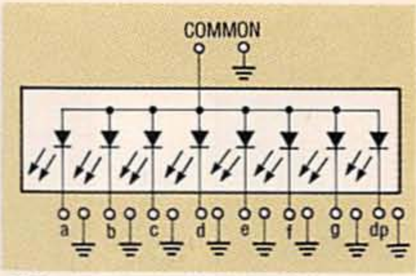


FIG. 19—**THE SCHEMATIC OF a common-anode 7-segment LED display.**

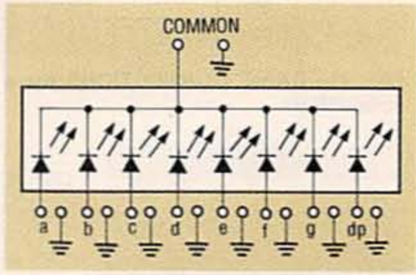


FIG. 20—**THE SCHEMATIC OF a common-cathode 7-segment LED display.**

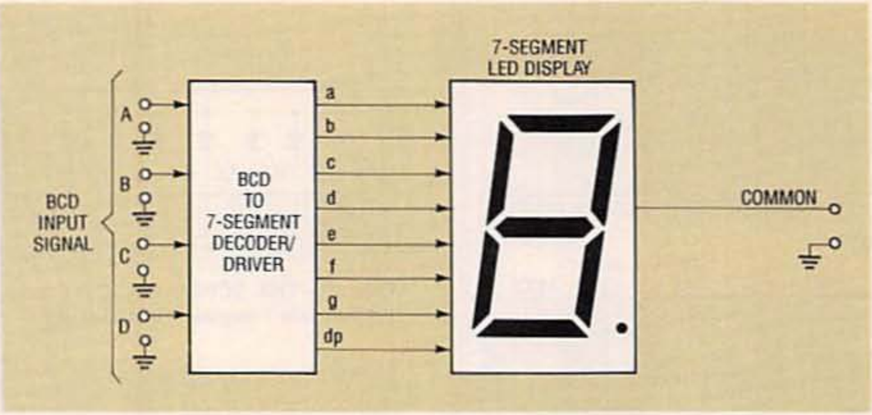


FIG. 21—BASIC CONNECTIONS for a BCD-to-7-segment LED-display decoder/driver.

BCD SIGNAL				DISPLAY	BCD SIGNAL				DISPLAY
D	C	B	A		D	C	B	A	
0	0	0	0	0	0	1	0	1	5
0	0	0	1	1	0	1	1	0	6
0	0	1	0	2	0	1	1	1	7
0	0	1	1	3	1	0	0	0	8
0	1	0	0	4	1	0	0	1	9

FIG. 22—THE TRUTH TABLE of a BCD-to-7-segment LED-display decoder/driver.

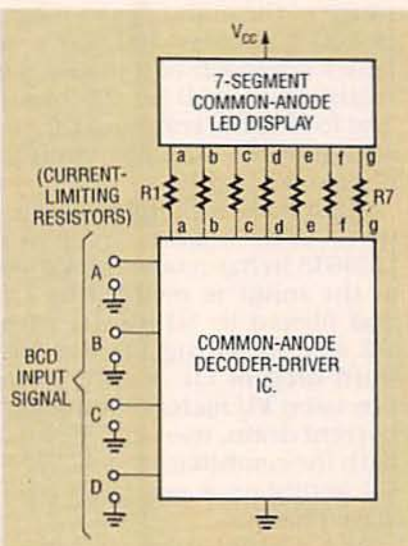


FIG. 23—HERE'S HOW to drive a common-anode 7-segment LED display.

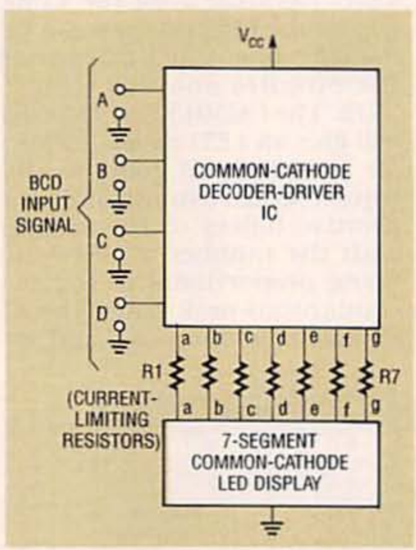


FIG. 24—HERE'S HOW to drive a common-cathode 7-segment LED display.

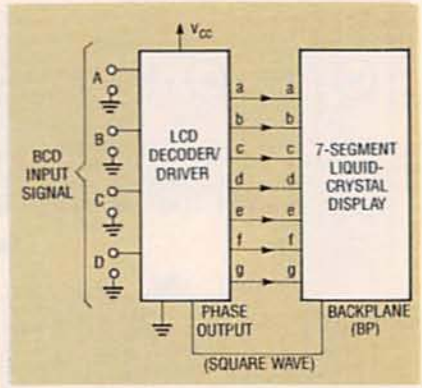


FIG. 25—HERE'S HOW to drive a liquid-crystal display (LCD).

type of alphanumeric display is the 7-segment LED or LCD display, as shown in Fig. 17. The segments are labeled a–g, and the decimal point is labeled dp. You can display either the digits 0–9, or the letters A–F (a mixture of upper and lower case letters), as shown in Fig. 18.

Most 7-segment LED displays need at least nine external connections. Seven of those connections access the segments, one the decimal point, and the eighth is common. If the display is an LED type, the seven segments are arranged as shown in Figs. 19 and 20. A common-anode version (Fig. 19) has all LED anodes going to common, while a common-cathode version (Fig. 20) is configured in the reverse format.

7-segment display/driver

A 7-segment LED display gives the output states of digital IC's such as decade counters and latches. They are usually internally arranged in 4-bit binary-coded decimal (BCD), and cannot directly drive a display. A special IC called a BCD-to-7-segment LED-display decoder/driver must go between the BCD and the display, as shown in Fig. 21, to convert BCD to a suitable form.

Figure 22 shows the relationship between the BCD representation, and the 7-segment LED-display digits. Normally, BCD-to-7-segment LED-display decoder/driver IC's are available in dedicated form suitable for driving only a special class of displays, whether the display is an LCD, or a common-anode or common-cathode LED display. Figures 23–25 show how such 7-segment LED displays and BCD-to-7-segment LED-display decoder/driver IC's are connected.

Figures 23 and 24 show how to drive common-anode and cathode 7-segment LED displays. Note that if the BCD-to-7-segment LED-display decoder/driver IC outputs are unprotected, as is the case in most TTL IC's, a resistor in series with each segment limits current; most CMOS IC's have such resistors internally. In Fig. 25 you can see how to drie an LCD. The common or backplane (BP) display terminal is driven with a symmetric square-wave, which is derived from the phase output terminal. R-E

HARDWARE HACKER

Using the IC Master; wavelets update; another caller-ID chip; musical note frequencies; and piano and organ resources.

DON LANCASTER

Several commercial products are starting to appear using that great *Rohm* BA-1404 FM stereo transmitter circuit. In particular, check out the *Pioneer* CD-FM-1 and the *Sony* XA7A CD to auto radio adapters. Dealer cost is in the $42 range.

What they do is let you play the output of a CD player through your existing car radio and audio system. The stereo channels are accepted by the BA-1404 IC and converted to a miniature but quite high-quality FM "broadcast" signal. You unplug your antenna, plug in your adapter, and then plug the antenna back into the adapter. Presto. Your CD audio now appears on the FM dial on your choice of one of two pushbutton-selected low-end channels.

As we've found out in the past, sloppily breadboarded BA-1404 chips tend to drift and mistune so much that they are unacceptable to most of the newer synthesized FM receivers that *demand* perfectly on-channel signals. While the ultimate way to stabilize an FM transmitter is to use a frequency-locked loop against a crystal reference, Pioneer and Sony both seem to have gone a simpler route.

Apparently they are just using a rigid and well-shielded design, tight supply regulation, and careful temperature compensation instead. They seem interested in a very low-level signal on a controlled cable, and they also do not see any antenna coupling or loading effects.

I will present more on those two beasties after I get a chance to test them. Either one of them should hack beautifully into a FM stereo wireless broadcaster circuit.

Wavelets update

We've had bunches of requests for lots more wavelet information. So, here is a summary of where we seem to be.

Wavelets are a stunning new set of math tools that are having a strong impact on just about every region of advanced scientific study. While the keenest interest in wavelets now lies in video compression, wavelets are being applied to everything from cardiology and seismology to animal vision—and everything in between.

Wavelets are a newer method of analyzing any complex set of signals and extracting useful information from those signals. Unlike the ancient *Fourier Transform*, wavelets have both *global* and *local* properties that let you selectively zoom in on signal portions of interest. For instance, good old Fourier is quite superb at working with the top and the bottom of a square wave. But the sides give it fits. Instead of Fourier's "one-size-fits-all," wavelets let you apply lots of detail only where needed.

Wavelets tend to work in a "log" manner rather than in that "linear" fashion of Fourier. This lets you pick up any fine details when wanted. Wavelets are also great at doing the "big lumps first." That becomes handy in decompressing pictures, where your crude (but complete) picture initially appears and detail gets added later. It also gives you the ability to select the amount of needed detail on the fly.

One detailed book on wavelets is *Wavelets and their Applications*, as published by *Jones and Bartlett*.

NEED HELP?

Phone or write your **Hardware Hacker** questions directly to:
Don Lancaster
Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

The topics thoroughly covered include wavelet fundamentals, video compression, digital signal processing, numeric analysis, and a bunch of advanced subjects. Sadly, the volume is written by math freaks for math freaks. It tends to run roughshod over mere mortals. But it is there and certainly is the precise center of the emerging wavelet universe.

One tad less formidable wavelet summary tutorial and bibliography appears in *IEEE-SP* (Signal Processing) magazine for October 1991 on pages 14–38. Note that there are dozens of different monthly IEEE publications. Make sure you get the right one.

For a useful collection of freebie reprints on wavelets for video compression, hardware chips, and design software, contact the folks at *Aware*. Wavelets do video compression far simpler, far faster, and with far fewer artifacts than the older (and now largely obsolete) DCT (discrete cosine transform) compression transforms. Their hardware is also far cleaner and more likely to be standard.

Finally, I have posted some great IBM wavelet shareware on my *GEnie* PSRT as the file #365 WAVELET.PAK. You can call (800) 638-9636 for your connect information.

A new caller-ID circuit

Motorola has just introduced an exciting new phone-caller identification chip called the MC145447. Free samples are available. They also have a very convenient but somewhat overpriced $100 evaluation kit breadboard that gives you a full telephone-to-computer serial interface.

Figure 1 shows one of many possible circuits. This one is intended for continuous powering.

Compared to the earlier chips,

the MC145447 includes internal ring detection, and it apparently can be used without an expensive coupling transformer. It optionally strips off that ID header and provides only "real" message bits. That's the difference between their *raw* data output (the entire caller-ID byte sequence) and the *cooked* data (only the useful bytes) message strings.

Note that those two 500-pF input capacitors must be closely matched and rated to at least 1500 volts. A varistor and the normal part-68 interface should precede the circuit. The output levels are TTL- or CMOS-compatible, but have to be suitably translated to be sent over a RS-232 serial cable or data line.

The crystal used is the standard for colorburst frequency, available for under a dollar through several of our **Radio-Electronics** advertisers.

Naturally, your caller-ID service must already be provided by your phone company before either the chip or the evaluation kit will work. If the service is not yet available, suitable machine language emulation software can easily be written for nearly any computer. The game paddle port on an Apple IIe is absolutely ideal as a fake source of ID coding signals.

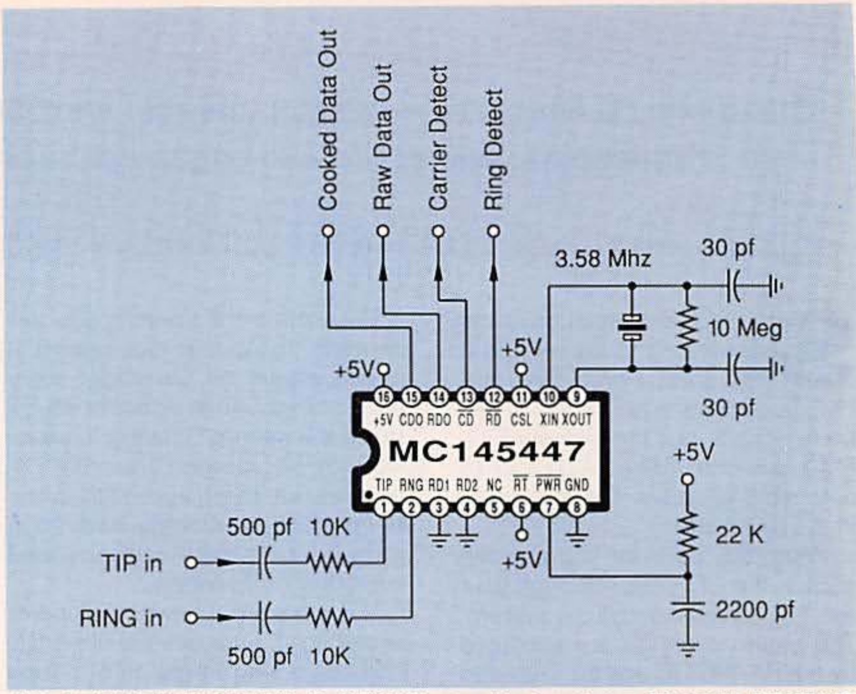


FIG. 1—ANOTHER CALLER ID CIRCUIT uses the brand new Motorola MC145447. Features include internal ring detection and data header stripping. Free samples are available. The service has to be available from your local phone company before this chip can be used.

We'll be seeing much more on this chip and suitable emulation software after I get a better chance to test it more thoroughly. The obvious thing to do is to "steal" enough power off a computer's RS-232 interface lines to eliminate any need for a stand-alone power supply. Internal power-down features of the MC145447 can greatly simplify this task. Stay tuned for more details.

The IC Master

Identifying the maker of an integrated circuit from just the part number can be tricky, especially if you are mistakenly reading the date code instead. As you have probably found out on your own, *Radio Shack* has a useful *Semiconductor Reference Guide* available for $4.

We've already seen that the two leading sources of service, repair, and replacement semiconductors are *NTE* and *ECG*. Parts and training specific to *RCA* and *GE* products are also available through *Thomson Consumer Electronics Publications*. This is an extension of the old "SK" series of replacement parts.

But *the* place to go for information on integrated circuit part numbers and cross references is a three-volume set known as the *IC Master* which is published by those *Hearst Business Communications* folks. The set is not cheap—it costs $160.

Hearst also publishes the fine *Electronic Products* magazine, plus their *EEM (Electronic Engineers Master Catalog)* directories. Both of these are free to qualified subscribers. But note that *EEM* and the *IC Master* are two totally different and separate sets of references.

Top-octave generators

This topic is more in the realm of "whatever happened to..." than anything else. But we still get lots of helpline calls concerning *top-octave generators*, especially in the *Mostek* MK50240 family. The bottom line: They're long out of date. They also have recently become impossibly difficult to get.

The traditional western musical scale is based upon twelve *equally*

	octave 0	octave 1	octave 2	octave 3	octave 4	octave 5	octave 6	octave 7	octave 8
B	30.868	61.735	123.47	246.94	493.88	987.77	1975.5	3951.1	7902.1
A#	29.135	58.270	116.54	233.08	466.16	932.33	1864.7	3729.3	7458.6
A	27.500	55.000	110.00	220.00	440.00	880.00	1760.0	3520.0	7040.0
G#	25.957	51.913	103.83	207.65	415.30	830.61	1661.2	3322.4	6644.9
G	24.500	48.999	97.999	196.00	392.00	783.99	1568.0	3136.0	6271.9
F#	23.125	46.249	92.499	185.00	369.99	739.99	1480.0	2960.0	5919.9
F	21.827	43.654	87.307	174.61	349.23	698.46	1396.9	2793.8	5587.7
E	20.602	41.203	82.407	164.81	329.63	659.26	1318.5	2637.0	5274.0
D#	19.445	38.891	77.782	155.56	311.13	622.25	1244.5	2489.0	4978.0
D	18.354	36.708	73.416	146.83	293.66	587.33	1174.7	2349.3	4698.6
C#	17.324	34.648	69.296	138.59	277.18	554.37	1108.7	2217.5	4434.9
C	16.352	32.703	65.406	130.81	261.63	523.25	1046.5	2093.0	4186.0

FIG. 2—THE STANDARD FREQUENCIES of the Western 12-note equally tempered music scale. It applies to most electronic and conventional musical instruments EXCEPT the piano. Piano keyboards must be "stretched" because of a piano's non-harmonic overtones.

tempered notes per *octave*. (An octave is a 2:1 frequency interval.) Each note is related by the twelfth root of two, or 1.059 times the frequency of its neighbor.

The notes, of course, are lettered as C, C#, D, D#, E, F, F#, G, G#, A, A#, B, and back around to the next C, one octave higher. The traditional organ people number the octaves from zero up through eight. The usual "standard pitch" frequency reference sets note A4 to precisely 440.0 Hertz.

The usual twelve-note-per-octave equally tempered frequencies appear in Fig. 2.

Because all of the music note frequencies are irrational, they have to be approximated. One way to do that is to take a high-frequency clock and divide it down by magic numbers which can hit the needed accuracy. Musicians define the interval between notes as one *semitone*, and further define *one percent* of a semitone as a *cent*. A one-cent frequency error is approximately 0.06 percent.

Reasonably trained individuals usually can spot a three-cent frequency error, while the best of professional musicians can resolve a single cent. Thus, the relative frequency accuracy of all the notes

PIANO AND ORGAN RESOURCES

Devtronics
6101 Warehouse Way
Sacramento, CA 95826
(916) 381-6203
CIRCLE 301 ON FREE INFORMATION CARD

Jrnl Audio Engineering Soc
60 East 42nd Street, Rm 2520
New York City, NY 10165
(212) 661-2355
CIRCLE 302 ON FREE INFORMATION CARD

MIX Bookshelf
6400 Hollis Street, Ste 12
Emeryville, CA 94608
(800) 233-9604
CIRCLE 303 ON FREE INFORMATION CARD

PAIA Electronics
3200 Teakwood Lane
Edmond, OK 73013
(405) 340-6300
CIRCLE 304 ON FREE INFORMATION CARD

Player Piano Company
704 East Douglas
Wichita, KS 67202
(316) 263-3241
CIRCLE 305 ON FREE INFORMATION CARD

Tuners Supply
88-94 Wheatland Street
Somerville, MA 02145
(800) 247-0702
CIRCLE 306 ON FREE INFORMATION CARD

NAMES AND NUMBERS

Aircraft Designs
25380 Boots Road
Monterey, CA 93940
(408) 649-6212
CIRCLE 307 ON FREE INFORMATION CARD

Antique Electronic Supply
6221 South Maple Avenue
Tempe, AZ 85283
(602) 820-5411
CIRCLE 308 ON FREE INFORMATION CARD

ARclad
PO Box 100
Glen Rock, PA 17327
(717) 235-7979
CIRCLE 309 ON FREE INFORMATION CARD

Astex
35 Cabot Road
Woburn, MA 01801
(617) 933-5560
CIRCLE 310 ON FREE INFORMATION CARD

Aware
One Memorial Drive
Cambridge, MA 02142
(617) 577-1700
CIRCLE 311 ON FREE INFORMATION CARD

ECG/Philips
PO Box 3277
Williamsport, PA 17701
(717) 323-4691
CIRCLE 312 ON FREE INFORMATION CARD

EMC Technology
PO Box D
Gainesville, VA 22065
(703) 347-0030
CIRCLE 313 ON FREE INFORMATION CARD

GEnie
401 North Washington Street
Rockville, MD 20850
(800) 638-9636
CIRCLE 314 ON FREE INFORMATION CARD

IC Master/Hearst
645 Stewart Avenue
Garden City, NY 11530
(516) 227-1300
CIRCLE 315 ON FREE INFORMATION CARD

IEEE/Signal Processing
445 Hoes Lane
Piscataway, NJ 08855
(908) 981-0060
CIRCLE 316 ON FREE INFORMATION CARD

ITW/Fastex
226 Gerry Drive
Wood Dale, IL 60191
(708) 350-8200
CIRCLE 317 ON FREE INFORMATION CARD

Jones & Bartlett
20 Park Plaza
Boston, MA 02116
(617) 482-3900
CIRCLE 318 ON FREE INFORMATION CARD

Media Magic
PO Box 507
Nicasio, CA 94946
(415) 662-2426
CIRCLE 319 ON FREE INFORMATION CARD

Motorola
PO Box 1466
Austin, TX 78767
(800) 521-6274
CIRCLE 320 ON FREE INFORMATION CARD

NTE Electronics
44 Farrand Street
Bloomfield, NJ 07003
(201) 748-5089
CIRCLE 321 ON FREE INFORMATION CARD

Rohm
PO Box 19681-631
Irvine, CA 92713
(714) 855-0819
CIRCLE 322 ON FREE INFORMATION CARD

Signetics/Philips
811 East Arques Avenue
Sunnyvale, CA 94088
(800) 227-1817
CIRCLE 323 ON FREE INFORMATION CARD

Synergetics
PO Box 809
Thatcher, AZ 85552
(602) 428-4073
CIRCLE 324 ON FREE INFORMATION CARD

Thomson Consumer Publictns
2000 Clements Bridge Road
Deptford, NJ 08096
(609) 853-2417
CIRCLE 325 ON FREE INFORMATION CARD

Voltek
100 Shepard Street
Lawrence, MA 01843
(508) 685-2557
CIRCLE 326 ON FREE INFORMATION CARD

should be better than 0.06 percent.

To get all of the notes to sound well together, well-chosen "magic" division ratios must be used. Figure 3 shows some detail. Of all the possible 8-bit divisor values, only the unique sequence of 116 123 ... 232 is good enough for a three-cent worst-case accuracy. If you have more bits available, then other sequences are also usable.

Figure 4 shows you how a top-

The 12 equally tempered musical keys repeat each **OCTAVE**, or **2:1** frequency interval.

This means each note is related to its neighbor by a geometric ratio of the **12th** root of two, or **1.05946:1**

Only this "magic" sequence of 8-bit divisors is good enough to let all of the notes sound good together...

232 219 207 195 184 174 164
155 146 138 130 123 116

Here is the better 9-bit "magic" sequence used by the MK50240...

478 451 426 402 379 358 338
319 301 284 268 253 239

FIG. 3—EQUALLY TEMPERED NOTES are irrational, so only this one "magic" 8-bit sequence of division ratios can be a good enough approximation.

octave generator works. This is an old N-channel integrated circuit that runs on a single 12-volt supply. An input clock of 2.000240 MHz is required. The clock can be obtained from a crystal for an absolute reference, or it can be variable for pitch blending or keyboard stretching variations. Thirteen outputs are provided, giving you all the notes of the highest octave, plus a spare C an octave lower.

To generate lower notes, you can either divide down the input clock for a single octave, or else add output dividers to generate the entire music keyboard as shown in Fig. 5.

Hackers have long ago found lots of other exciting uses for top-octave generators, which include musician's pitch references, piano tuning aides, meditation, and musical toys.

Perhaps one of the most off-the-wall new-age uses involved John Simonton's *chord egg*. Polyphonic chords obtained from a lowered pitch top-octave generator were chosen at random and routed to a stereo headset. With suitable delay and phasing techniques, the apparent source of the stereo sounds is forced *between* your ears, and the chords literally bounce around *inside* your head. A few chord eggs remain available through PAIA electronics.

Assembly details for a traditional top-octave generator music module system appeared long ago in the June 1976 issue of *Popular Electronics*.

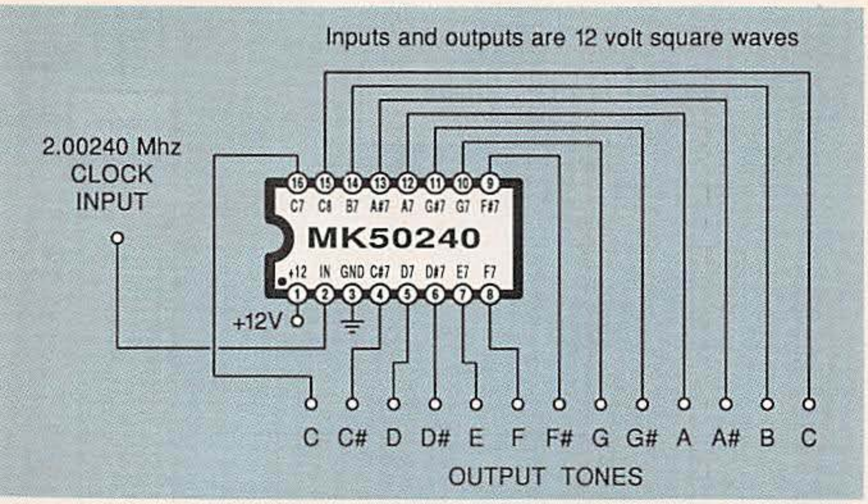


FIG. 4—TOP OCTAVE GENERATOR integrated circuits produce all the needed notes of the musical scale. Input or output lines can be binarily divided for lower octaves. Sadly, these chips are getting hard to find.

There are several reasons why the top-octave generators are no longer popular. The "locked in" nature of octave-shifted notes sound as a single richer tone, rather than as a separate pair of chorused voices. Having all the notes sounding continuously in the background can lead to serious system noise problems. Zillions of wires are needed because the keyboard is usually non-scanned. The envelope and voicing opportunities are also severely limited.

But the main reason is that MIDI-based and all-digital sampled synthesizers do a much better job with a far cheaper, a far simpler, and far cleaner system architecture. Moreover, they are infinitely more flexible and sound much better than anything else.

At any rate, new sources of top-octave generators seem to be long gone. A very few of the original chips *may* remain available through *PAIA* or *Devtronix* on a catch-as-catch-can basis. It should also be possible to fake the top-octave generators with programmable gate array devices. The FPGA costs are dropping rapidly enough to make this possible.

Note that any pitch reference must be a nearly pure sine wave. Any higher harmonics will fool the ear and also cause potential tuning problems.

Finally, if any of you out there know of any secret stashes of this one-time great chip, be sure to let all of us know.

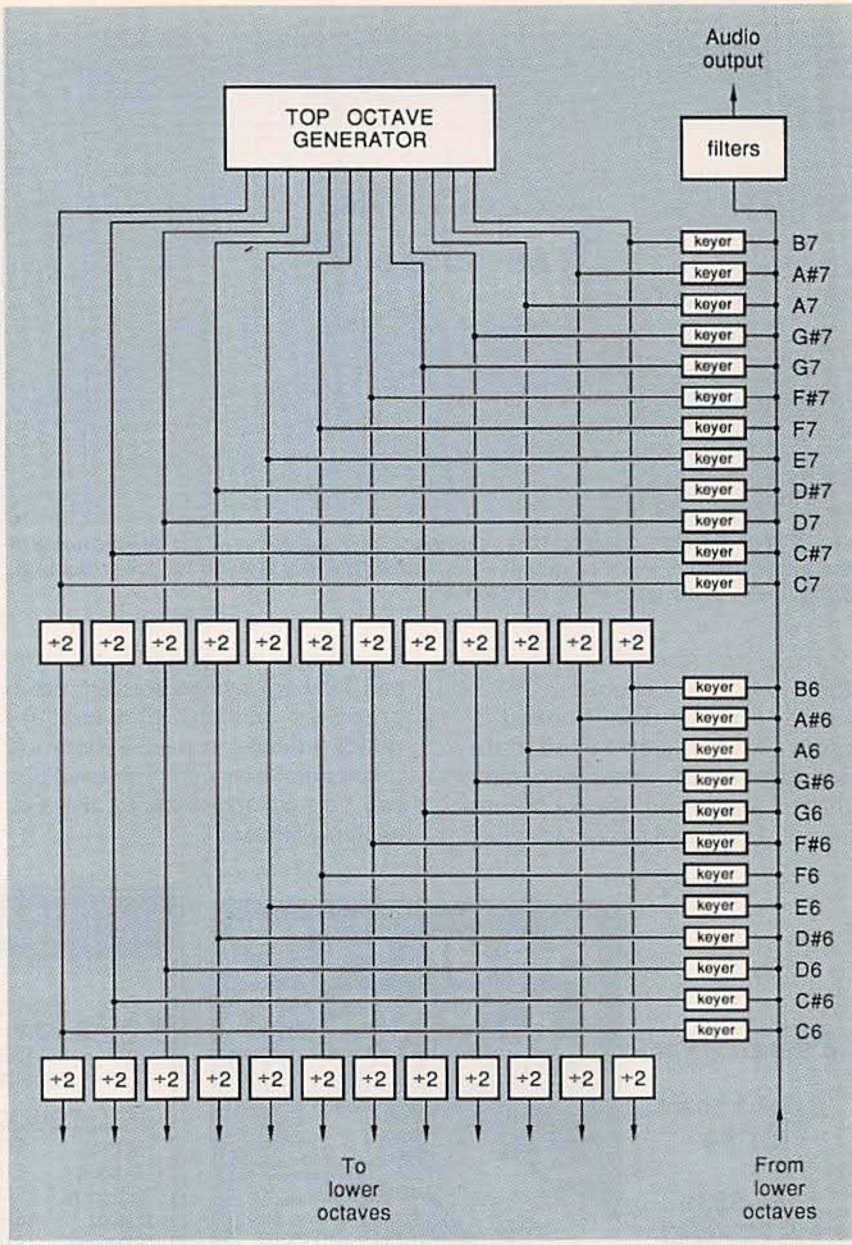


FIG. 5—A TRADITIONAL ELECTRONIC ORGAN architecture using top octave gener ators and dividers. Today's MIDI-based sampled synthesizer circuits can produc much better sound far simpler and in an infinitely wider variety.

Piano and organ resources

I thought I'd gather together some traditional music names and numbers for this month's resource sidebar. For piano tuning materials and supplies try *Tuner's Supply*, while the best source for antique instrument parts and data is the *Player Piano Company*. And a good horse's mouth book is *Piano Tuning and Allied Arts*.

Note that piano tuning is (1) a lot harder than it appears; (2) a minuscule, unprofitable, and rapidly declining market; and (3) an easy way to cause irreparable damage.

Note also that most piano keys are *never* tuned to all their "correct" frequencies. Instead, the keyboar has to be "stretched" to allow fo the non-harmonic nature of rea world string overtones. Keep ir mind that it takes several *weeks* to properly tune a piano!

One classic organ kit company is *Devtronix*, while a company callec *PAIA* offers a wide range of tradi tional to new age kits.

An excellent source for electronic music titles is the *MIX* Bookshelf stocked by the folks that also pub lish the *Electronic Musician* maga zine. Fundamental synthesizer secrets can often show up first in the *Journal of the Audio Engineering Society.*

Some additional electronic music resources appear in my *Hardware Hacker II* reprints.

New tech lit

A great "gottahave" is the *Video Data Handbook* from *Signetics Philips*, which is chock-full of digital video-interface chips, RGB digitizers, multimedia chips, sync strippers, color decoding, and all of the usual A/D and D/A conversion chips and circuits.

Speaking of multimedia, the *Media Magic* people offer a *Computers in Science and Art* catalog full of good books, tapes, and software.

A free bibliography of papers on microwave plasma applications is offered by *Astex*.

From *Antique Electronic Supply*, a 1992 wholesale catalog of supplies, books, tubes, info, and parts for the electronic collector. We've had lots of calls from experimenters trying to find Fahnstock clips in this day and age. These folks are one of the few remaining suppliers.

Another trade journal on magnetic and electric shielding ideas is *EMC Technology*. And a wide selection of aircraft hacker books is available by way of *Aircraft Designs*.

This month's freebie mechanical samples include foams, films, and foils from *ARclad*, a *Foam Specifier Kit* from *Voltek*, and some self-stick bumpers from *ITW/Fastex*.

A reminder that I have recently revised my *Incredible Secret Money Machine II* and have autographed copies on hand for you when you call or write. You can get the ISMM by itself or as a portion of my *Lancaster Classics Library*.

You can also reach me via *GEnie* PSRT (800) 638-9636 where you will find hundreds of downloadable files and tutorials on hardware hacking and also those midnight engineering topics.

Our usual reminder here that most of the products and services that have been mentioned appear either in the "Names and Numbers" or in the "Piano and Organ Resources" sidebars. **R-E**

AUDIO UPDATE

AES: Audio Fact and Fantasy.

LARRY KLEIN

The theme of the recent 91st Audio Engineering Society Convention held in New York—"Audio Fact and Fantasy"—was one dear to my heart. I thoroughly enjoyed both the formal sessions and the lunches and hallway conversations with some of my old friends and new acquaintances.

As I've done in years past, I intend to discuss some of the more interesting papers. But first, I'd like to set the stage, so to speak, with a recapitulation of what I see to be some of the basic problems of high-fidelity reproduction—which is what the 91st Convention was all about.

What's the Problem?

In the very early days of hi-fi we kept talking about "concert-hall realism." Later, it came as a shock to many of the audio faithful to read that some new or rebuilt concert halls failed to achieve the "realism" supposedly inherent in live sound. In any case, how can the live listening experience ever be even approximately duplicated by scattering a dozen or more microphones throughout the ranks of a strangely grouped orchestra? And then when pop recording went multi-track, frequently done in several venues over weeks or months, the philosophical problems of duplicating a live sound that never was became intense—at least for the thinking listener.

Those and other questions arise during the process of getting the music into the storage medium. Extracting the music out again and delivering it to the ears of a listener in believable form is the other side of the coin. The success of a recording can only be judged during playback. But playback through what equipment, into what environment, and with what jury of listeners?

A recording of a live event entails a selected sampling of the sound field in the recording environment. The success of the sampling process—which basically involves the choice and placement of microphones—depends mostly on the talent of the recording engineer. If under reasonable playback conditions the recording can produce a plausible simulation of a live sonic event, it is deemed a success.

Be aware that this thumbnail input-output description of the audio process leaves many questions unanswered. Not unexpectedly, the input part of the recording process excites far fewer passions than the playback end of things. In playback, the audiophile gets involved obsessively exploring the real or imagined effects produced by each of a wide range of components. Objectively, most electronic equipment is really very good. Speaker quality, however, is somewhat variable from model to model and brand to brand. A third category of equipment, accessories, ranges from the sometimes helpful through the silly to the truly demented. (For further exploration of that last category, browse through virtually any issue of *The Stereophile* and *The Absolute Sound*.)

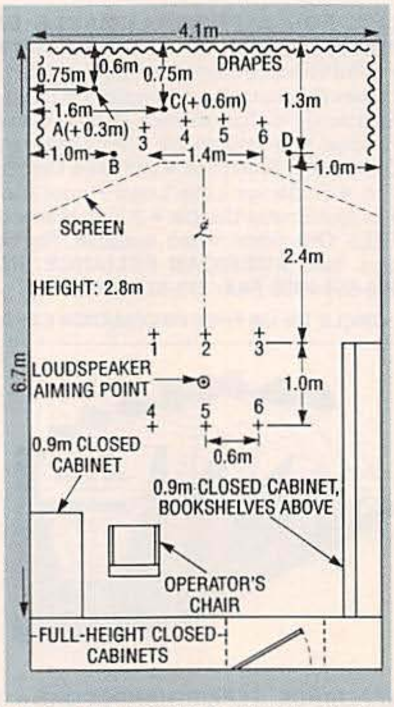


FIG. 1—THE FLOOR PLAN of the National Research Council of Canada's speaker listening room shows loudspeaker and listener locations. Loudspeakers were placed at positions 3, 4, 5, and 6 in monophonic tests, with listeners at positions 1, 3, and 5. In stereophonic tests, loudspeakers were at position B and D, and listeners at positions 2 and 5.

Loudspeakers

It seems to me that amplifiers are pretty much cut and dried in the sense that competent designers can give them any desired sonic quality. Although I find it strange that an engineer would deliberately introduce—or fail to eliminate—nonlinearities in an amplifier design, I know for a fact that this has sometimes been done in the misguided pursuit of euphonic (ear-pleasing) effects. In any case, it's not *that* difficult to produce a virtually perfect amplifier, which is defined as one being free of audibly disturbing artifacts.

Loudspeakers are an altogether different ball game. Their complexities are reflected in the seemingly endless series of technical papers, experiments, and products produced over the years. The recent AES Convention provided an excellent overview of the raging controversies and unsolved problems still besetting the world of loudspeakers. The essential questions confronting the loudspeaker designer are: What should a loudspeaker do, and how can the designer determine when it's doing it correctly?

A comprehensive, if somewhat weighty, overview of those speaker evaluation problems was presented by M.R. Jason of National Public Radio. I'll discuss some of the issues raised by Mr. Jason.

The listener-preference approach as a means of evaluating loudspeaker performance would seem on the face of it to be an easy way to separate the good from the bad from the indifferent. But unless the evaluations are based on *very* careful procedures and sophisticated statistical analysis, rather than simple listening tests, the results are likely to be misleading.

In fact, listener preference appears to be so unreliable an evaluation tool that a number of reputable academic researchers have suggested that listener-preference tests be replaced by detectable-difference tests. Those would test the ability of a listener to discriminate between a test signal and a reference signal. The thought seems to be that preference is determined by too many uncontrolled subjective variables, while "detectability" at least eliminates individual taste from the equation.

"Detectability" also eliminates some of the problems of fast-Fourier transform time-delay spectrometry. One of the earliest users of the technique confided to me at one point that while the displays were undoubtedly impressive-looking and contained lots of information about what was happening during the first several milliseconds of a pulse, the exact relevance to the music-reproductive abilities of any particular speakers was, at best, unclear.

A Standard Listening Room

No one argues that loudspeaker performance is independent of the room in which it is playing. Even if you had an ideal speaker—whatever that is—the relative balance of the high and low frequencies, the evenness of the distribution of sound throughout the room, is strongly influenced, for better for worse, by the room size, proportions, wall treatments, furniture, speaker location(s), and listener positions. All of those variable have to be standardized before evaluations can be meaningful to others who are working—or listening—with a different set of conditions.

A major step toward standardization was taken in 1985, when the International Electrotechnical Commission (IEC) specified a standard listening room when it published its recommended practice for listening tests, *Listening Tests on Loudspeakers* publication 268-13. The standard room was not, as one might suppose, derived from some mathematically optimized ideal acoustic environment. It was based, instead, on a 22×13.5×9.2-foot room, shown in Fig. 1, used for listening tests at the National Research Council of Canada in Ottawa. (The NRC roughly corresponds to the National Institute of Science and Technology in the U.S., but does far more practical research in support of various Canadian industries. The NRC test and research facilities are largely responsible for the general excellence of Canadian loudspeakers—but that's another story for another month.)

The room's acoustics were adjusted somewhat with drapes and upholstered chairs. I visited the room shortly after it had been set up and I remarked on its acoustic normalcy. It was explained that it was intended to represent a good domestic listening environment typical of North America and Europe. Reverberation time is 0.35 ± .085 seconds from 250 Hz to 4 kHz, rising to 0.85 seconds at 40 Hz and falling to 0.25 seconds at 10 kHz.

Having a common reference environment for speaker listening tests is a necessary tool, but certainly only part of what needs to be done. Without going further into the complexities of speaker evaluation, let it suffice to say that it is no easy task—and certainly not as easy as most audio publications would have you believe. Floyd Toole, formerly of the NRC, has done significant work in correlating listener evaluations with measured performance. In the view of many experts, Toole's efforts have advanced audio art significantly toward the goal of "What you hear is what you measure—and vice versa."

Next month, I'll look at some additional AES papers that I think you'll find interesting. **R-E**

DRAWING BOARD

Our oscilloscope is shaping up nicely.

ROBERT GROSSBLATT

If you're a regular reader of "Drawing Board," you know that the principles of design are just as important as the particulars of the circuit. Even though each series of columns winds up with a working gadget of one kind or other, the real idea behind all of it isn't to see how to design something in particular, but how to design anything in general. The real message is the method, not the minutiae.

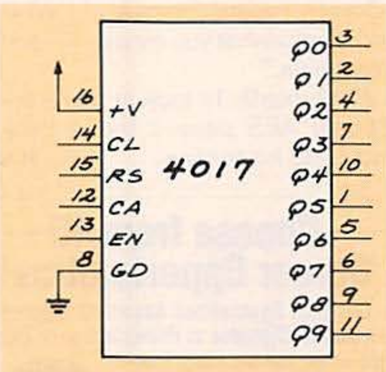


FIG. 1—THE 4017 DECADE COUNTER will be used to sequentially enable each of the LED columns at a rate chosen by the clock circuit we put together last month.

The reason for mentioning this is that we've come to the point where we're going to do the design of the horizontal driver circuit and there are lots of ways to get the job done. What we'll be doing together here is only one of them.

The job of this circuit is to sequentially enable each of the LED columns at a rate chosen by the clock circuit that we put together last month. Most small digital scopes (those with ten or less columns), use a 4017 decade counter to do this; that makes sense because it's exactly the kind of job the 4017 was designed to do. For scopes like ours where there are more than ten columns, the sequencing circuit generally gets more complex because there are no single-chip solutions to get the job done, and the 4017 wasn't really designed for sequential cascade counting. Decade counting is simply a matter of using the cascade output built into the chip, but doing sequential counting is something else altogether.

As you can see in Fig. 1, the chip has a limited number of control inputs, and there's no easy way to disable all the outputs. One output will always be enabled no matter what you do to the control lines and whether or not the chip is getting clock pulses.

That's not to say, however, that it can't be done. After all, a 4017 is so cheap, so available, and so perfect for the job, it would be a shame not to use it. All it takes is some logical glue and a bit of imaginative gating. And that's what we're going to do.

I've been using various versions of this arrangement of 4017's for years since it's a neat way to get around the ten-count limit of the 4017. As we all know, nothing is for free and that goes here as well. Since the 4017 will always have one of its outputs enabled, there's no way we can string a bunch of them together sequentially and use every output on every chip. That's the reason there are three 4017's being used in Fig. 2 even though we need only twenty outputs. We lose the last output of the first 4017 and two outputs from each of the others.

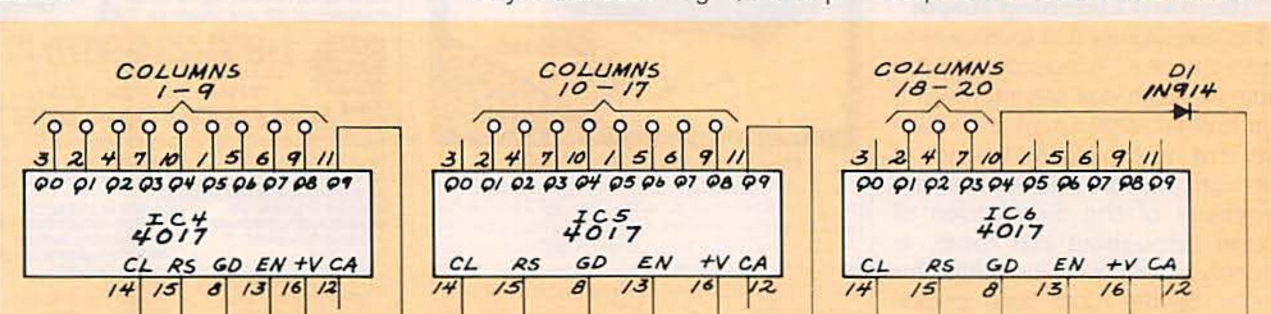


FIG. 2—BECAUSE ONE OUTPUT OF THE 4017 will always be enabled, we can't use every output on every chip. That's why there are three 4017's being used here even though we need only twenty outputs.

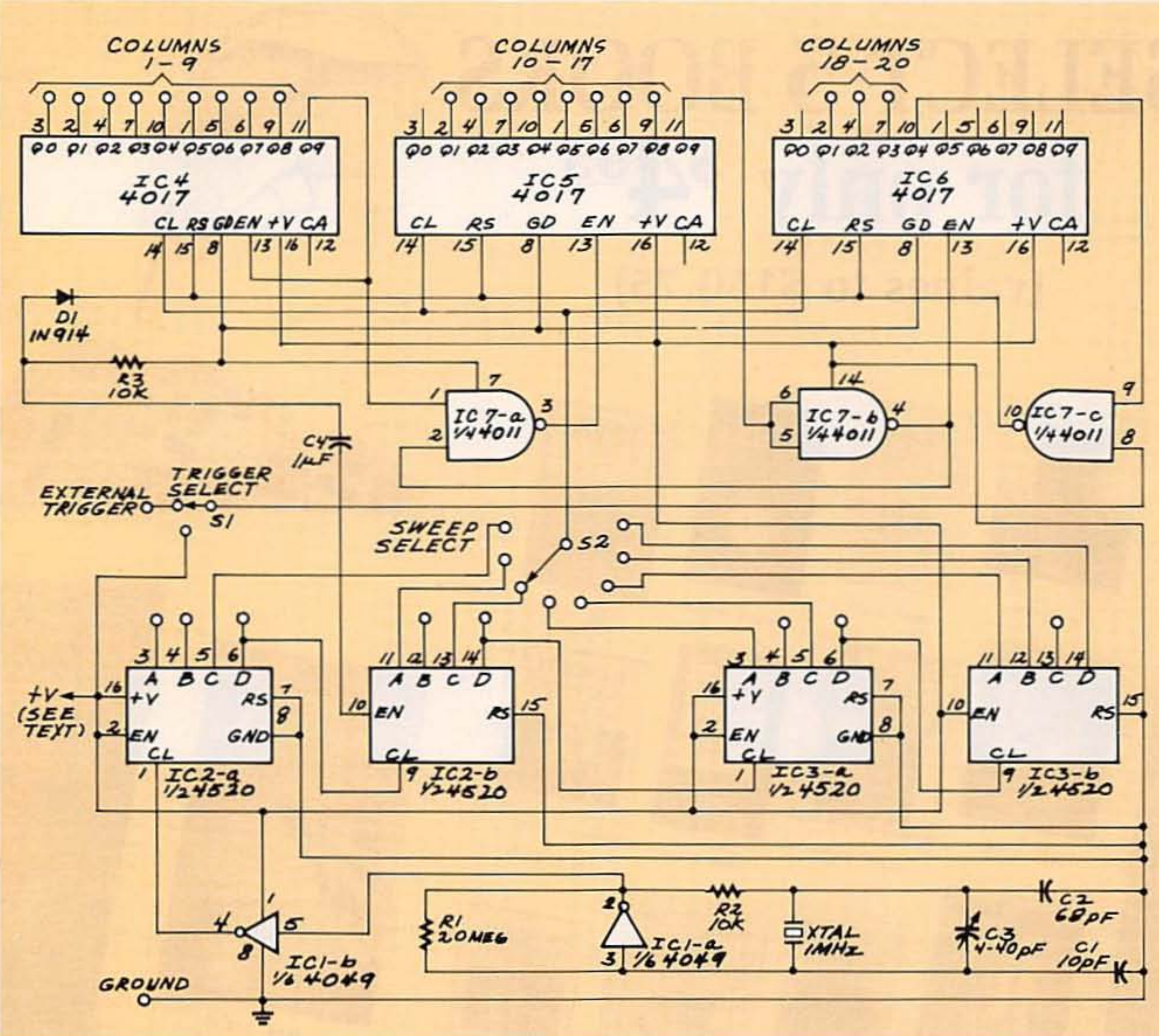


FIG. 3—HERE'S OUR OSCILLOSCOPE SO FAR. The NAND gate IC7-c is switched into the circuit in the triggered sweep mode. It resets when the trigger signal puts a high on the second leg of the NAND gate. If we want the scope to be free running, we switch the trigger leg of the gate to +V.

You should file this circuit away in vour notebooks because it comes in handy when you least expect it. And for all you out there who were trained to eat absolutely everything on your plate, there are ways to reconfigure the circuit so you can use every single output of every single chip. Without going into the details, the problem is to create some sort of an external output enable control for the 4017. That can be done with buffers or transistors between the outputs of the 4017 and whatever the outputs are intended to control.

But I leave that to you. Any more of these asides and I'll wind up writing like Lawrence Sterne did in Tristram Shandy—digression upon digression upon digression.

By adding Fig. 2 to the stuff we did last month, we now have a working version of the horizontal circuit we defined at the outset of this design project. It does everything we specified and, if you wire it up on a breadboard, you'll see that the only other piece you have to add is an eight-position, single-pole rotary switch (a break-before-make type), so you can select the sweep speed being fed to the common clock inputs of the 4017's.

Before we leave the horizontal section of the scope, this is a good time to talk about how the scope is going to be triggered. If you're familiar with scopes, you know that most scopes offer you a choice of three basic ways to control the horizontal sweep: as a single shot, free-running, or triggered. Each of them is useful in different situations and, with the exception of free-running (most scopes refer to this as "normal"), the circuitry to make them happen needs some of the signals we'll be generating when we get to work on the design of our scope's vertical drive.

Any control of the horizontal sweep is directly translatable into what we do with the reset control lines of the 4017's. As you can see in Fig. 2, all the reset lines have been tied together and are controlled by

continued on page 98

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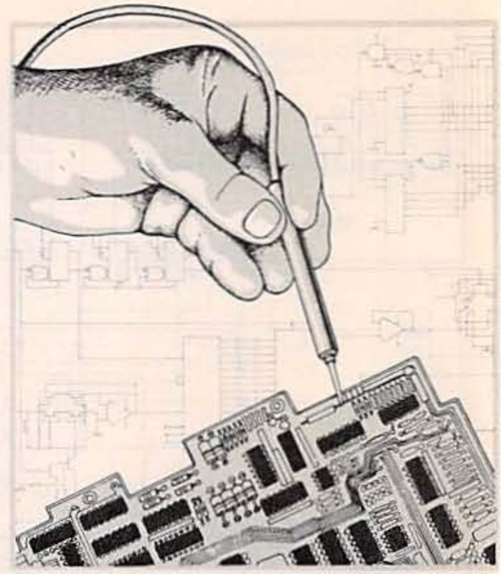

PHONE-LINE MONITOR

continued from page 58

high-frequency tone groups, which are then decoded into one four-bit code per key, as shown in Table 3.

The DTMF decoder informs the microprocessor when a tone has been detected by asserting T-STB, which drives bit 6 of port 1 of the 8031, shown back in Fig. 2. The 8031 then reads the 4-bit code by asserting T-OE through port C0 of the PIO, and reading bits PB0–PB3 of the PIO. In addition to reading DTMF codes, the PIO also reads the status of configuration switch S1 and off/standby switch S2, and can assist RS-232 data flow via the DTR output and the CTS input.

Audible signalling

The speaker driver is shown in Fig. 4-e. Digi-Call can generate several different sounds, as follows.

- Digi-Call produces a warble sound when the unit is turned on; it emits a beep when the user selects standby mode. Cannot be disabled.
- Digi-Call produces a ringing sound when the unit is on and the phone rings. Can be disabled.
- The turn-on reminder warble sound will chime every ¼ hour when the unit is in standby mode. Can be disabled.
- Power loss causes a short beep to be produced every minute. Cannot be disabled.
- A RAM-full condition causes an alarm to sound every minute until data is erased using the PC-based utility program. Cannot be disabled.
- Illegal configurations of S1 cause a continuous slow-going high-low beep. Cancel by choosing legal switch positions. We'll discuss S1 further next time.

The microprocessor has an internal serial interface that Digi-Call uses to transfer stored telephone data to the PC. However, the microprocessor's TTL levels are not compatible with standard RS-232 levels, so we use a MAX-232, shown in Fig. 4-

TABLE 3—
DECODED DTMF OUTPUTS

DIGIT	D3	D2	D1	D0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0

e, both to drive the RS-232 lines, and to generate the ±9-volt signalling voltages. We also "steal" the −9-volt DC output to power op-amp IC1.

Status indicators

Three status LED's indicate Digi-Call's operational status.

The green "On" indicator (LED4) lights steadily when the unit is on and the phone is on-hook; it blinks when the phone line is off-hook or ringing.

The red "Full" indicator (LED3) indicates that the data RAM is full and no further call logging is possible. The "Full" LED also lights during the Power On Self Test (POST), and during the diagnostics accessible through the host PC software. Last, LED3 blinks slowly if configuration switch S1 is set to an illegal combination.

The Watch Dog indicator (LED5) blinks slowly under normal circumstances, and rapidly if powered by the batteries.

The power supply, shown in Fig. 5, is designed to operate even in the absence of AC power. Blocking diode D9 isolates back-up cells B1–B6 while AC power is present; resistor R31 determines charge current into the batteries. Digi-Call can function with nonrechargeable batteries, in which case R31 should not be installed.

Next time we'll build the unit and get it up and running. **R-E**

COMPUTER CONNECTIONS

Industry evolution

JEFF HOLTZMAN

IBM dominates the news this month. Since last time, Big Blue signed an historic accord with Intel, formed a trade group with Apple and Motorola, and commenced internal restructuring that, if successful, could point the way to survival for several major U.S. industries (not just the computer industry). If, however, that restructuring is unsuccessful, it may be a harbinger of how the computer industry will follow the automotive and steel industries down the tubes.

IBM + Intel

With the new-found friendship among IBM, Apple, and Motorola reached last summer, you may have wondered about IBM's commitment to the Intel platform. Well, wonder no longer. IBM and Intel signed a ten-year agreement under which they will collaborate on the design of new 80x86 IC's. About the significance of this deal, Intel's CEO Andrew Grove has said, "This is probably the biggest deal I have signed in my professional career."

The two companies will establish a 100-person development center composed of scientists and engineers from both IBM and Intel. Intel will contribute CPU designs; IBM will contribute systems-level expertise and semiconductor manufacturing technology. (It's not well known that IBM is one of the largest semiconductor manufacturers in the world.) It will take about two years to produce results, including highly integrated modules that incorporate CPU, cache memory, memory management, bus interface logic, disk controller, and graphics. The companies will develop these products jointly; IBM will have a four-month lead in commercializing systems, after which time Intel can sell IC's on the open market. IBM has had the right to build and enhance its own 386 CPU's since 1987. (An enhanced CPU would include the 386SLC, the "weird" CPU mentioned here last time as part of IBM's Ultimedia PC.) However, the new agreement precludes IBM from enhancing future 486-based CPU's.

IBM's four-month lead, as well the changing business climate, has competitors like Compaq deeply worried. For years Compaq was one of Intel's most loyal customers. Recently, however, the company has been warming up to AMD, which is expected to release a line of 486 clones sometime in 1992. Because AMD and Chips & Technologies have already successfully cloned the 386, Intel's marketing effort is focusing more and more on the 486 line. AMD is achieving great success with its 386 line by exceeding its own sales forecasts of 386 clones by 400% through 1991, for a total of about 20% of the 386 market. Intel also suffered a setback in the math coprocessor clone department: a judge in Texas has ruled that Cyrix may continue selling its FasMath clones until a combined antitrust/patent infringement case reaches trial in late summer 1992.

The good thing about all of this is that Intel is not content with trying to protect its prior accomplishments, and in the process leaving the fate of the company (not to mention the industry that depends on x86 chips) up to its lawyers. Rather, it is moving ahead and designing innovative new products, thereby staying a step or two ahead of the cloners. If the software industry followed this kind of model, we'd probably be much further along in the move toward graphical operating environments.

IBM + Apple + Motorola

Those three companies are forming a trade association, PowerOpen, dedicated to defining and promulgating software standard[s] for the RISC-based PowerPC archi[tecture] announced as part of las[t] summer's historic Apple/IBM ac[c]ord. These standards involve defi[ni]ning the instruction set of th[e] PowerPC, a cross-platform binar[y] compatibility layer called the Ap[p]lication Binary Interface (ABI), an[d] high-level programming interfaces[.] The intent of these technologies i[s] to provide a "universal" softwar[e] environment that will support futur[e] Macintosh and OSF/Motif applica[tions], as well as current Mac an[d] DOS applications (through emu[lators]), and AIX applications. (AIX i[s] IBM's version of UNIX.) IBM an[d] Apple are also talking about merg[ing] AIX and AU/X (Apple's versior[n]) over the next few years.

With both Motorola and Intel in it[s] hip pocket, IBM now stands poise[d] to build an incredible machine, on[e] that provides hardware-level sup[port] for the major operating sys[tems] of the 90's: Macintosh, DOS[,] Windows, and standards-base[d] UNIX. 1993 will be an interestin[g] year for PC system architecture[s].

IBM restructuring

IBM's restructuring may seem t[o] be one of those ho-hum things th[at] the company seems to go throug[h] with increasing frequency in recer[nt] years. Don't bet on it. IBM is in dee[p] trouble. Not only IBM the compan[y] but America's whole way of doin[g] business. If IBM fails, we're all goin[g] to be liable to significantly increase[d] risk of domination by unfriendly fo[r]eign vendors. There are people wh[o] believe that this risk represents [a] greater threat to our society an[d] way of life than the political and mi[li]tary risks usually harped on by th[e] press, in Washington, and in ou[r] state and local governments. Yo[u] may not like IBM, but you'd bett[er] hope that it finds a way of respon[d-]

ng competitively to the changes go-
ng on in the world at large.

The most visible but probably east strategically important change was the "reduction" of 20,000 jobs, at a one-time cost of $3 billion. More significant is the decision to educe control over and grant in- creased autonomy to IBM's major divisions (mainframe, AS/400, RS/6000, PC's, core technologies, etc.). Under this new scheme, each division will exert greater control over its fate, thereby allowing faster esponse time to rapidly changing market conditions. In recent years, BM has suffered increasingly at the hands of smaller, more efficient, more integrated companies that could detect and rapidly respond to some market need, be it portable PC's, engineering workstations, operating systems, or what have you. BM suffered again and again because its bureaucracy got in the way of responding to rapidly changing customer needs. In addition, the company suffered from internal bickering over product features and marketing. In some cases, competitors were able to commercialize products before IBM could get out of the planning stage. Meanwhile, he company's market share and credibility dropped on a yearly basis, achieving crisis level in the early part of this decade.

It's still too early to tell whether hese changes will provide the needed benefits. There are plenty of keptics who say that A) the hanges do not go far enough, and 3) even if they did, they cannot be mplemented in time.

I hope the nay-sayers are wrong. he U.S. needs new models of doing business on a very large cale; IBM is poised to lead the way. IBM fails, who, if anyone, will be ble to show us how?

lews bits

Intel has leaked more details of he **586**, which will contain 256K of ache memory, a 64-bit data bus, nd a 36-bit address bus. It will run t speeds of 33-, 50-, 66-, and 100- MHz, and it will execute common nstructions at a rate of two per lock cycle. By contrast, the 486 uns at a maximum of one instruction per cycle, and the 386 at two.

Phoenix Technologies (of clone BIOS fame) has created a reference design for a new class of device called a Companion PC. It will have a 6" × 10" footprint, a full keyboard, CGA graphics, long battery life, and software support (including DOS 5.0 in ROM) by Microsoft and Lotus. Sony, meanwhile, has shown a hand-held pen-based input device, currently sold only in Japan for about $500. The PTC-300 measures about 2.5" × 6" × 1", and has a large LCD used for both input and output. The device performs scheduling, database, and note-taking functions, appears to have a calculator-style keypad, and communicates with a docking station via infrared link. Apple is known to be working with Sony on some sort of miniaturized hand-held device, possibly CD-ROM based.

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- Word for Windows 2.0 ($495), Microsoft Corp., One Microsoft Way, Redmond, WA 98052-6399. (206) 882-8080.
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- *Multimedia Programmer's Reference* ($27.95), *Multimedia Authoring and Tools Guide* ($24.95), and *Multimedia Programmer's Reference* ($22.95), Microsoft Corp.
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- *The Programmer's PC Sourcebook* ($39.95), Microsoft Corp.
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- Lantastic 4.0 ($99/$50 upgrade), Lantastic for Windows ($299), Artisoft, Artisoft Plaza, 575 E. River Road, Tucson, AZ 85704. (602) 293-6363.
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Product watch

About twice a year or so I feel obligated to report on the software I'm currently using. Things have actually settled down in the past year and a half or so; I haven't switched a single major application in that time. Best Windows word processor: still Word for Windows, recently upgraded to version 2.0. It is unquestionably the most powerful and best integrated product for the Windows environment. Its desktop publishing features are still weaker than I'd like, but otherwise, I have few complaints. WW2 now has built-in drawing and charting packages, and a much more logical user interface. (If you install all the extras, you'll need about 15MB of disk space. I know it hurts, but this is a trend that seems likely to continue.) The program lists for $495, but just about anyone can obtain an "upgrade" for $129 by calling (800) 323-3577, Ext. W87. Drawing/illustration package: Designer 3.1, which boasts much increased speed compared with the previous version, text along a curve, batch printing, and more. Best Windows utility: Adobe Type Manager (ATM), version 2.0. Print any font on any Windows-supported printer, and see it accurately displayed onscreen. Best telecommunications program: Crosstalk for Windows, version 1.2. This version adds support for networked modems, icon-based session launching, dialing queues, and numerous small enhancements. I regularly transfer huge files in the background at 9600 bps with total reliability.

Best small-office network: LANtastic 4.0 The latest version adds speed and support for operating both servers and workstations under the 386-enhanced mode of Windows 3.0 (see Fig. 1). A new utility allows a dedicated server to devote all its resources to the network, greatly improving performance. LANtastic for Windows provides full

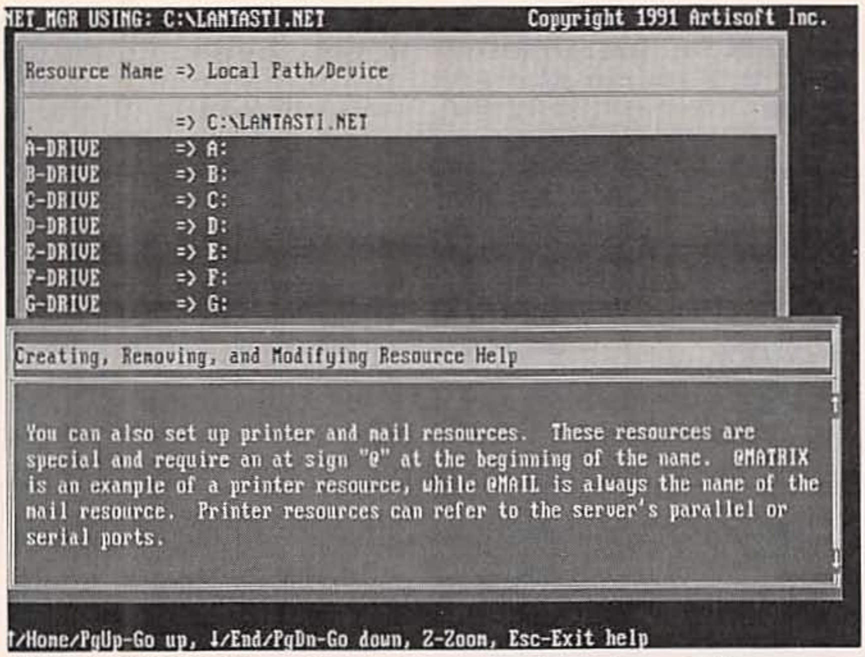

FIG. 1—LANTASTIC 4.0 provides greater speed and security, and full support for Windows 3.0. A separate Windows utility allows full access to all network and management functions.

Windows-based versions of the NET and NET—MGR programs which allow you to log on and off the network, administer network resources, etc. If you're in the market for a fully Windows-integrated, low-cost, DOS-based local area network, there's really no other choice.

Book nook

If you're interested in getting started with multimedia development under Windows, but don't have a clue about how to get started, check out these three volumes: *Multimedia Programmer's Reference, Multimedia Authoring and Tools Guide*, and *Multimedia Programmer's Reference*. All three ar published by Microsoft; they ar also included as part of Microsoft' Multimedia Development Kit. Th *Reference* details Windows systen calls, file formats, and data struc tures; the *Workbook* describe sample applications; the *Guid* shows how to build multimedia ap plications. Another impressive Mi crosoft volume is the secon edition of the *The Programmer's PC Sourcebook*, which contains abou 800 pages of tables covering jus about everything you could possibl want to know about the PC archi tecture, both hardware and soft ware. Want to know how to cross wire a 9- to 25-pin RS-232 adapter No problem. How about the struc ture of the boot sector of a flopp disk? Easy. Maybe a listings of a BIOS, DOS, and Windows functio calls? Simple. Mayb 8088/86/286/386/486 instructio sets? Piece of cake. Not to mer tion: physical sizes and shapes c XT/AT/EISA/MicroChannel expar sion cards, expansion bus pinouts IC pinouts, etc., etc., etc. If you ow just one technical reference on th PC architecture, this should be it.

Next time: An in-depth look a CompuAdd's Multimedia upgrad components. **R-**

MESSAGING SYSTEM

continued from page 64

whenever A6 or A7, or both, are low at the time $\overline{CE}$ goes low. The ISD 1016's storage array is arranged in 160 segments of 0.1 second each. The segments are numbered 0–9Fh. They may be accessed randomly, however play and record operations will access them sequentially beginning with the address supplied by DIP switch S4 at A0–A7, until an EOM marker is encountered, or the operation is terminated by bringing $\overline{CE}$ high.

To determine the address to use to select a particular message, or to record a message at a specific point in memory, we will use a simple example. Suppose we want to hear a message we know starts at the 5-second point in memory. Each memory segment is 0.1-second long, so our message starts at segment 50 (5/0.1 = 50). Now we simply convert the decimal segment number into hex (50 decimal = 32 hex). Thus S4 switches 1–4 must be a binary "3" and switches 5–8 must be a binary "2," so switches 2, 5, and 6 would be open (bits 1, 4, and 5 high).

Configuration mode

If address bits 6 and 7 are both high (S4 switches 7 and 8 both open) at the time $\overline{CE}$ goes low, the ISD 1016 enters the "Configuration Mode," in which address bits A0–A5 (S4 switches 1–6) take on a different meaning. In this mode, those address bits no longer specify addresses. Instead, they select among the various options available as shown in Table 2.

To illustrate the use of Configuration mode, let's assume w recorded a message using th instructions given earlier, an we would like to have it repea continuously. (Make sure th message is less than 16 second long so the "overflow" conditio won't disable the chip after th first replay. Also, the Addressin mode and Configuration mod are mutually exclusive, so yo can have only one message i Configuration mode.) To pla the message back continuousl we want to be in the Configura tion mode; A3, A6, and A7 hig (open), and the rest of the ac dress switches closed. Now se Power down/Up to the "up" pos tion, and set Disable/Enable t the "enable" position. The mes sage that your recorded will no repeat continuously until $\overline{CE}$ i set to the "disable" position (o of course, until your battery power gets used up). **R-**

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DRAWING BOARD

continued from page 83

the last output being used on the last 4017 in the circuit. The only other things on the reset line are the resistor and capacitor pair that generate the power-up reset pulse and the diode that isolates the last used 4017 output from that pulse.

The reset pulse at power-up, by the way, is needed because the 4017, no matter which logic family it belongs to, has a nasty habit of waking up stupid and putting a completely illegal state at its outputs. That can be either no outputs active or, worse than that, more than one active.

By having the reset lines configured as shown in Fig. 2, the circuit is essentially free running. Each successive horizontal sweep will immediately follow the previous one and, since we can control the sweep speed only in discreet steps, most waveforms will creep horizontally across the display. That can be cut to a minimum if you have a variable clock available as an alternative to drive the horizontal section (another good idea to look at later), but using one makes it difficult to estimate frequencies on the display since you never know exactly what the sweep speed is.

A much better way to steady the displayed waveform is to have a circuit that starts each horizontal sweep at the same reference point on the test signal. That's known as "triggered sweep" and it's one of the most powerful features we can add to the design we're working on. Since the trigger signal has to come from the test signal being sent to the vertical section of the scope, we have to wait until we work on that section before we can get into the details of the design. But we can make allowances for it now.

Adding triggered sweep to the circuit means we want the ability to control the situation that makes the horizontal section reset the display to the first column. You might think that all we have to do is pick off some voltage level on the test signal and have that make the display return to the first LED column. If you think that, you should think again.

Under that sort of arrangeme[illegible] things would get really strange if t[illegible] trigger occurred more often th[illegible] the time it took to sweep the displ[illegible] across all twenty LED columns [illegible] the display. If, for example, t[illegible] sweep speed was set to 2 millis[illegible]conds, it would take 40 millisecon[illegible] for each complete horizont[illegible] sweep. And if the trigger level fr[illegible] the input occurred every 10 millis[illegible]conds, the display would be only [illegible] LED columns wide.

That complication doesn't ari[illegible] on conventional scopes becau[illegible] they have a CRT for the display a[illegible] the hardware controlling the ho[illegible]zontal action of the electron bea[illegible] will always let it finish a horizon[illegible] sweep before zipping it back to t[illegible] left hand side of the screen for t[illegible] start of the next sweep. Since we [illegible] dealing with discrete LED column[illegible] we have to add circuitry that do[illegible] the same thing.

In our scope, when we want [illegible] triggered sweep, we have to ga[illegible] the trigger signal with an indicati[illegible] that the old sweep is finished a[illegible] the circuit is ready to start the n[illegible] one. The way to accomplish that [illegible] shown in Fig. 3, the schematic [illegible] the scope so far. The NAND gate IC[illegible] c is switched into the circuit wh[illegible] we set the scope to trigger[illegible] sweep. When the last LED colu[illegible] has been displayed, the Q4 outp[illegible] of IC6 will go high, but the circ[illegible] won't reset and begin a new swe[illegible] until the trigger signal puts a high [illegible] the second leg of the NAND gate[illegible] we want the scope to be free ru[illegible]ning, all we have to do is switch t[illegible] trigger leg of the gate to +V a[illegible] the 4017-based horizontal secti[illegible] will reset as soon as the old swe[illegible] has been finished.

Get the circuit shown in Fig. [illegible] working so we can get to work [illegible] the vertical section next month. A[illegible] keep a list of any ideas you m[illegible] come up with to add goodies to t[illegible] final scope design. One thing y[illegible] might consider is that, since we[illegible] dealing with an LED display, [illegible] shouldn't take much to be able [illegible] freeze the display and make o[illegible]selves an LED storage scope.

But that's my idea, so exerc[illegible] those gray cells, come up with a f[illegible] of your own, and let me know w[illegible] they are.

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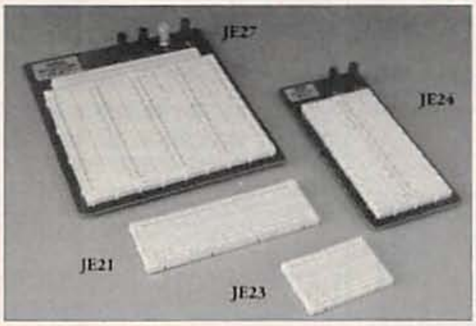

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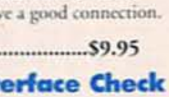

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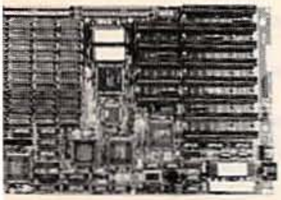

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12T	.45	.41

** Call for a complete listing of ICs*

Memory

Part No.	Function	Price
41256-120	256K DIP 120ns	$1.79
41256-150	256K DIP 150ns	1.69
511000P-80	1MB DIP 80ns	5.99
511000P-10	1MB DIP 100ns	5.49
41256A9A-10	256K SIPP 100ns	18.95
41256A9B-80	256K SIMM 80ns	20.95
421000A9A-80	1MB SIPP 80ns	59.95
421000A9B-80	1MB SIMM 80ns	64.95

Miscellaneous Components*

Potentiometers

Values available (insert ohms into space marked "XX"):
500Ω, 1K, 5K, 10K, 20K, 50K, 100K, 1MEG

43PXX	3/4 Watt, 15 Turn	$.99
63PXX	1/2 Watt, 1 Turn	.89

Transistors And Diodes

PN2222	$.12	1N751	$.15
PN2907	.12	C106B1	.65
1N4004	.10	2N4401	.15
2N2222A	.25	1N4148	.07
1N4735	.25	2N3055	.69
2N3904	.12	1N270	.25

Switches

JMT123	SPDT, On-On (Toggle)	**$1.15**
206-8	SPST, 16-pin (DIP)	**1.09**
MPC121	SPDT, On-Off-On (Toggle)	**1.19**
MS102	SPST, Momentary (Push-Button)	**.39**

**Additional components available*

Connectors

Part No.	Description	Price
DB25P	Male, 25-pin	$.65
DB25S	Female, 25-pin	.75
DB25H	Hood	.39
DB25MH	Metal Hood	1.35

LEDs

XC209R	T1, (Red)	$.14
XC556G	T1 3/4, (Green)	.16
XC556R	T1 3/4, (Red)	.12
XC556Y	T1 3/4, (Yellow)	.16

IC Sockets

Low Profile		Wire Wrap (Gold) Level #2	
8LP	$.10	8WW	$.49
14LP	.11	14WW	.69
16LP	.12	16WW	.79
24LP	.19	24WW	1.15
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